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To cite this article: N I Sari *et al* 2026 *IOP Conf. Ser.: Earth Environ. Sci.* **1581** 012025

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Smart packaging based on purple sweet potato (*Ipomoea batatas* L.) anthocyanin as an indicator of quality decrease in smoked catfish (*Pangasius hypophthalmus*) during room temperature storage

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Abstract. Smoked fish is a fishery product that is susceptible to quality degradation during storage, necessitating the use of smart packaging technology as a quality indicator. This study aimed to develop a polyvinyl alcohol (PVA)-based indicator film with the addition of purple sweet potato anthocyanins to monitor degradation of smoked catfish at room temperature. The research method used was an experiment with two anthocyanin concentration treatments (0% and 1%). The quality parameters analyzed included pH, Total Volatile Base Nitrogen (TVBN), and peroxide value (PV) on day 0, day 4, and day 8, as well as the visual response of the indicator film. The results showed an increase in pH from 6.35–6.51 (D-0) to 6.56–6.66 (D-4), and 6.63–6.7 (D-8). TVBN from 32.06–28.08 mg N/100 g (D-0) to 40.7–39.7 mg N/100 g (D-4), and 71.5–43.3 (D-8). PV from 7.3–3.4 meq O₂/kg (D-0) to 9.1–6.1 meq O₂/kg (D-4) and 11.01–8.2 meq O₂/kg (D-8). Despite the increase, all values are still below the SNI 2725:2013 threshold, so that smoked catfish is still suitable for consumption. The PVA-anthocyanin indicator film remained stable without significant color changes, consistent with the fish quality, which had not yet exceeded the critical limit.

1. Introduction

Catfish (*Pangasius hypophthalmus*) is a popular freshwater fishery commodity and has very high economic value. Catfish is widely cultivated and is an important commodity for the community. According to data from [1], catfish production in Riau Province reached 30,352 tons. Kuantan Sengingi Regency 365 tons, Indragiri Hulu Regency 1,604 tons, Indragiri Hilir Regency 134 tons, Pelalawan Regency 2,310 tons, Siak Regency 291 tons, Rokan Hulu Regency 368 tons, Rokan Hilir Regency 1,533 tons, Bengkalis Regency 14 tons, Meranti Islands Regency 1 ton, Dumai City 3 tons, Pekanbaru City 1,288 tons and Kampar Regency is the largest area in producing catfish in Riau Province, namely 22,441 tons. The abundant availability of raw materials makes it a leading commodity widely used by the public, both for household consumption and as a raw material for the fishery processing industry. One popular processed product is smoked catfish, which has a distinctive flavor, dense meat texture, and a smoky aroma that consumers love.

Smoked fish products have significant market potential due to their popularity and higher added value compared to fresh fish. However, smoked catfish has a limited shelf life, especially when stored at room temperature without packaging. This quality decline is difficult to detect visually of smoked catfish with the naked eye, potentially exposing consumers to spoiled products, increasing the risk of health problems due to microbial contamination or harmful compounds. The research of states that smoked fish products have a limited shelf life of 2-3 days without packaging at room temperature, whereas with packaging, smoked fish can last for more than a week [2]. Furthermore, research by [3] states that the shelf life of smoked fish is only 2-3 days without packaging at room temperature. During storage, fat oxidation and protein degradation occur, producing volatile base compounds such as ammonia, dimethylamine, and trimethylamine,



thereby reducing the quality of the smoked fish. Several environmental factors such as humidity, oxygen levels, and unstable light exposure can also affect the decline in product quality [4].

One innovative solution that can be developed to overcome this problem is the application of smart packaging. Smart packaging is a type of packaging that is able to provide information about product condition directly, accurately, and easily recognizable through color changes on its indicators. This makes it easier for producers and consumers to monitor and assess the quality of the products produced [5]. In its development, smart packaging can utilize anthocyanin compounds found in purple sweet potatoes (*Ipomoea batatas* L.) as pH-sensitive color indicators reflecting product spoilage. Purple sweet potatoes have a fairly high anthocyanin content, ranging from 169.31 to 224.97 mg per 100 grams [6]. Anthocyanins themselves are natural pigments that can change color according to variations in the pH of the environment. This characteristic makes anthocyanins very potential for use as indicators in smart packaging. The color changes that occur can be a marker of product quality based on the volatile base compounds formed during the spoilage process [7].

Based on the background description above, the decline in the quality of smoked catfish is a very serious problem in the fisheries industry, especially in maintaining the quality and shelf life of products during room temperature storage. Limitations in detecting visual quality degradation make it difficult for producers and consumers to monitor and determine the safety of products for consumption. Several previous studies have demonstrated the effectiveness of anthocyanin films in detecting fish quality [8]. However, studies on smoked catfish are still limited. Therefore, it is necessary to conduct research on the effectiveness of anthocyanin films as an indicator of the decline in the quality of smoked catfish. This study aims to determine the effectiveness and develop a polyvinyl alcohol (PVA)-based indicator film with the addition of purple sweet potato anthocyanins to monitor the degradation of smoked catfish at room temperature.

2. Materials and methods of research

2.1 Materials and Equipment

Those involved in this study were smoked catfish (*Pangasius hypophthalmus*) with a size of 100 g/tail obtained from UMKM Putra Niaga, Lubuk Agung Village, XIII Koto Kampar District, Kampar Regency, Riau Province and purple sweet potato (*Ipomoea batatas* L.) obtained from Pasar Selasa, Panam, Pekanbaru. The chemicals used were PVA (polyvinyl alcohol), Glycerol, citric acid (Merck), acetic acid (Merck), Aquades, ammonia (NH₃) (Merck), pH buffer (1, 4.5, 8 and 11), potassium chloride (KCL) (Merck), Propanoyl chloride (PCA), sodium hydroxide (NaOH) (Merck), boric acid (H₃BO₃) (Merck), hydrochloric acid (HCl) (Merck), phenolphthalein indicator (C₂₀H₁₄O₄) (Merck), and vaseline. The consumables used are aluminum foil, stand-up pouches, label paper (Fox), paper (Natural), tissue (Jolly), plastic cups, M6 plastic bowls, gloves (saveglove latex), masks (one care duckbill), head covers (nurse caps), jars, teaspoons, and coarse filter paper (Whatman no.42).

The tools used in this study were blender, tray, basin, knife, scissors, 80 mesh sieve, grated sweet potato, funnel, rotary evaporator, hot plate stirrer, UV-Vis spectrophotometry, magnetic stirrer, thermometer, oven, beaker (Pyrex), petri dish (Pyrex), beaker glass (Pyrex), Erlenmeyer flask (Pyrex), dropper pipette (Pyrex), spatula, pH meter, vernier caliper, brown glass bottle, analytical balance (Radwag polandia, AS 220.R2 Plus), mortar and pestle, funnel, burette and static, centrifuge tube, centrifuge (PLC SERIES), distillator and desiccator.

2.2 Purple Sweet Potato Anthocyanin Extraction

The extraction method refers to the research of [9]. Weigh 500 grams of purple sweet potato, peel, grate using a sweet potato grater, wash and drain. Dry using an oven at 50°C for 24 hours. After drying, cool at room temperature for 30 minutes. Blend the purple sweet potato until smooth,

then filter it using an 80 mesh sieve. The sweet potato powder is put into a brown glass bottle, extracted with 3% citric acid solvent (ratio 1:10 w/v, meaning that every 1 gram of dry material is mixed with 10 ml of solvent), macerated at room temperature for 24 hours. The filtrate is filtered using coarse filter paper, then the extract is concentrated using a rotary evaporator at 40°C at 60 rpm for 3 hours. The concentrated extract is stored at 4°C or in an airtight container until reused.

2.3 Analysis of Total Anthocyanin Concentration

Total anthocyanin concentration was analyzed based on the procedure outlined in [10]. This measurement utilized the pH differential technique. Two reaction tubes were prepared: one containing 3 mL of potassium chloride buffer at pH 1, and the other containing 3 mL of sodium acetate buffer at pH 4.5. Subsequently, 0.5 mL of the sample was added to each tube to assess the anthocyanin content, followed by a 15-minute incubation period. Absorbance readings for both pH conditions were taken using a UV-Vis spectrophotometer at 510 nm and 700 nm wavelengths. The absorbance data were then calculated using the equation below:

$$A = [(A_{510} - A_{700})_{pH\ 1} - (A_{510} - A_{700})_{pH\ 4.5}]$$

$$\text{Total anthocyanin concentration (mg/L)} = "A \times MW \times FP \times 1000" / "\epsilon \times l"$$

Where:

A = Absorbance value

A₅₁₀ = Absorbance value at a wavelength of 510 nm

A₇₀₀ = Absorbance value at a wavelength of 700 nm

MW = Molecular weight (449.2)

FP = Dilution factor

ε = Molar extinction coefficient (26,900 L/cm)

l = Cell thickness (cm)

2.4 Making Indicator Films

The manufacture of indicator films refers to the research of [11]. The manufacture of indicator films was carried out using the solvent casting method, starting with the manufacture of 10% PVA (Polyvinyl alcohol). This procedure consists of dissolving 10 grams of PVA into 100 mL of distilled water, then stir the solution until it is evenly mixed and clear. Add 2% (v/v) of glycerol from the total volume of the film solution, namely 2 mL of glycerol per 100 mL of solution which functions as a plasticizer. Add anthocyanin extract according to the treatment concentration, namely 1%. Anthocyanin concentration of 1% (v/v) is adding 1 mL of anthocyanin extract to 99 mL of film solution (PVA + glycerol). Homogenize using a magnetic stirrer at 40°C at 400 rpm for 45 minutes, pour the film solution into a petri dish, dry it in an oven at 50°C for 24 hours. Remove the film and cut it into 3x3 cm pieces. Store the film in an airtight container.

2.5 Packaging and Storage Applications

Smoked catfish is packed in a standing pouch, then attach an indicator film to the inside of the packaging, store at room temperature (25-30°C), observations and testing are carried out on days 0, 4, and 8.

2.6 Data Analysis

The data obtained were analyzed descriptively. The total anthocyanin concentration and indicator film thickness test were presented descriptively using Microsoft Excel, showing the mean values

and their standard deviations. Meanwhile, data on pH, TVBN, and peroxide value were presented in line graphs.

3. Results and Discussion

3.1 Purple Sweet Potato Anthocyanin Extraction

The results of the extraction of purple sweet potato anthocyanins macerated for 24 hours using 3% citric acid solvent produced a red extract with a pH of 2.5. Then, the extraction results were concentrated using a rotary evaporator at a temperature of 50°C at a speed of 60 rpm for 3 hours, thus obtaining a concentrated purple extract of ± 95 mL with a pH of 6.5. The results of anthocyanin extraction from purple sweet potatoes are shown in **Figure 1**.



Figure 1. Purple sweet potato anthocyanin extract (a) maceration result (b) concentrated extract

Anthocyanins contained in purple sweet potatoes are easily soluble in polar solvents such as distilled water, but distilled water cannot stabilize anthocyanins because anthocyanins are stable at acidic pH. The use of weak organic acids such as citric acid is necessary to lower the pH [12]. The characteristics of the solvent (citric acid) have ionization properties that easily release positively charged hydrogen ions, resulting in the solution having a pH towards acidic which causes the formation of a reddish extract solution [13]. The red color will gradually faded after concentration with an evaporator. The color change after concentration is caused by the amount of solvent in the solution decreasing and separating from the solution, so that the number of hydrogen ions gradually decreases and causes a change in the pH of the extract liquid, resulting in a color change from red to purple. Based on the results of this study, it is in line with the results of research conducted by [14] and [15] who used citric acid as a solvent in the purple sweet potato anthocyanin extraction process which produced a concentrated purple extract.

3.2 Total anthocyanin concentration analysis

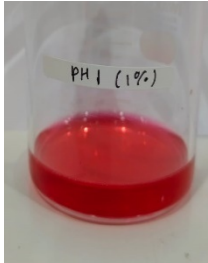
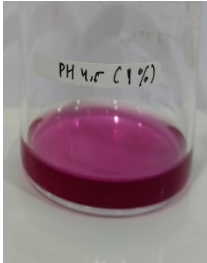
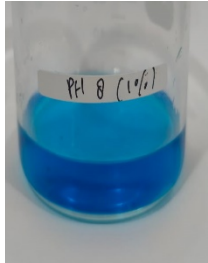
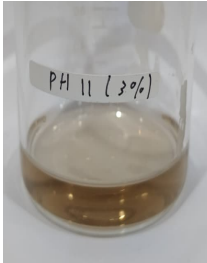
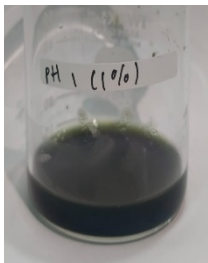
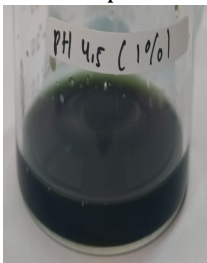
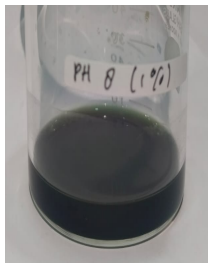
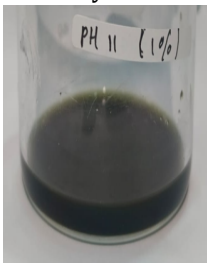
The purple sweet potato extract obtained was analyzed using UV Vis spectrophotometry at the length of the wave of 510 nm, and 700 nm under conditions of pH 1 and pH 4.5. The absorbance values obtained were then used to calculate the anthocyanin concentration. The results of the total anthocyanin concentration is 43.75 ± 0.02 . Based on research the amount of anthocyanin produced by purple sweet potato extract is quite high. This concentration was higher than the study by [16] who found the anthocyanin content obtained was only 8.39-18.03 (mg/L). Anthocyanins are red, purple, and blue pigments that are commonly found in plants and used as natural dyes [17]. The high amount of anthocyanin in purple sweet potatoes indicates that purple sweet potatoes have the potential can be used to produce indicator films.

3.3 Indicator solution sensitivity

This test was conducted by preparing 10 mL extract of purple sweet potato in a beaker glass and adding buffer solutions with pH 1, 4.5, 8, and 11. Prepare 25 mL of ammonia in a separate beaker

glass. Arrange the indicator solution into a desiccator by placing the ammonia in the center of the desiccator. The results of the indicator solution sensitivity test can be seen in **Table 1**.

Table 1. Indicator solution sensitivity test results

pH	1	4.5	8	11
Original color (Zero hour)				
	Red	Purple	Blue	Pale yellow
Final color (2 nd hours)				
	Dark green	Dark green	Dark green	Dark green

Based on Table 1 shows the color change in the purple sweet potato extract solution after being mixed with solutions in acidic and basic conditions. At hour 0, the indicator solution showed various color changes according to pH conditions, namely pH 1 is red, pH 4.5 is purple, pH 8 is blue, pH 11 is pale yellow. Research conducted by [18] and [19] showed the same results, namely purple sweet potato anthocyanin extract experienced color changes in various pH conditions. The color of the indicator solution with a pH range of 1-3 will be red, pH 4-7 is purple, pH 8 is blue, pH 9-10 is green and pH 11-14 is yellow. This discoloration is caused by structural changes. of the anthocyanin molecule which is influenced by the behavior of the acidity (pH) of the environment [20]. This is in accordance with the standard color change of the anthocyanin indicator at various pH conditions which can be seen in **Figure 2**.

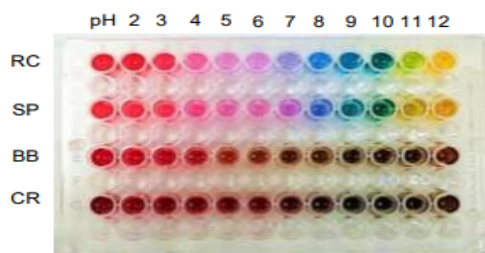


Figure 2. Change in color of purple sweet potato anthocyanin

Source : Sitanggang *et al*, 2020

At the 2nd hour, the indicator solution changed color to blackish green. Similar result were reported by [21] and [22] showing that, namely that the indicator solution that had reacted with ammonia vapor (NH_3) would show a color change under alkaline conditions, namely greenish. The results of the indicator solution sensitivity test showed that the anthocyanin content in purple

sweet potatoes was sensitive to the strong base compounds present in NH_3 vapor. This was evidenced by the color change in each variation of the indicator solution when evaporated with NH_3 vapor for two hours. Therefore, this indicator solution can be used as an indicator film to monitor the decline in the quality of smoked catfish.

3.4 Anthocyanin Indicator Film

The indicator film was successfully prepared using 10% PVA as the base material with the addition of glycerol (as a plasticizer) and anthocyanin at a concentration of 1%. The film was dried in an oven at 50°C for 24 hours until a thin, transparent purple sheet was formed. These results are consistent with research by [23], which reported that PVA is a good hydrophilic polymer for forming indicator films because it is compatible with phenolic compounds, including anthocyanins.

3.5 Indicator Film Thickness

In the tests that have been carried out, the thickness value for the film with 0% extract was ± 0.22 mm, while for the film with 1% extract it was ± 0.24 mm, which means that both films have met the JIS 1975 (Japanese Industrial Standard) sensor film thickness parameter standard, namely ≤ 0.25 mm [24]. The results of the film thickness test can be seen in **Table 2**.

Table 2. Film Test Results

Concentration	Film Test Results (mm)
0%	0.22 ± 0.01
1%	0.24 ± 0.01

In this study, the volume of the solution poured into the mold (petri dish) was 20 mL. The thickness of the film is influenced by the amount of film solution used and the surface area of the mold used, the greater the volume of the film solution inserted into the mold, the thicker the resulting film will be. The film thickness is also influenced by the thickness or viscosity of the film solution used, the greater the percentage of solids of the raw materials and plasticizers used, the more it will increase the thickness of the resulting film [25]. The addition of anthocyanin to the indicator film can also affect the thickness of the indicator film. This is in line with the findings of research conducted by [26], which states that the addition of active compounds in polymers can affect the viscosity of the solution and the thickness of the resulting film.

3.6 Indicator Film Color Change

The results of visual observations showed that the PVA-anthocyanin indicator film did not experience significant color changes during 8 days of storage, which can be seen in **Figure 3**.

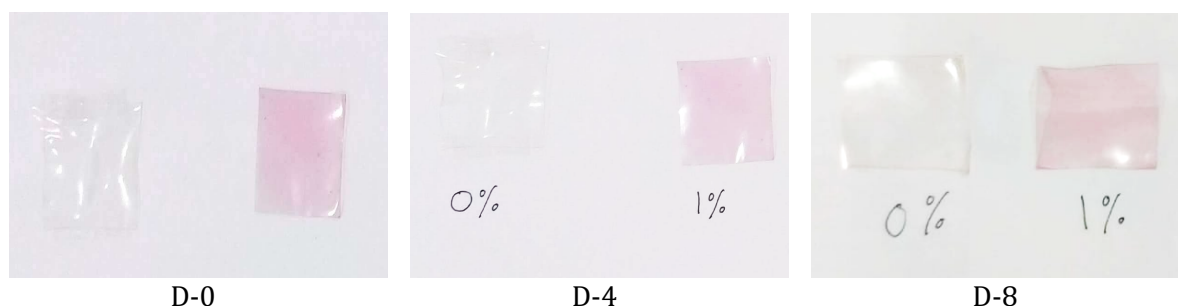


Figure 3. Indicator Film Color Change

Figure 3 shows the purple anthocyanin indicator film during storage. Color changes in the indicator film will appear according to the pH conditions of the environment. The color change of anthocyanin becomes more apparent at pH levels above 7, which indicates the onset of product deterioration. This is in line with study [27], which states that the color change of anthocyanin is influenced by pH levels, where pH 1-4 is red, pH 5-7 is purple, pH 8 is blue, pH 9-10 is green, and pH 11-14 is yellow. Based on the results of this study, the pH of smoked catfish remained below 7 until the end of the storage period, so that the color change in the indicator film did not show significant visual changes, only fading. In addition, TVBN and peroxide values can also affect the color change of the film due to volatile base compounds and protein degradation. These findings are consistent with study [28], which states that the color change of the indicator is influenced by pH conditions and the degree of product damage

3.7 pH

Based on the observation results that can be seen in **Fig 4**. It shows that the pH value of smoked catfish increased during storage, from 6.35-6.51 (D-0) to 6.56-6.66 (D-4) and 6.63-6.7 (D-8).

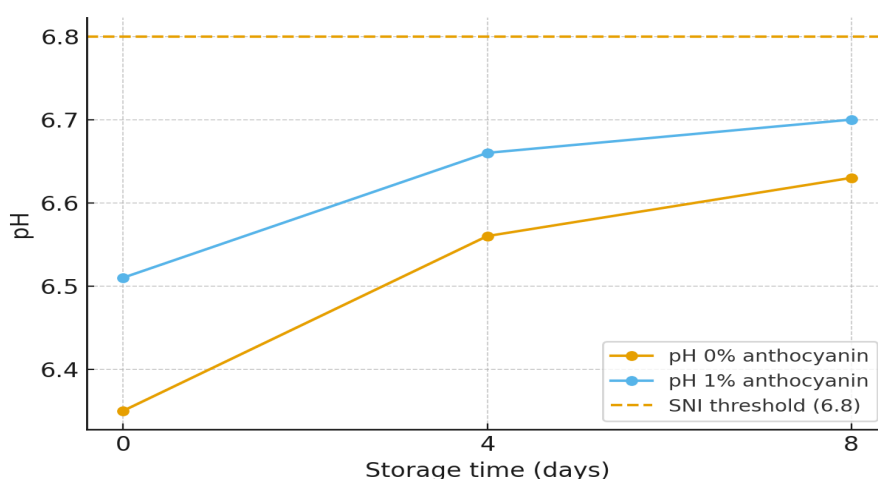


Figure 4. pH of smoked catfish during storage

The pH increase is due to the activity of destructive microbes and endogenous enzymes that break down proteins into volatile alkaline compounds, such as ammonia, trimethylamine (TMA), and dimethylamine (DMA). The increase in pH during room temperature storage is an early indicator of spoilage. Based on SNI 2725:2013 [29], the maximum pH of smoked fish suitable for consumption is 6.8. Thus, during storage up to D-8, smoked catfish still meets the standards for suitability for consumption. This is in accordance with researchers [30] who stated that the pH of smoked fish will experience an increase during storage which is influenced by environmental conditions and the level of spoilage.

3.8 TVB-N

Based on the observation results **Figure 5**, the TVBN value increased from 32.06-28.08 mg N/100 g (D-0) to 40.7-39.7 (D-4) and 71.5-43.3 (D-8).

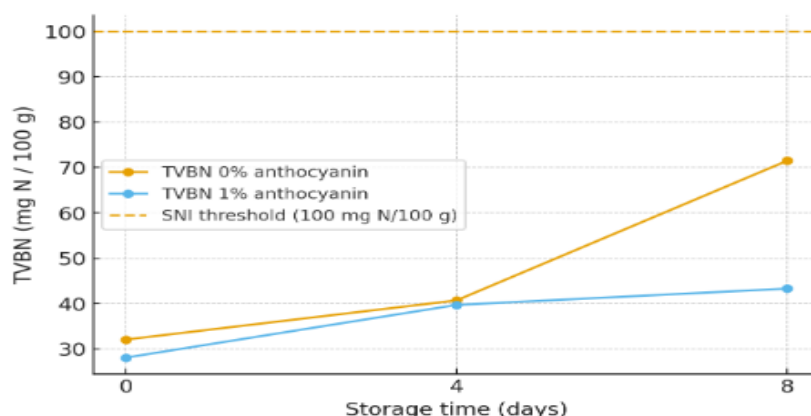


Figure 5. TVBN of smoked catfish during storage

The increase in TVBN was faster in samples without anthocyanin (0%) compared to those with added anthocyanin film (1%). This indicates that the addition of anthocyanin film in standing pouch packaging can slow down protein degradation. Anthocyanin is reported to have antimicrobial properties by damaging bacterial cell walls and disrupting nitrogen metabolism [31]. These results are in line with research by [32] who reported that anthocyanin-based indicator films were able to inhibit the rate of increase in TVBN in catfish fillets during storage. However, in this study, the TVBN value was still far below the SNI threshold (100 mg N/100 g), so that smoked catfish remained safe for consumption for up to 8 days.

3.9 Peroxide Value

Peroxide value indicates the level of lipid oxidation in fish. Data Figure 6 shows that the PV increased over time: from 7.3–3.4 meq O₂/kg on day 0 to 9.1–6.1 meq O₂/kg on day 4, and 11.01–8.2 meq O₂/kg on day 8. However, a sharper increase occurred in fish packaged without anthocyanin film (0%).

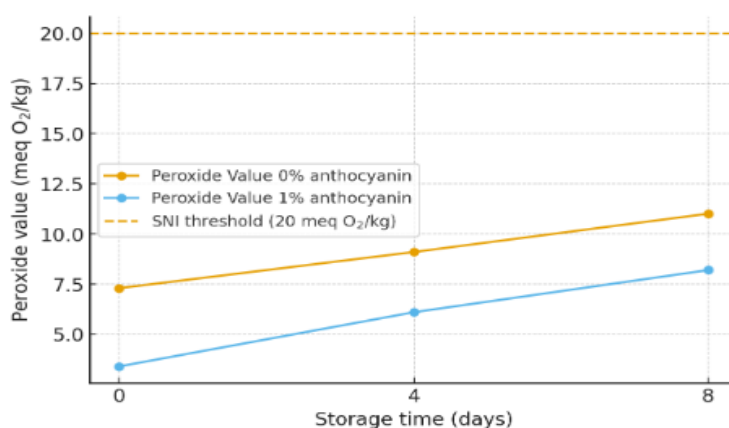


Figure 6. Peroxide value of smoked catfish during storage

The addition of anthocyanin film has been shown to suppress the rate of lipid oxidation, as evidenced by lower PV values during storage. Anthocyanins function as natural antioxidants, capable of scavenging peroxy free radicals and stabilizing double bonds in unsaturated fatty acids [33]. This is in line with the research of [34] on catfish fillets, where the use of antioxidants significantly suppressed the increase in PV. Thus, anthocyanin films are not only visual indicators, but also play a dual role as protective antioxidants.

4. Conclusion

Purple sweet potato anthocyanin concentration of 43.75 mg/L proved to be effective as an indicator of freshness change on PVA films with thicknesses of ± 0.22 mm (0%) and ± 0.24 mm (1%). During storage of smoked catfish, there was a significant increase in pH value (6.35-6.7), TVBN (28.08-71.5 mg N/100 g), and peroxide value (3.4-11.01 meq O₂/kg) which were responded by changes in film color. To improve the clarity of color changes and indicator sensitivity, it is recommended to use 3% anthocyanin concentration with a storage period of more than 10 days, so that the performance of the indicator film can be observed more optimally.

Acknowledgment

The author would like to express the Institute for Research and Community Service (LPPM) of the University of Riau through the University of Riau's Leading Research (RUUR) funding scheme, 2025, with contract number 29123/UN19.5.1.3/AL.04/2025 on behalf of Ir. N. Ira Sari, M. Si. We also would like to thank M Zakiyul Fikri for his contribution in the sample collection process.

References

- [1] Badan Pusat Statistik Provinsi Riau 2022. *BPS*. Pekanbaru
- [2] Hermawan S, Yaqin RA, Adhim A, Choirunnisa E, Amaliyah R, Astika IW 2021. *Jurnal Pusat Inovasi Masyarakat*. **1;3(1)**:59-68.
- [3] Tumonda S, Mewengkang HW, Timbowo SM 2017. *Media Teknologi Hasil Perikanan*. **27;5(2)**:64-8.
- [4] Sarungallo ZL, Santoso B, Tethool EF, Situngkir RU, Tupamahu J 2018. *Agritech*. **38(1)**:64-70.
- [5] Muhammad Y, Sri I, Nur Fitriani UA 2018. *Jurnal Galung Tropika*. **7(1)**:46-55.
- [6] Sukardi S, Kiswaya SM, Pranowo D 2018. *Industria: Jurnal Teknologi dan Manajemen Agroindustri*. **28;7(3)**:133-42.
- [7] Kaiang DB, Montolalu LA, Montolalu RI 2016. *Media Teknologi Hasil Perikanan*. **1;4(2)**:75-84.
- [8] Pangesti Dp, Ningtyas R 2023. *Inseminar Nasional Teknologi Cetak Dan Media Kreatif 2023 (Vol. 2)*.
- [9] Rahmadhia SN, Saputra YA, Juwitaningtyas T, Rahayu WM 2022. *Journal of Functional Food and Nutraceutical*. **21**.
- [10] Seftyani M 2019. *Skripsi, Jember: Universitas Jember*.
- [11] Widiastutik, Y., Lutfi, M. and Susilo, B 2018. *Journal of Tropical Agricultural Engineering and Biosystems-Jurnal Keteknikaan Pertanian Tropis dan Biosistem*, **6(3)**, pp.278-285.
- [12] Nizori A, Sihombing N 2020. *Jurnal Teknologi Industri Pertanian*. **(2)** 31;30.
- [13] Muhammad Y, Sri I, Nur Fitriani UA 2018. *Jurnal Galung Tropika*. **7(1)**:46-55.
- [14] Maharani, B.C., Lindriati, T. and Diniyah, N 2016. *Jurnal Penelitian Pangan (Indonesian Journal of Food Research)*, **1(1)**.
- [15] Syahrina D, Noval N 2021. *Jurnal Surya Medika (JSM)*. **30;7(1)**:156-72.
- [16] Salim M, Dharma A, Mardiah E, Oktoriza G 2017. *Jurnal Zarah*. **25;5(2)**:7-12.
- [17] Sampebarra AL 2018. *30;13(1)*:63-70.
- [18] Sitanggang AB, Irsali MF, Rawdkeun S 2020. *Jurnal Teknologi Dan Industri Pangan*. **26;31(1)**:66-75.
- [19] Apriliyanti MW, Ardiansyah MA, Wahidah N 2020. *Jurnal Ilmiah Inovasi*. **(2)** 31;20.
- [20] Ayun Q, Ajeng A 2022. *Jurnal Crystal: Publikasi Penelitian Kimia Dan Terapannya*. **31;4(1)**:1-6.
- [21] Ningtyas R, Saraswati AD 2022. *Sagu*. **20(2)**:40-8.
- [22] Fauzan UN, Pancani AR, Yulistiani F, Djenar NS 2022. *Jurnal Kimia Riset*. **(1)** 1;7.
- [23] Yessica Y 2023. *ZIGMA*. **6;38(2)**:60-72.

- [24] Standard, E 1993. 3–5.
- [25] Nofrida R, Warsiki E, TIP IY 2013. *Jurnal Teknologi Industri Pertanian*. **23(3)**.
- [26] Seftyani M 2023. *Skripsi, Jember: Universitas Jember*.
- [27] Bria HR, Leba MA, Kopon AM 2021. *Jurnal Beta Kimia*. **16;1(2)**:35-41.
- [28] Silvia D, Ishaaq AN, Prastiwinarti W 2021. *J. Fishtech*. **10(2)**:86-94.
- [29] Standar Nasional Indonesia 2013. SNI-2725-2013.
- [30] Ahmad ZA, Lekahena VN, Laitupa IW 2024. *BIOSAINSTEK*. **27;6(1)**:61-75.
- [31] Yessica Y, Setijawaty E, Jati IR 2025. *Jurnal Teknologi Pangan dan Gizi (Journal of Food Technology and Nutrition)*. **30;24(1)**:38-55.
- [32] Maulana, F. Y 2023. *Universitas Politeknik Jakarta*.
- [33] Febora V, Jati IR 2024. *ZIGMA*. **8;39(1)**:76-88.
- [34] Hidayati F, Darmanto YS, Romadhon R 2017. *Saintek Perikanan: Indonesian Journal of Fisheries Science and Technology*.; **12(2)**:116-23.