

# Smart Packaging of Temperature and Light Susceptible Product with Purple Sweet Potato (*Ipomoea batatas* L.) Indicator Label

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**Abstract**—The main role of packaging in the food industry is to preserve and protect products from external contamination such as light, heat, oxygen, moisture, microorganisms, and others. Product shelf life can be increased by reducing the risk of contamination from microbes, especially for products that are vulnerable to temperature and light such as pasteurized milk. Consumers generally evaluate the quality and freshness of packaged foods through the shelf life printed on the package. Still, for some products, the shelf life date is not enough to evaluate the quality and freshness of the food. In this regard, using the color indicator packaging has been found to be an innovative and smart process for detecting, tracking and protecting the quality of food, and it turns out to be an ultimate tool for safe and convenient food packaging. Smart packaging can show the color change of the packaging film according to the state of the food and evaluate the quality or freshness of the packaged food in real-time, is increasing. Anthocyanins, a family of polyphenol-based flavonoids, are natural colorants that reflect light from red to blue in the visible spectrum. Recently, studies on anthocyanins are rapidly increasing as an alternative to toxic synthetic food colorants due to their excellent functional properties. Anthocyanin's pH dependent color change properties are very important in that it can monitor food quality, indicate the shelf life of food, increase consumer interest in food, and eventually be used as a color indicator in food packaging applications. The pH indicator used in this study was sourced from purple sweet potato extract with edible film membranes from chitosan, and CMC. In this study, the extraction of purple sweet potatoes was carried out with ethanol: acetic acid: aquadest as a solvent with a ratio of 25:1:5 ml, so that a total anthocyanin content was obtained of  $70.16 \pm 0.899$  mg / 100 g with a pH of  $5.60 \pm 0.015$ . The freshness parameter of the milk can be seen from the color change on the label that shows the pH of the product. If the pH gets lower than the pH of the milk, the product has spoiled. The label contains three color parameters that indicate that the milk is fresh, still fresh, and not fresh. Therefore, the pH indicator label developed can be used as a diagnostic tool to detect product freshness.

**Keywords**—*Anthocyanin, Edible Film, Milk, Purple Sweet Potato, Smart Packaging*

## I. INTRODUCTION

Packaging plays an essential role in maintaining food quality, food safety, and extending the shelf life of food in the food industry [4]. In general, changes in safety and quality occur during the storage, distribution, and transportation of food products. Consumers generally evaluate the quality and freshness of packaged foods through the shelf life printed on

the package. Still, for some products, such as fresh fruits and vegetables, the shelf life date is not enough to evaluate the quality and freshness of the food. In this regard, using the intelligent color indicator packaging has been found to be an innovative and smart process for detecting, tracking and protecting the quality of food, and it turns out to be an ultimate tool for safe and convenient food packaging [4].

Anthocyanins, a family of polyphenol-based flavonoids, are natural colorants that reflect light from red to blue in the visible spectrum [14]. Anthocyanin, composed of the glycosylated structure of anthocyanidins, is one of the most interesting and extensively studied plant compounds. There are six types of anthocyanidins found primarily in the environment: cyanidin, pelargonidin, delphinidin, petunidin, peonidin, and malvidin [5].

This review first describes the natural sources, properties, and functions of anthocyanins. Then we thoroughly discussed the use of anthocyanins with various types of biodegradable polymers, and finally, the application of pH-responsive smart packaging films to monitor the freshness and quality of food. This review also provides a deep understanding of the benefits of anthocyanin-based pH responsive color-changing shelf-life indicators for food packaging applications for specific foods. To the best of our knowledge, only a few review papers have been published in this area [4]. Therefore, this comprehensive review appropriately provides insights into the pH-responsive color-changing indicator technology and can be applied to intelligent food packaging and new food packaging designs.

## II. METHOD

### A. Preparation of Purple Sweet Potato Anthocyanin Extract for Indicator Labels.

Preparation of the extract begins with washing the purple sweet potato until clean and then cutting it into small pieces. The purple sweet potato slices are weighed as much as 100 g and then crushed together with 200 mL of ethanol, acetic acid, and distilled water (25: 1: 5) solvent. After that, the solution is stored in a dark bottle during the maceration process. After 24 hours, the extract solution was filtered using Whatman paper no. 41. The extract was concentrated through a vacuum rotary evaporator at a temperature of 70°C for 1 hour. The supernatant produced was stored in a dark bottle and used as an extract of natural purple sweet potato dye. In

the first phase of the study, two replications were carried out, in each repetition 3 observations were made. The tests carried out included pH parameters and anthocyanin concentrations from purple sweet potato anthocyanin extracts.

#### B. Indicator Labels and Edible Film as a Milk Freshness Level Sensor

Indicator labels use cellulose paper, namely Whatman paper No. 1. The paper is cut to a size of 2 cm x 2 cm and soaked with purple sweet potato extract for 30 minutes and dried at room temperature [9].

The edible film layer is made of chitosan and CMC. 1.5 grams of chitosan was dissolved with 100 ml of 1% acetic acid and heated using a magnetic stirrer for 30 minutes. 1 gram of CMC was dissolved in 100 ml of distilled water and heated using a magnetic stirrer for 30 minutes. Then, the chitosan and CMC solutions were combined and heated for 15 minutes. The solution is molded using a baking sheet and heated in an oven at a temperature of 60°C. After 24 hours, the edible film is cut to a size of 2.5 cm x 2.5 cm. The presence of the edible film layer aims to minimize immobilization of the purple sweet potato extract indicator label with the product.

#### C. Application of Purple Sweet Potato Anthocyanin Extract Indicator Label on Smart Packaging as an Indicator of Milk Freshness Indicator

Labels that have been immobilized with purple sweet potato anthocyanin extract and a layer the edible film is applied in smart packaging to determine the freshness level of chicken meat stored at room temperature (27°C ± 3°C) and cold temperatures (5°C ± 3°C). The test is carried out every 2 hours from the 0<sup>th</sup> hour to the 8<sup>th</sup> hour, and 4 hours from the 8<sup>th</sup> hour to the 24<sup>th</sup> hour stored at room temperature (27°C ± 3°C) and every day for 6 days stored at cold.

### III. RESULT

The test parameters for the freshness of milk include pH test, and changes in milk color intensity, while the smart label testing parameters include: color and pH test.

#### A. Measurement of pH and Anthocyanin Levels of Purple Sweet Potato Extract

The pH test of the purple sweet potato anthocyanin extract was carried out using a hand pH meter. The results of the purple sweet potato anthocyanin extract were taken 10 ml and put into a 50 ml beaker glass, then entered the hand pH meter and observed the pH results from the purple sweet potato anthocyanin extract [13].

Measurement of total anthocyanin concentrations from natural dyes in liquid form was carried out using the pH differential method developed by AOAC [3]. Two test tubes were prepared, the first test tube was inserted with 2 mL of pH 1 potassium chloride buffer, then the second test tube was added with 2 mL of sodium acetate buffer pH 4.5. Each test tube was added with a sample to determine the anthocyanin level of 0.5 mL and let stand for 15 minutes. The absorbance measurements of the two pH treatments were measured using a UV-Vis spectrophotometer at a wavelength of 520 nm and 700 nm. The absorbance value is calculated by the equation:

$$A = [(A_{520} - A_{700})_{pH 1} - (A_{520} - A_{700})_{pH 4.5}] \quad (1)$$

$$\text{Anthocyanin concentration} = \frac{(A \times BM \times F \times 1000)}{V} \quad (2)$$

Anthocyanin extract of purple sweet potato as a natural coloring agent used as a pH indicator on smart labels. The pH analysis results of purple sweet potato anthocyanins were 5.60 ± 0.015. The purple sweet potato anthocyanin extract produced is light purple and is in an acidic pH atmosphere. Anthocyanins are more stable in acidic or low pH conditions than alkaline or high pH situations [1]. Anthocyanin extracts that are at acidic pH have a stable and most colorful color [2]. Therefore, the anthocyanins obtained with a pH value of 5.60 ± 0.015 can be used as a smart label indicator based on the color changes that occur. The standard deviation value of 0.015 indicates that the area of the data deviation is low between the pH value of the first and second repeated purple sweet potato anthocyanins.

The value of purple sweet potato anthocyanin content was 70.16 ± 0.899 mg / 100 g. Anthocyanin levels are influenced by several factors, including temperature, changes in pH, light, and oxygen, besides that the sample preparation process, sample conditions, and sample storage period affect anthocyanin levels [10]. Increasingly acidic conditions will cause more anthocyanin pigments to be in the form of colored flavylum cations and absorbance measurements will show a greater number of anthocyanins [8]. The standard deviation value of 0.899 indicates that the area of deviation in the value of anthocyanin levels for repeat one and repeat two is not large, so the data can be said to be valid.

#### B. Indicator Label Application of Purple Sweet Potato Anthocyanin Extract

RGB (values are Red, Green, Blue) calculated using the help of software *ImageJ*. The assessment is *mean* RGB obtained from the average RGB value on the smart label that has been immobilized in the purple sweet potato anthocyanin extract. RGB values are obtained from three different sides of the smart label.

The value *means* RGB on the smart label which has the highest to lowest value is the *mean* red of 175.648 ± 0.006, the *mean* blue is 108.313 ± 0.014, the *mean* green is 157.464 ± 0.013, so the value *means* used for the analysis of the *mean* RGB in testing the intensity of the smart label color change is *mean* red. The higher the value of *mean* one of the basic colors indicates that the color is read most dominantly by *ImageJ* software. Color is a combination of three basic colors, namely red, green, and blue (Red, green, blue-RGB), a base color is a color that cannot be obtained from a mixture of other colors, and each change in the *mean* RGB shows a change in the average intensit color in the sample [6].

The level of freshness of milk is categorized into three with different intensity of color changes from purple to reddish-purple. The smart label of purple sweet potato anthocyanin extract works based on the pH changes that occur in the milk. Smart labels indicate the level of freshness of milk with a color change in color so that consumers are expected to know the level of freshness of milk without opening the packaging.

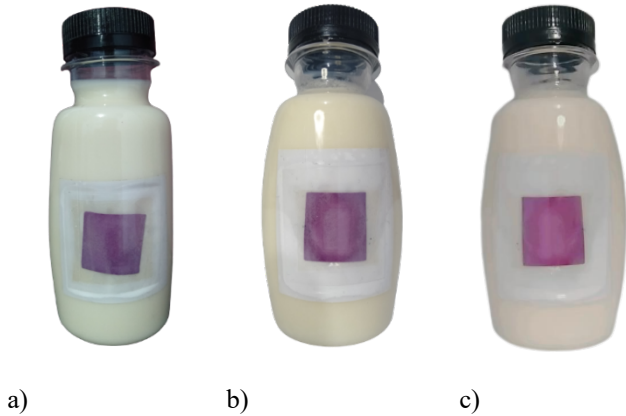


Fig. 1. Application of purple sweet potato anthocyanin extract indicator label to determine the freshness level of milk

A reddish-purple color indicates the milk is not fresh or fit for consumption. The change in label color intensity occurs due to changes in the pH of the milk during the storage process, either at room temperature or cold. pH 1 shows a stable red color, for pH 3 and pH 5 shows a red color but is slightly faded than pH 1, while at pH 7 it is purple and pH 9 is dark green, this indicates that pH greatly affects the color change of anthocyanin compounds [7]. Fresh milk has a pH of 6, is still fresh at a pH of 5, and is not fresh at a pH of 4. The increase in pH indicates that the anthocyanin uptake value is decreasing so that the color of the anthocyanins fades due to the red flavylum cation experiencing hydration into the colorless pseudo base hemiketal carbinol, quinoidal and chalcone [15]. The smart label of purple sweet potato anthocyanin extract will show a change in color intensity when the pH of the milk changes.

C. Freshness Level of Milk in Room Temperature Storage State Based on Intensity of Color Change Smart Label on Smart Packaging Smart

The label is applied to determine the freshness level of 24-hour storage milk at room temperature conditions. Milk is tested every 2 hours from the 0th hour to the 8th hour and then the test is carried out every 4 hours starting from the 8th hour to the 24th hour. The smart label was scanned with a printer Canon MP 258 and then entered ImageJ software. ImageJ software was used to determine the value of the *means* red of the smart label color change of purple sweet potato anthocyanin extract on the freshness of the milk. The color intensity change of the smart label of purple sweet potato anthocyanin extracts, to the freshness of the milk for 24 hours of storage at room temperature. People can know the freshness level of milk without opening the package.

Intensitas warna									
Jam ke-	0	2	4	6	8	12	16	20	24

Fig. 2. Changes in the intensity of the color indicator label on the freshness milk by storage at room temperature for 24 hours

The color change of the smart label on the freshness level of milk that has been stored for 2 hours does not show a significant difference from the color of the initial smart label, which is purple which means that the meat is fresh and

very suitable for consumption. The smart label color change for milk that has been stored for 4 to 6 hours shows a color change, namely faded purple which means that the milk is still fresh and still fit for consumption. The smart label color change on milk that has been stored for 8 to 24 hours indicates that the milk is damaged with a pH of 4 and a change in color to reddish-purple which means that the milk is not fresh and unsuitable for consumption.

Milk stored at room temperature undergoes a faster process of decomposition. The protein decomposition process in rotten milk causes a change in the color of the smart label [12]. The decomposition of milk results in the formation of volatile acid compounds which react with smart labels causing color changes on these indicators. Change in the color of the biosensor occurs along with the length of storage, due to the increase in pH in milk due to the presence of the volatile acid components produced [11].

D. Freshness Level of Milk in Cold Storage Conditions Based on the Intensity of Smart Label Color Change on Smart Packaging

Milk was tested every day for 10 days of storage at cold temperatures. Smart labels are tested in three different parts of the ImageJ software to find out the mean red. The smart label of purple sweet potato anthocyanin extract was scanned with a printer Canon MP 258. Milk that was stored for 7 days in cold conditions experienced a color change due to the decomposition of the milk which caused the pH of the milk to change.

Intensitas warna								
Hari ke-	0	1	2	3	4	5	6	7

Fig. 3. Changes in the intensity of the color indicator label on the freshness milk by storage at refrigerator temperature for 7 days

The color change of the pinter label based on anthocyanin extract serves to determine the freshness of the milk during cold storage. The label color change category consists of three groups, namely light purple, faded purple, and reddish-purple. The smart label color on day 0 to day 4 is purple. The light purple color indicates that the milk is still in fresh condition (fit for consumption). The color of the smart label on days 5 and 6 changes color, namely faded purple. Faded purple indicates that the milk is still fresh (still suitable for consumption). Smart label color on day 7 becomes reddish-purple when milk is stored at cold temperatures with a pH of 4. Bluish purple indicates that the milk is not fresh (not suitable for consumption).

E. pH stability of the Purple Sweet Potato Anthocyanin Extract Pintrak Label Stability testing of the smart label pH label purple sweet potato extract aims to

Test the stability of the smart label pH label purple sweet potato extract aims to determine the color change of the smart label in various pH conditions both in acidic and alkaline conditions. The pH stability of the smart label purple sweet potato extract was tested by immersing the smart label with the difference in pH solution. The color change of the smart label tested in different pH solutions was calculated using ImageJ software to determine the difference in *mean* red. Testing the color stability of the smart label pH purple sweet

potato extract in an acidic atmosphere soaked in a solution of pH 7, pH 4, pH 2, pH 7 then continued in an alkaline atmosphere, namely a solution of pH 9.







					
Awal	pH 7	pH 4	pH 2	pH 7	pH 9

Fig. 4. Color stability indicator label under acidic conditions

Indicator label for purple sweet potato anthocyanin extract soaked in pH 2, pH 4, pH 7, and pH 9 solution conditions. The initial smart label has a light purple color, the color of the smart label soaked at pH 7 is dark purple bluish at pH 4 at 8 hours is light purple, the color of smart labels soaked at pH 2 at 16 hours is reddish-purple reddish-purple, then smart labels that are soaked again at pH 7 at 24 hours have a slightly bluish-purple color which is not the same color as smart labels immersed at pH 7 at the beginning of immersion, and smart labels immersed at pH 9 have a bluish color.







					
Awal	pH 7	pH 9	pH 11	pH 7	pH 4

Fig. 5. Color stability indicator label under alkaline conditions

Smart labels are immersed in various pH solutions under alkaline conditions. The initial smart label has a light purple color, the color of the smart label immersed at pH 7 is deep bluish-purple, the color of the smart label soaked at pH 9 at 8 hours is bluish-purple, the color of the smart label soaked at pH 9 at 16 hour is bluish, then smart labels soaked again at pH 7 at 24 hours have a deep purple bluish color even though the purple color is not as dark as the color of smart labels immersed in pH 7 at the beginning of immersion, and smart labels soaked at pH 4 have a light purple color.

#### IV. CONCLUSION

Based on observations and data analysis results of smart label research of purple sweet potato anthocyanin extracts to determine the freshness level of milk at room temperature and cold temperature storage, the following conclusions can be drawn:

- 1) The prototype smart label of purple sweet potato anthocyanin extract was developed in the anthocyanin extraction method and smart label design. Purple sweet potato anthocyanin extract obtained by maceration method of ethanol 96% solvent, acetic acid, and distilled water obtained a stable color. Purple sweet potato anthocyanin levels were  $70.16 \pm 0.899$  mg / 100g and  $pH 5.60 \pm 0.015$ . Anthocyanin pH is in an acidic atmosphere which means it has a stable color so it is suitable for use as a natural dye which is immobilized on Whatman paper no 1 as a smart label and coated with edible film from chitosan and CMC.
- 2) The freshness level of milk is categorized into three, namely fresh (smart label color purple), still fresh (smart label color faded purple), and not fresh (smart label color reddish-purple). Fresh milk has a pH of 6, is still fresh at a pH of 5, and is not fresh at a pH of 4. Changes in the pH of milk are due to the presence of acidic compounds.
- 3) The smart label of purple sweet potato anthocyanin extract is suitable to be used as an indicator of the freshness of milk in the field. This is evidenced by the results of the study, that smart labels soaked in acidic and alkaline conditions change color but are more stable in acidic conditions.

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