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SYNTHESIS AND CHARACTERIZATION OF SMART PACKAGING FILM LABELS USING PURPLE SWEET POTATO ANTHOCYANIN AS CHICKEN MEAT QUALITY INDICATOR

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ABSTRACT

Kebutuhan akan kemasan cerdas (smart packaging) yang mampu memberikan informasi nyata tentang kesegaran dan keamanan pangan terus meningkat seiring dengan kesadaran konsumen terhadap mutu produk. Penelitian ini bertujuan mensintesis dan mengkarakterisasi label film berbasis antosianin dari kulit ubi jalar ungu (Ipomoea batatas L.) sebagai indikator kesegaran daging ayam. Ekstraksi antosianin dilakukan secara maserasi menggunakan etanol 96% yang diasamkan dengan HCl 1%, kemudian diuji stabilitas warnanya pada pH 2–11. Film dibuat dengan variasi konsentrasi antosianin 0%, 3%, 5%, dan 7%. Hasil menunjukkan perubahan warna dari ungu (pH 5,8) menjadi kuning kehijauan (pH 8,7) seiring meningkatnya pH daging akibat pembusukan. Uji fisik menghasilkan laju transmisi uap air 4,40 g/j·m², ketebalan 0,08 mm, kelarutan 40%, dan biodegradabilitas 100%. Analisis FTIR mengonfirmasi keberadaan gugus fungsi khas antosianin (O–H, C–H, C=C, dan C–H aromatik). Secara keseluruhan, film ini berpotensi sebagai indikator alami dan ramah lingkungan dalam sistem kemasan cerdas untuk memantau kesegaran daging ayam.

Keywords: Antosianin, *lpomea batatas L.*, Smart Packaging, pH Indikator, Film Label

ABSTRACT

The demand for smart packaging that provides real-time information on food freshness and safety continues to rise with growing consumer awareness of product quality. This study aimed to synthesize and characterize anthocyanin-based film labels from purple sweet potato peel (Ipomoea batatas L.) as freshness indicators for chicken meat. Anthocyanins were extracted via maceration using 96% ethanol acidified with 1% HCl and tested for color stability at pH 2–11. Films with 0%, 3%, 5%, and 7% anthocyanin concentrations were prepared. The films showed color changes from purple (pH 5.8) to greenish yellow (pH 8.7) with increasing meat pH, indicating spoilage. Physical tests revealed a water vapor transmission rate of 4.40 g/h·m², thickness of 0.08 mm, solubility of 40%, and biodegradability of 100%. FTIR analysis confirmed characteristic anthocyanin functional groups (O–H, C–H, C=C, aromatic C–H). Overall, the film shows potential as a natural and eco-friendly indicator for smart packaging to monitor chicken meat freshness.

Keywords: Anthocyanins, *lpomoea Batatas L.*, Smart Packaging, pH Indicator, Film Label

INTRODUCTION

Increasing concerns over food safety have driven the development of smart packaging that provides real-time freshness information. This innovative system not only protects food but also indicates its condition through integrated sensors or indicators (Arif et al., 2022). pH indicator-based packaging is especially promising, as it detects biochemical changes from microbial spoilage such as ammonia and amine release in chicken meat which raise pH and trigger visible color changes in pH-sensitive materials (Ningsih et al., 2021).

Synthetic dyes like bromophenol blue and chlorophenol red have been used as indicators but are limited in food applications due to toxicity concerns (Kim et al., 2019). In contrast, natural pigments such as anthocyanins offer a safer, eco-friendly alternative. Found abundantly in purple sweet potato peel (Ipomoea batatas L.) containing 521.82–729.74 mg/100g (Nunki, 2018) anthocyanins exhibit distinct pH-dependent color changes from red to yellowish-green, making them ideal natural indicators for smart packaging (Abedi-Firoozjah et al., 2022).

Several studies have reported the application of anthocyanins in food packaging indicators, where their combination with biopolymers such as gelatin (Sitanggang et al., 2020), carrageenan and cellulose (Amalia et al., 2021), and tuber starch (Pangesti & Rina, 2023) has yielded films responsive to pH changes with favorable mechanical properties.

However, most of these studies have not explored the potential of anthocyanins extracted from purple sweet potato skins, which are abundant agricultural waste materials, nor have they evaluated their performance in indicating the freshness of protein-rich foods such as chicken meat. Therefore, this study focuses on synthesizing and characterizing an anthocyanin-based film derived from purple sweet potato skin as a smart indicator for chicken meat quality in smart packaging applications.

This approach emphasizes not only the mechanical characterization and pH sensitivity of the films but also their eco-friendly potential and applicability in smart packaging systems. Therefore, this study aims to synthesize and characterize film labels incorporating anthocyanins extracted from purple sweet potato peel (Ipomoea batatas L.) as natural pH indicators to monitor the freshness of chicken meat in smart packaging applications.

METHOD

Tools and Materials

The equipment used included an analytical balance, magnetic stirrer, blender, petri dish, oven (IKA 125 Basic Dry), pH meter, caliper, rotary evaporator, Universal Testing Machine (UTM), UV-Vis spectrophotometer (Shimadzu 2450), and FTIR-ATR spectrophotometer. The materials consisted of purple sweet potato peel, 1% chitosan, 5% glycerol, 96% ethanol, 1% HCl, pH 1–12 buffer solutions, corn starch, chicken meat, distilled water, and 1% acetic acid.

Anthocyanin Extraction

A total of 80 grams of dried and mashed purple sweet potato skins were macerated in 96% ethanol for pigment extraction solvent acidified with 1% HCl (1:1, v/v) with a sample solvent ratio of 1:5 (b/v) for 72 hours. The maceration duration and temperature of 50°C were selected based on previous studies reporting that prolonged extraction under mild acidic and warm conditions enhances anthocyanin yield while minimizing pigment degradation (Agustin & Ismiyanti, 2023). This extraction procedure was adapted and slightly modified from earlier methods to optimize pigment recovery from Ipomoea batatas L. peels used in this study. The extracted filtrate was evaporated using a rotary evaporator at 50°C to obtain a thick extract.

Qualitative Test of Extracts

Flavonoids were identified using the Wilstätter test with Mg ribbon and concentrated HCl, while anthocyanins were confirmed by adding 2M HCl (stable red color) and 2M NaOH (color shift to green/blue).

Anthocyanin Stability Test

A 1 mL aliquot of the extract was mixed with buffer solutions ranging from pH 1 to 12, and the absorbance along with color changes were measured using a UV-Vis spectrophotometer within the wavelength range of 300–800 nm.

Label Film Synthesis

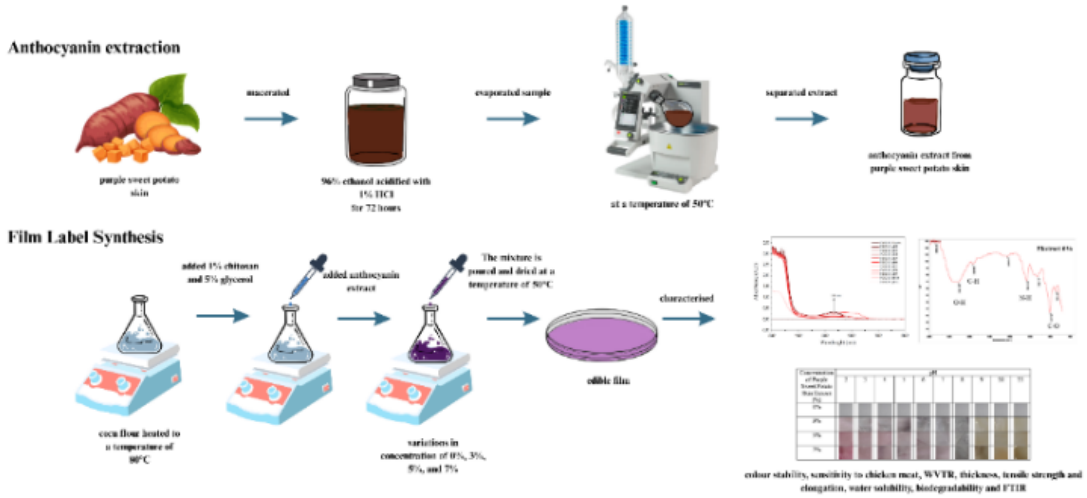


Figure 1. Illustration of anthocyanin extraction and film label synthesis

Corn starch solution (5 g in 50 mL of distilled water) was heated to 80°C for 10 minutes. 1% chitosan (5 g in 500 mL of 1% acetic acid) was mixed with the corn starch solution with the addition of 5% (v/v) glycerol as plasticizer. Furthermore, anthocyanin extract was added at concentrations of 0% (control), 3%, 5%, and 7% of the total volume of the film solution. The mixture was poured into petri dishes and dried in an oven at 50°C for 24 hours.

Film Label Characterization

Film labels were characterized for color stability (pH 2–11), sensitivity to chicken meat freshness, and physical properties including thickness, tensile strength, elongation, and WVTR. Water solubility and biodegradability were determined through weight changes after immersion and soil burial, while FTIR analysis identified functional groups in the film matrix.

RESULTS AND DISCUSSION

Purple Sweet Potato Peel Extraction

The extraction of anthocyanins from Ipomoea batatas L. peel using 96% ethanol acidified with 1% HCl yielded a purplish-red extract characteristic of stable anthocyanins. Acidic conditions maintained the flavylium cation form, ensuring pigment stability (Agustin & Ismiyanti, 2023). Qualitative tests confirmed the presence of flavonoids and anthocyanins, indicating that purple sweet potato peel is a rich source of phenolic compounds. Similar results were reported by

Anggraini and Reggy (2022), Santoso et al. (2022), and Fendri et al. (2018), supporting the effectiveness of the applied extraction parameters in preserving anthocyanin stability.

Phytochemical screening confirmed that Ipomoea batatas L. peel extract contains both flavonoids and anthocyanins. The Wilstätter test produced an orange color after adding Mg ribbon and concentrated HCl, indicating aromatic rings and hydroxyl groups characteristic of flavonoids (Oktaviani et al., 2022). The green-brown coloration upon NaOH addition confirmed the presence of anthocyanins, known for their strong pH sensitivity (Febriani et al., 2021). These qualitative results demonstrate that the extraction successfully preserved both compounds. The reversible color shift from red in acidic to greenish in alkaline conditions further verified the pH-responsive behavior of anthocyanins, supporting their suitability as natural colorimetric indicators for smart packaging applications. Detailed results are presented in Table 1.

Table 1. The Results of the Phytochemical test of Purple Sweet Potato Skin

Compounds	Reagent	Color Change	Test Result
Flavanoids	Mg tape + concentrated HCl	Red to orange	positive
Anthocyanins	HCl 2 M, Heating 5 min	Stay red	positive
Anthocyanins	NaOH 2 M	Green fade	positive

Anthocyanin Stability Test

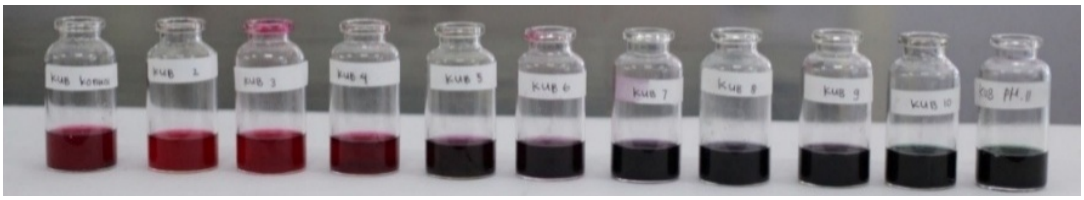


Figure 2. Color change of purple sweet potato peel extract (lpomea batatas L.) in buffer 2-11

The color stability of anthocyanin extract from purple sweet potato peel (Ipomoea batatas L.) was tested in buffer solutions with pH values ranging from 2 to 11. As shown in Figure 2, the extract displayed a gradual color change from bright red at acidic pH to purple, blue, and finally yellowish green under alkaline conditions. These variations reflect the structural transformation of anthocyanins in response to pH changes.

Based on the UV-Vis spectra (Figure 3), the extract showed maximum absorption at 531 nm (pH 2), characteristic of the flavylium cation. With increasing pH, the peak shifted to 540–545 nm and finally 420 nm at pH 9–11, indicating structural transition from red flavylium to blue

quinonoid and yellow chalcone forms. The λmax values align with cyanidin-type anthocyanins (515–545 nm) (Anggraini & Reggy, 2022), confirming good pH-responsive color stability suitable for smart packaging applications.

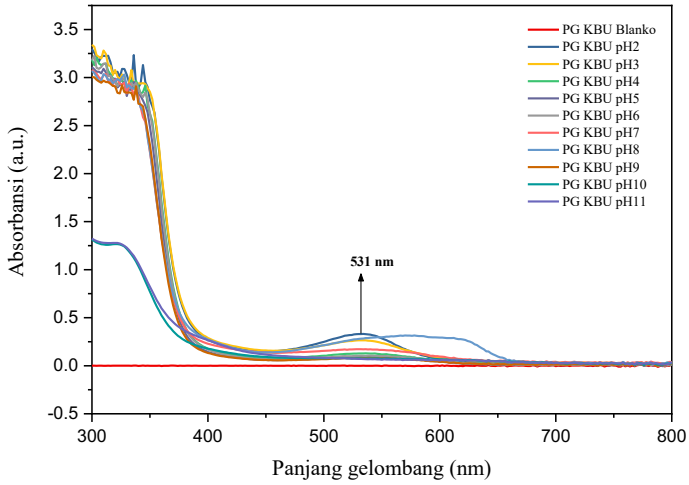


Figure 3. UV-Vis spectrum of anthocyanin extract from purple sweet potato skin (*Ipomea batatas L.*)

Edible Film Synthesized

The film labels were formulated using Ipomoea batatas L. anthocyanin extract, corn starch, glycerol, and chitosan, with glycerol as a plasticizer and chitosan as structural reinforcement (Arif et al., 2022). Four extract concentrations (0%, 3%, 5%, and 7% v/v) were prepared based on chitosan weight to improve color and pH sensitivity. Visually, the control film (0%) was transparent, while increasing anthocyanin concentrations produced progressively darker purple films with reduced transparency, indicating higher pigment density and stronger color response (Figure 4).

(a) (b) (c) (d)

Figure 4. Appearance of the edible film in various concentration of purple sweet potato skin anthocyanin extract (*Ipomoea batatas L.*) (a) 0% (control) (b) 3 % (c) 5 % and (d)7 %

Film Label Characterization

Film Label Stability Test

This test was conducted by dipping the film label in a pH 2-11 buffer solution. The purpose of this test was to determine the color change of the film label as the pH changed as a color parameter. The film label with the addition of anthocyanin extract from purple sweet potato skin (Ipomoea batatas L.) underwent changes in line with changes in pH, as can be seen in Table 2.

Table 2. Color Changes in Film Labels in Buffer Solutions

Concentration of Purple Sweet Potato Skin Extract (%)	pH									
	2	3	4	5	6	7	8	9	10	11
0%										
3%										
5%										
7%										

Based on Table 4.2, film labels with various anthocyanin concentrations showed similar color changes, except for the 0% control. Labels containing Ipomoea batatas L. anthocyanins responded to pH variations from 2–11, displaying red at pH 2–3, purple at 4–7, blue at 8, yellow at 9, and yellow-green at 10–11 (Fendri et al., 2018). Color stability was evaluated using ImageJ through RGB color index analysis, with results summarized in Table 3.

Table 3. RGB Color Index Values of Film Labels in Buffer Solution 2-11

Concentration of Purple Sweet Potato Skin Extract (%)	RGB color	Buffer Solution pH 2-11									
		2	3	4	5	6	7	8	9	10	11
0	*Red*	186	185	186	185	186	186	185	186	185	186
	Green	175	174	174	175	174	175	175	175	175	174
	Blue	171	170	170	169	170	170	170	171	171	170
3	*Red*	204	204	204	204	204	170	146	96	90	81
	Green	171	173	168	178	176	180	200	201	201	201
	Blue	159	155	148	162	157	177	198	200	203	203
5	*Red*	203	203	203	199	201	171	143	143	133	133
	Green	152	153	174	172	201	171	180	200	201	202
	Blue	139	141	166	153	135	179	180	201	202	202
7	*Red*	205	205	205	205	205	205	148	144	145	135
	Green	205	180	183	187	190	191	202	203	205	205
	Blue	174	178	178	180	183	198	200	204	204	204

RGB analysis was used to evaluate the color components of film labels in buffer solutions at pH 2–11. According to Mustika (2015), the lower the pH, the higher the RGB index value for red, while green and blue decrease; conversely, the higher the pH, the lower red and the higher green and blue. The results of this study are consistent with these findings. Higher RGB index values

indicate brighter and more visually distinct colors, making color changes as indicator labels easier to observe. The film with the addition of 7% anthocyanin extract from purple sweet potato skin (Ipomoea batatas L.) showed the highest RGB index value, indicating the most dominant color and sensitivity to pH changes.

Testing the Sensitivity of Film Labels to Chicken Meat

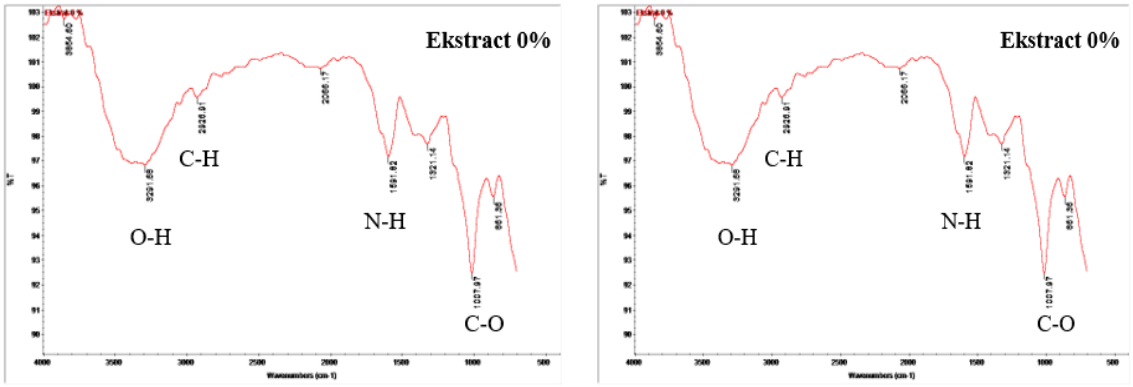
The film labels exhibited distinct color changes as chicken meat freshness declined, corresponding to the pH increase during storage. The most rapid response occurred in the film containing 7% anthocyanin extract, which changed color at 10 hours when the meat reached a pH of 7.2. This higher sensitivity is attributed to the greater anthocyanin concentration, enhancing the film's responsiveness to environmental pH variations. The 7% film also showed the highest RGB color index (Table 3), indicating a brighter and more visually distinct color. These results suggest that the film's sensitivity is influenced not only by anthocyanin concentration but also by its physical characteristics such as uniform thickness and even pigment dispersion that facilitate faster interaction with pH changes, as illustrated in Table 4.

Table 4. Film Label Color Change

Storage Duration	Label Film	pH of Chicken Meat	Storage Duration	Label Film	pH of Chicken Meat
0		5,8	13		7,8
1		5,8	14		7,8
2		5.9	15		7,9
3		5,9	16		8,2
4		6,2	17		8,2
5		6,4	18		8,2
6		6,4	19		8,3
7		6,6	20		8,3
8		6,7	21		8,4
9		6,8	22		8,5
10		7,2	23		8,5
11		7,3	24		8,7
12		7,7			

According to SNI 3924-2009, fresh chicken meat has a pH of 6–7, while Afriani et al. (2024) reported a range of 5.3–6.5 under normal conditions. As meat spoils, microbial activity produces volatile bases such as ammonia and amines, increasing pH and causing the film color to shift from purple to yellowish-green through anthocyanin deprotonation to quinonoid or chalcone forms (Nitiyacassari et al., 2021). This result aligns with Oktaviani (2022), who observed a similar color shift in anthocyanin-based smart packaging as chicken meat pH rose from 6.04 to 8.41, confirming its effectiveness as a freshness indicator.

Functioanal group analysis with FTIR



(a) (b)

Figure 5. FTIR Analysis Spectrum of Film Labels (a) 0% (control) (b) 7%

Figure 5 shows the results of functional group analysis on film labels using an FTIR spectrophotometer to verify the presence of anthocyanins in film labels. The absorption of film label functional groups can be seen in Table 5.

Table 5. Absorption of All Film Labels

Wave Number (cm^{-1})		Functional Groups	Refrence
0%	7%		
3291	3372	O-H	Sari, 2020
2926	2925	C-H	Noordam, dkk., 2025
1591	1596	N-H	Hasri, dkk., 2021
-	1414	C=C	Ratnasari, dkk., 2016
1007	1015	C-O	Bayu, 2023
-	674	C-H aromatik	Nandiyanto, dkk 2023

FTIR analysis (Figure 5) showed peaks at 3291–3371 cm^{-1} (O–H), 2923–2926 cm^{-1} (C–H), 1591 cm^{-1} (N–H), 1411 cm^{-1} (C=C), 1007–1015 cm^{-1} (C–O), and 674 cm^{-1} (aromatic C–H). The presence of C=C and aromatic C–H only in anthocyanin films confirmed successful incorporation

and hydrogen bonding with polymer groups, enhancing film stability. Control films lacked aromatic signals, consistent with Amsikan (2023), indicating anthocyanins modified both chemical and functional film properties.

Testing the Rate of Water Vapor Transmission

The WVTR results showed that adding Ipomoea batatas L. anthocyanin extract markedly reduced water vapor transmission from 8.56 to 4.40 g/m²·h. This reduction is attributed to the formation of a denser polymer matrix that limits vapor diffusion, despite the hydrophilic nature of anthocyanins (Fitriani, 2021). Similar findings were reported by Santoso et al. (2022), confirming the role of anthocyanins in enhancing film compactness. All WVTR values were below the JIS limit of 10 g/m²·h, indicating that the developed films possess good barrier performance and meet edible film quality standards.

Film Label Thickness Test

The addition of Ipomoea batatas L. anthocyanin extract slightly reduced film thickness from 0.09 to 0.08 mm, indicating minimal effect on physical structure. All values met the JIS standard (<0.25 mm), confirming compliance with international quality criteria.

Solubility Test in Water

Film solubility decreased from 50% to 40% with increasing anthocyanin concentration, as phenolic compounds formed hydrogen bonds that densified the matrix and reduced solubility (Santoso et al., 2022). All values remained below the JIS (1975) limit of ≤96%, confirming compliance with international quality standards.

Biodegradability Test

The biodegradability test showed 98% degradation after 12 days at 0% extract and complete (100%) degradation at 7%. Anthocyanins from Ipomoea batatas L. enhanced decomposition through hydrophilic and hydroxyl interactions, consistent with Suriyatem et al. (2018). All values exceeded the SNI standard of 60% (National Standards Agency, 2016), confirming the film's high biodegradability and eco-friendly performance.

CONCLUSION

The developed film label exhibited favorable physical and functional properties, including a WVTR of 4.40 g/hour·m², 0.08 mm thickness, and 40% water solubility, all meeting JIS and SNI standards. FTIR analysis confirmed anthocyanin incorporation through characteristic O–H, C–H,

C=C, and aromatic C–H peaks. At a 7% extract concentration, the film showed a rapid color change from purple (pH 5.8) to yellowish-green (pH 8.7) within 24 hours at room temperature, indicating chicken meat freshness. The film successfully combined biodegradability, stability, and pH responsiveness, highlighting its novelty as a natural anthocyanin-based biodegradable label for intelligent food packaging.

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