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THE USE OF TURMERIC (*Curcuma longa*) EXTRACT AS A NATURAL COLORANT IN SMART PACKAGING TO DETECT QUALITY DETERIORATION OF FRESH WHOLE VANNAMEI SHRIMP (*Litopenaeus vannamei*)

Penggunaan Ekstrak Kunyit Kuning (*Curcuma longa*) Sebagai Bahan Pewarna Alami dalam Kemasan Pintar untuk Mendeteksi Kemunduran Mutu Udang Vaname (*Litopenaeus vannamei*) Utuh Segar

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ABSTRACT

This study aimed to determine the optimal concentration of yellow turmeric (*Curcuma longa*) extract incorporated into smart packaging capable of detecting quality deterioration of Vannamei shrimp through indicator label color changes in response to variations in pH and Total Volatile Base (TVB) values, as well as providing timely information regarding the freshness of the packaged fresh Vannamei shrimp. The study was designed using a Completely Randomized Design (CRD) with an experimental method consisting of four treatments, namely the addition of yellow turmeric extract at concentrations of 0%, 1%, 2%, and 3%, with ten replications. The treatments were subsequently applied in the packaging of Vannamei shrimp stored for 6 days at a temperature of 10°C. Observation parameters included the characteristics of color changes of the indicator label during storage and their relationship with the organoleptic characteristics of shrimp freshness, including appearance, odor, and texture, as well as measurements of pH and TVB values during storage. Organoleptic test data were analyzed using the Kruskal–Wallis test, and when significant differences were observed, a multiple comparison test was conducted. Data on color changes, pH, and TVB values were analyzed descriptively. The results demonstrated that the use of smart packaging for Vannamei shrimp with indicator labels incorporated with yellow turmeric extract and stored for 6 days showed that the addition of 2% yellow turmeric extract was the best treatment. The 2% turmeric extract effectively detected quality deterioration of Vannamei shrimp based on clear gradations of indicator label color changes during storage and in terms of timeliness with respect to shrimp quality deterioration. The indicator label color changed from bright yellow to yellowish-brown along with the decline in shrimp freshness, accompanied by increases in pH and TVB values during storage at 10°C.

Keywords: Shrimp Quality, Smart Packaging, Turmeric Extract

ABSTRAK

Penelitian ini bertujuan untuk menentukan konsentrasi penambahan ekstrak kunyit kuning terbaik ke dalam kemasan pintar yang dapat mendeteksi kemunduran mutu udang vaname melalui perubahan warna label indikator terhadap perubahan nilai pH dan *Total Volatile Base* (TVB), secara tepat waktu terhadap kesegaran produk komoditas udang vaname segar yang dikemasnya. Penelitian dirancang menggunakan percobaan rancangan acak lengkap (RAL) dengan metode eksperimental yang terdiri dari empat perlakuan, yaitu penambahan ekstrak kunyit kuning 0%, 1%, 2%, dan 3% yang diulang sebanyak 10 kali, selanjutnya diaplikasikan dalam pengemasan udang vaname selama 6 hari yang disimpan pada suhu 10°C. Parameter pengamatan dilakukan terhadap karakteristik perubahan warna dari label indikator selama penyimpanan dan dihubungkan dengan karakteristik organoleptik dari kesegaran udang vaname yang meliputi kenampakan, aroma, dan tekstur, serta pengujian nilai pH dan TVB pada udang vaname selama penyimpanan. Analisis data untuk hasil uji organoleptik, dengan mengggunakan uji Kruskal-Wallis, dan jika terdapat perbedaan yang nyata, akan dilanjutkan dengan uji perbandingan berganda. Hasil uji perubahan warna, pH, dan TVB dianalisis secara deskriptif. Hasil penelitian dapat disimpulkan bahwa penggunaan kemasan pintar dalam mengemas udang vaname dengan label indikator yang sudah ditambahkan ekstrak kunyit kuning dan disimpan selama 6 hari, penambahan ekstrak kunyit kuning 2%, merupakan perlakuan terbaik. Penambahan ekstrak kunyit kuning sebesar 2%, mampu mendeteksi kemunduran mutu udang vaname berdasarkan perubahan gradasi warna label indikator yang jelas selama penyimpanan dan dari segi ketepatan waktu dengan kemunduran mutu udang vaname. Warna label indikator berubah dari warna kuning cerah menjadi kuning kecokelatan seiring dengan penurunan mutu kesegaran udang vaname, dengan nilai pH dan TVB yang meningkat selama penyimpanan pada suhu 10°C.

Kata Kunci: Ekstrak Kunyit, Kemasan Pintar, Mutu Udang

INTRODUCTION

Whiteleg shrimp (*Litopenaeus vannamei*) is a leading Indonesian commodity that plays a significant role in export activities (Latifah et al., 2025). According to the Ministry of Marine Affairs and Fisheries (KKP) in 2022, whiteleg shrimp boasts several advantages, including rapid growth, lower production costs, and greater disease resistance. Whiteleg shrimp boasts excellent nutritional value, containing 84 calories and 20 g of protein per 85 g of cooked shrimp. They also contain essential minerals such as calcium, phosphorus, magnesium, potassium, and zinc (Naibesi et al., 2022).

However, fresh fishery products, such as whiteleg shrimp, are susceptible to quality deterioration or spoilage if errors occur during harvesting, post-harvest handling, transportation, or storage, which allow biological and chemical factors to multiply and grow (Ghoshal, 2018; Souza et al., 2018). Whiteleg shrimp are highly perishable due to their high-water content of 76.14% and protein content of 17.72% per 100g of meat (Salim et al., 2018).

Decreased quality in whiteleg shrimp is characterized by organoleptic changes such as changes in meat color, flavor, and the appearance of an unpleasant odor (Mayodra et al., 2021). Research by Sipahutar et al. (2020) found that storing whiteleg shrimp at low temperatures resulted in significant changes in pH and an increase in total volatile base (TVB) values. This occurs due to the degradation of protein and its derivatives, producing other volatile compounds such as ammonia, histamine, H_2S, and trimethylamine, which contribute to the unpleasant odor (Wati & Hafiludin, 2023).

Indicators indicating that whiteleg shrimp have experienced quality decline are pH and TVB values (Sarif, 2024). With the advancement of science and technology, the two main indicators of whiteleg shrimp quality degradation can be directly detected by a renewable packaging system, namely smart packaging, which can detect pH changes and provide timely information on quality changes (Schaefer & Wai, 2018). Smart packaging is a system that functions intelligently, such as by detecting, recording, communicating, and sensing through chemical and biosensors. Through these two sensors, it will be easy to monitor product quality and safety during marketing (Sariningsih et al., 2019). One of the simplest methods in smart packaging is by measuring pH and Total Volatile Base (TVB) values using indicator labels (Rahimah et al., 2020). Indicator labels act as sensors to detect the condition of the packaged product and provide timely information on quality degradation (Ananta et al., 2017).

Indicator labels must be made from natural, non-toxic materials and have no harmful side effects on the human body if ingested or consumed (Othman et al., 2018). An example of a material that can be used to make indicator labels is edible film. Edible film has been widely developed as a food wrapping film in smart packaging and can act as a freshness sensor (Otoni et al., 2017). Edible film is made from biopolymers, such as chitosan. Chitosan is a product derived from chitin, which is found in marine crustaceans such as crab shells, shrimp carapaces, and blue swimming crab shells (Damayanti et al., 2016).

Indicator labels are generally mixed with dyes that are highly sensitive to changes in pH (Sariningsih et al., 2019). Natural dyes at specific concentrations can be used in the manufacture of indicator labels if they contain anthocyanin or curcumin compounds (Zhao et al., 2022, Zia et al., 2019). Some natural dyes with predetermined concentrations frequently used in research include purple sweet potato (*Ipomea batatas* L.) in a study (Warsiki et al., 2016); beetroot (*Beta vulgaris* L.) in a study (Sangadji 2017); and red rose (*Rosa* L.) in a study (Silvia et al., 2023). Turmeric (*Curcuma longa*) is also readily available on the market.

Turmeric is a readily available natural dye, relatively inexpensive, has antioxidant properties, is biodegradable, and contains curcumin, producing a bright yellow color (Nursari et al., 2023). Based on research conducted by (Rhokimah, 2020) in the creation of indicator labels with the addition of turmeric extract at 0 mL, 2 mL, 4 mL, and 6 mL, the resulting indicator labels containing curcumin compounds were bright yellow at an acidic pH range (1-7) and dark yellow/brownish red at a wet pH range (8-14). The quality of the indicator labels varied between treatments. The results of research conducted by Nadila & Nurjanah (2023) using turmeric as a natural indicator of acids and bases showed similar results: at acidic pH, the color was bright yellow, and at alkaline pH, the color changed to yellow-brown. This makes the curcumin compound in turmeric possible to be used as an indicator material capable of detecting pH changes in whiteleg shrimp.

This study aims to determine the best formulation for adding yellowleg turmeric extract as a natural dye to indicator labels for use in smart packaging to detect quality deterioration in fresh whole whiteleg shrimp. The analysis conducted in this study was the analysis of color changes on the indicator label (transparency value of the indicator label) which was linked to the organoleptic analysis of vaname shrimp (appearance, texture, and aroma), pH analysis of vaname shrimp, and Total Volatile Base (TVB) analysis of vaname shrimp.

METHODS

Research Location and Time

This research was conducted from September 2025 to October 2025 at the Fisheries Product Processing Laboratory, Faculty of Fisheries and Marine Sciences, Padjadjaran University. This involved the production of yellow turmeric extract, indicator labels, smart packaging application, storage, and pH testing. The indicator labels containing yellow turmeric extract were dried using an oven blower in the Biogeochemistry Laboratory, Faculty of Fisheries and Marine Sciences, Padjadjaran University. The Total Volatile Base (TVB) value was tested in the Laboratory of the Faculty of Food Industrial Technology, Padjadjaran University.

Research Equipment and Materials

The equipment used included a blender, thinwall, hotplate stirrer, beaker glass, measuring cylinder, Erlenmeyer flask, burette, Kjeldahl distillation apparatus, micropipettes, oven blower, filter cloth, digital scales, and a pH meter. The ingredients used included yellow turmeric, whiteleg shrimp, chitosan, 1% acetic acid, 1.5 mL glycerol, and mineral water.

Research Design

The research method used was a Completely Randomized Design (CRD) with an experimental method. The experiment involved the creation of indicator labels with yellow turmeric extract, which were used in smart packaging for fresh whole whiteleg shrimp. The research process included the creation of yellow turmeric dye extract, the creation of indicator labels with yellow turmeric extract, and four treatments: 0%, 1%, 2%, and 3%, with 10 semi-trained panelists as replications.

Yellow Turmeric Extract Preparation

The preparation procedure was based on a modified method from Rhokimah (2020). The steps begin by peeling the yellow turmeric, then grinding it using a blender and adding water. The ratio of yellow turmeric to water is 2:1 (w/v). The yellow turmeric is then filtered using a filter cloth to obtain pure turmeric extract. Then, store the filtered yellow turmeric extract in a tightly closed plastic bottle.

Making Indicator Labels with the Addition of Yellow Turmeric Extract

The manufacturing procedure follows a modified method from Rhokimah (2020). The steps begin by dissolving 1.25 g of chitosan in 100 mL of 1% acetic acid. The chitosan is added gradually to prevent clumping. Homogenize at 50°C at 250 revolutions per minute (rpm) for 30 minutes using a stirrer. Next, add the yellow turmeric extract prepared in varying concentrations of 0%, 1%, 2%, and 3%, along with 1.875 mL of glycerol as a plasticizer. Homogenize again using a stirrer at 50°C at 250 revolutions per minute (rpm) for 30 minutes. Afterward, prepare a plastic tray that has been cleaned with a 70% alcohol spray. Then, pour each sample into a plastic tray with a customized code for printing. The indicator label samples were then dried using a blower oven at approximately 50°C for 6 hours. Once dry, the indicator label samples for each treatment were cut into 2 cm x 3 cm rectangles for use in the prepared smart packaging containers.

Application to Whiteleg Shrimp

The application procedure follows a modified method from Imami (2019). The application steps begin with packaging fresh whole whiteleg shrimp using thinwall with an indicator label added to the bottom of the lid to detect deterioration. The samples were then stored in the smart packaging for 6 days at 10°C. After the storage period, each indicator label sample was tested for color changes, and each whiteleg shrimp sample was analyzed through organoleptic tests, pH values, and Total Volatile Base (TVB) values.

Observed Parameters

The observed parameters were the organoleptic characteristics of the indicator label's color change and the freshness of the whiteleg shrimp during six days of storage. The organoleptic characteristics of the whiteleg shrimp observed included appearance, aroma, and texture. The pH and Total Volatile Base (TVB) values of the whiteleg shrimp samples were then observed.

Indicator Label Color Change Testing

The color change test was conducted to assess the indicator label's ability to detect deterioration in the quality of whiteleg shrimp. Observations were made visually using the sense of sight and using a spectrophotometer on the indicator labels tested for six days of packaging whiteleg shrimp.

Indicator Label Thickness Testing

The thickness of the indicator label was tested by measuring the thickness on each side of the indicator label using a vernier caliper, then averaging the results to determine the overall thickness (Huri et al., 2014).

Transparency Testing

Transparency testing measures the final level of color brightness on indicator labels used as a tool to detect the deterioration of whiteleg shrimp quality using a spectrophotometer using the following formula (Khairunisa et al., 2018):

$$T = \frac{A_{550}}{x}$$

Where:
T : Transparency
A_{550} : Standard absorbance at 550 nm
x : Film thickness

Organoleptic Testing

Organoleptic testing plays a crucial role as an early detection tool in assessing product quality and identifying deviations and changes (Quraisy et al., 2021). In this study, the organoleptic test used 10 semi-trained panelists. The panelists assessed the organoleptic characteristics of whiteleg shrimp freshness, including texture, aroma, and appearance, based on SNI 02-2346-2006, which regulates the quality of fresh shrimp.

pH Testing

The pH test in this study aimed to examine the correlation between the freshness level of whiteleg shrimp and the color change of the indicator label after adding yellow turmeric extract (Fuertes et al. 2016). The pH test on whiteleg shrimp was conducted using a pH meter.

Total Volatile Base (TVB) Testing

The TVB analysis in this study aimed to determine the amount of volatile base compounds in fresh whiteleg shrimp, which are formed due to protein degradation during storage.

Data Analysis

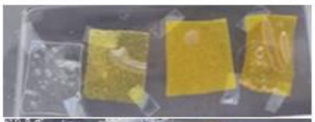
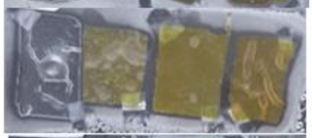
Organoleptic testing was conducted using 10 semi-trained panelists from the Fisheries Study Program, Padjadjaran University. The panel used a score sheet with a scale of 1-9 to analyze the organoleptic parameters of whiteleg shrimp freshness, namely appearance, aroma, and texture. The organoleptic data were analyzed using the Kruskal-Wallis test, followed by a multiple regression analysis if significant differences were found between treatments.

RESULTS

Indicator Label Color Changes

The results of the color changes on the indicator labels, observed visually using the sense of sight, are presented in Table 1.

Table 1. Results of Color Changes on Indicator Labels

Waktu Penyimpanan (Hari ke-)	Perubahan Warna Label Indikator Pada Perlakuan 0% 1% 2% 3%
0	
1	
2	
3	
4	
5	
6	

Indicator Label Transparency Testing

The results of the transparency testing for each indicator label treatment in smart packaging are shown in Figure 1.

Indicator Label Thickness Testing

The results of the thickness testing for each indicator label treatment in smart packaging are shown in Figure 2.

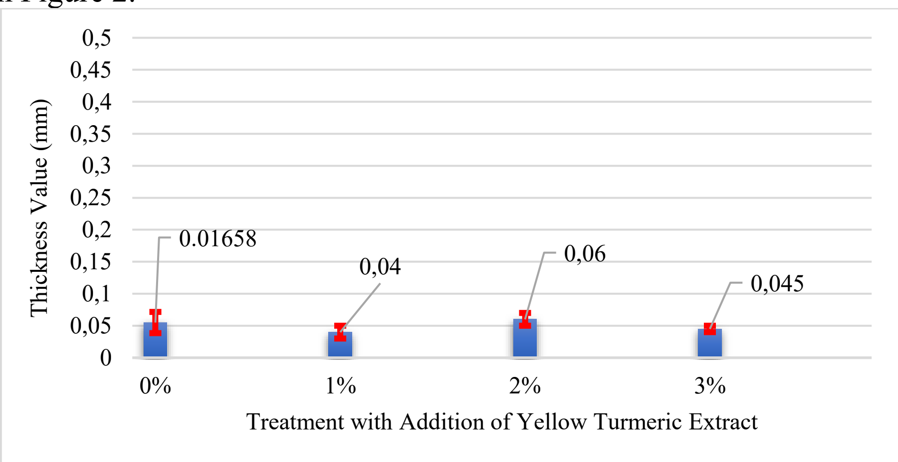


Figure 2. Indicator Label Thickness Value

Organoleptic Testing of Whiteleg Shrimp

The organoleptic analysis conducted in this study used a score sheet test with parameters of appearance, texture, and aroma of whiteleg shrimp, referring to SNI 02-2346-2006. These parameters are presented in Table 2.

Table 2. Organoleptic Test Results on Whiteleg Shrimp

Parameter	Organoleptic Value on the Day						
	0	1	2	3	4	5	6
Appearance	8	7.25	6.5	5	5	3	1
Texture	8	7.25	6.75	5.75	5	3	1
Aroma	8	8	7	5	3	2	1

Description: 9 = very fresh; 8 = still fresh; 7 = fresh; 5 = starting to become stale; 3 = stale; 1 = very stale

pH Testing of Whiteleg Shrimp

The results of the pH test on whiteleg shrimp, measured using a pH meter, are presented in Figure 3.

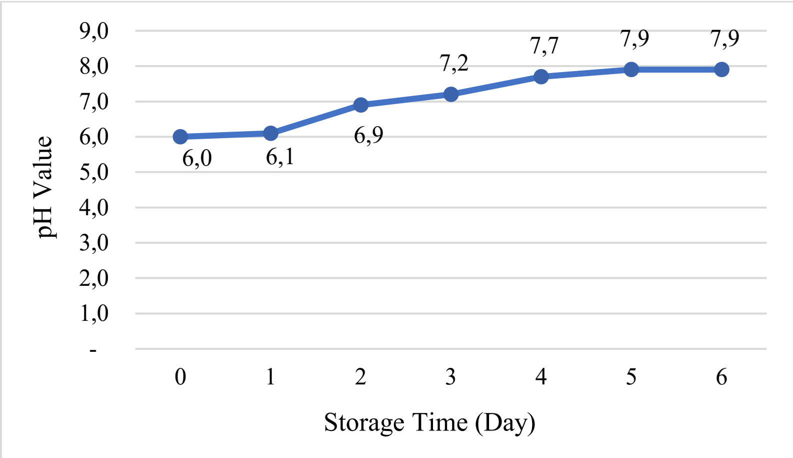


Figure 3. Results of pH Values in Vaname Shrimp

Total Volatile Base (TVB) Testing in Whiteleg Shrimp

The results of the TVB test in whiteleg shrimp on days 0, 3, and 6, using the Kjedhal test, are presented in Figure 4.

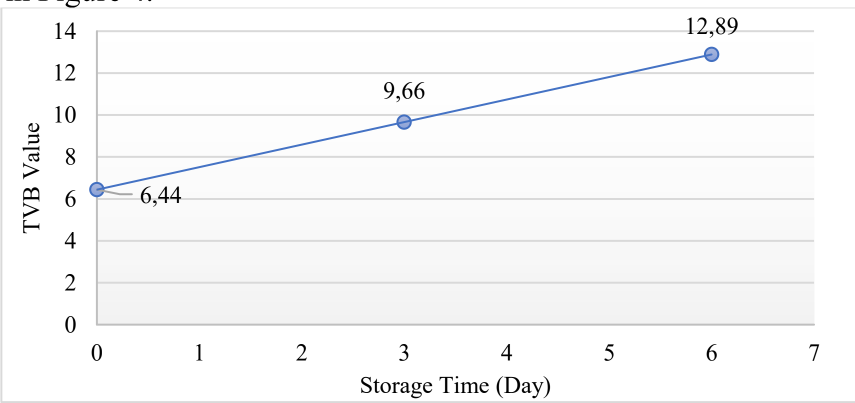


Figure 4. TVB Value Results for Vaname Shrimp

DISCUSSION

Indicator Label Color Change

The research results showed that the indicator labels treated with 0% yellow turmeric extract did not change color during storage. Indicator labels treated with 1%, 2%, and 3% yellow turmeric extract showed a color change from bright yellow to dark yellow. The color change in each treatment began to appear on the first day, with the indicator labels with yellow turmeric extract appearing to darken. The color change from bright yellow to dark yellow occurred each day. By the fourth day, the indicator labels with yellow turmeric extract were already dark yellow.

These results align with research conducted by Rhokimah (2020), which showed that the indicator labels with 0% turmeric extract did not change color because the curcumin compound in the turmeric extract was absent. Therefore, the indicator labels were unable to detect changes in pH and TVB values in the packaged shrimp samples. Meanwhile, the indicator labels with yellow turmeric extract showed a color change from bright yellow to dark yellow with increasing storage time. The color changes indicated that the indicator labels with the addition of yellow turmeric extract were able to detect changes in pH and TVB values in whiteleg shrimp.

Indicator Label Transparency Testing

Based on the research results, the transparency value in the 0% yellow turmeric extract treatment increased from day 1 to day 2. Thereafter, no significant changes were observed on days 3 and 6. In the 1% treatment, the indicator labels with the addition of yellow turmeric extract did not experience a significant change in transparency from day 0 to day 2, but a significant decrease occurred on day 3. On days 4 to 6, the transparency value increased again. In the 2% and 3% turmeric extract treatments, the transparency value of the indicator labels decreased with increasing storage time.

These results align with research conducted by Rostini et al. (2023) entitled "Designing a Bio-based Color Sensor from Myofibrillar-Protein-Based Edible Film Incorporated with Sappan Food Extract for Smart Packaging" showed that indicator labels treated with a pH detector resulted in a darker color as the quality of the packaged product deteriorated.

Indicator Label Thickness Testing

The study revealed that differences in indicator label production with varying percentages of yellow turmeric extract resulted in a slight difference in indicator label thickness across all treatments. According to Sinaga & Rejekina (2013), differences in film formula composition, with significant differences in values, can contribute to differences in indicator label thickness.

Organoleptic Testing of Whiteleg Shrimp

Appearance

Based on the research results, the organoleptic value for the appearance of whiteleg shrimp on day 0 was 8, indicating that the sample used was still very fresh. The organoleptic value decreased daily due to the deterioration of the whiteleg shrimp. On the second day of storage, whiteleg shrimp stored at a cold temperature of 10°C had an organoleptic value below the acceptance threshold according to SNI 02-2346-2006. The decline in organoleptic value in the appearance section was due to the presence of ammonia compounds produced by the metabolic processes in whiteleg shrimp (Mayodra et al., 2021).

These results also align with research conducted by Sipahutar et al. (2020) stated that on day 0, no signs of melanosis (black spots) appeared on the whiteleg shrimp. However, with prolonged storage, melanosis began to appear, causing a decline in the shrimp's appearance.

The study found that the whiteleg shrimp samples used in smart packaging with treatments of 0%, 1%, 2%, and 3% had similar appearance (not significantly different). The Kruskal-Wallis H.Calculated (5.737) value was lower than the H.Table (7.814) value. Therefore, the color change on the indicator label was not affected by differences in the quality of the whiteleg shrimp samples in each treatment.

Texture

The study found that the organoleptic value for the texture of the whiteleg shrimp on day 0 was 8, indicating that the whiteleg shrimp samples used were still fresh. The organoleptic texture value continued to decline during storage at a cold temperature of 10°C. On the second day of storage, the organoleptic texture value was below the acceptable threshold for human consumption based on SNI 02-2346-2006 regarding shrimp freshness. This value was below the maximum acceptable limit for whiteleg shrimp freshness, which is 7.

The results of this study also align with other research conducted by Taningo et al. (2014), which states that fishery products experience a decline in quality during storage. This occurs due to protein denaturation in whiteleg shrimp, which causes the texture of the whiteleg shrimp to begin to decrease.

Based on the research results, it was found that the whiteleg shrimp samples used in smart packaging with treatments of 0%, 1%, 2%, and 3% had the same texture quality (no significant difference). The Kruskal-Wallis H.Calculation (1.4634) was smaller than the H.Table (7.814). Therefore, the color change on the indicator label following the addition of turmeric extract was not affected by differences in the quality of the whiteleg shrimp samples used.

Aroma

Based on the research results, it was found that on day 0, the organoleptic value of whiteleg shrimp aroma was 8, indicating that the whiteleg shrimp samples used were still fresh. The organoleptic value of aroma continued to decline throughout storage, and on the 3rd day of storage, the organoleptic value of aroma was below the acceptance threshold according to SNI 02-2346-2006 regulations.

These results also align with other research conducted by Suhono et al. (2025) stated that whiteleg shrimp stored at cold temperatures for 48 hours obtained an organoleptochemical value of 6.8, indicating that the sample had experienced a decline in quality. The decline in the aroma of whiteleg shrimp can be characterized by the appearance of an indole odor and an unpleasant odor in the shrimp.

Based on the research results, it was found that whiteleg shrimp samples used in smart packaging with treatments of 0%, 1%, 2%, and 3% had the same aroma quality (not significantly different), with the Kruskal-Wallis H.Calculation test value (0.58) being smaller when compared to the H.Table value (7.814) so that to assess the color change on the indicator label, there was no bias due to differences in the whiteleg shrimp samples used.

Whiteleg Shrimp pH

Research results revealed that the pH of fresh whole whiteleg shrimp increased toward an alkaline pH, indicating that whiteleg shrimp stored at chiller temperatures (10°C) were beginning to decline in quality and lead to spoilage. This finding is also supported by research conducted by Fahrurrozi et al. (2023), which stated that an alkaline pH in shrimp supports the growth of spoilage bacteria. The increase in pH in whiteleg shrimp is caused by the activity of metabolic enzymes in whiteleg shrimp and the formation of volatile amines resulting from the activity of spoilage microorganisms, as well as the production of ammonia, which causes the accumulation of alkaline compounds (Liu et al., 2022).

The pH changes in whiteleg shrimp samples caused the indicator labels for the 1%, 2%, and 3% treatments used in smart packaging to change color. Initially, the bright yellow indicator label changes to a dark yellow or brick red color due to the curcumin compound in the indicator label, which reacts significantly to changes in pH in the whiteleg shrimp samples (Rhokimah, 2020). Meanwhile, smart packaging using the 0% indicator label treatment shows no color change due to the absence of additional curcumin.

Total Volatile Base (TVB) Value of Whiteleg Shrimp

Research results indicate that the TVB value in fresh whole whiteleg shrimp continues to increase quite drastically over time, with an average increase of approximately 3.22%. The increase in TVB content during whiteleg shrimp storage is due to the breakdown of proteolytic enzymes into carboxylic acid, sulfide acid, ammonia, or other acids (Herawati et al., 2020).

Based on government regulations SNI 08-2354-2009, the maximum acceptable limit for fresh whole whiteleg shrimp is 20-30 mgN/100 g (Goncalves & Gindri, 2009), so the TVB value in whiteleg shrimp samples is still safe for human consumption. Factors that can affect the TVB value in fresh food products include handling, storage, and preservation processes (Mulyanto et al., 2017).

CONCLUSION

Packaging whiteleg shrimp using smart packaging incorporating an indicator label with turmeric extract can detect quality deterioration in fresh whole whiteleg shrimp, characterized by the indicator label changing color to darker as the quality of the whiteleg shrimp deteriorates over time.

The best indicator label formulation for detecting quality deterioration in whiteleg shrimp was achieved with a 2% treatment, which resulted in a timely relationship between color change and quality deterioration. The resulting indicator label remained in good condition until testing on the 6th day.

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