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Smart Packaging for Chicken Meat Quality: Absorbent Food Pad and Whatman Paper Applications

Andi Dirpan[1]*, Muhammad Iqbal[1], Diyah Yumeina[1], Kusumandari Indah Prahesti[2], Muspirah Djalal[1], Adiansyah Syarifuddin[1], Nur Alim Bahmid[3], Februadi Bastian[1], Salengke[1] and Suryono[4]

[1]Department of Agricultural Technology, Hasanuddin University, Makassar 90245, Indonesia

[2]Department of Animal Production, Faculty of Animal Science, Hasanuddin University, Makassar, Indonesia

[3]Research Center for Food Technology and Processing, National Research and Innovation Agency (BRIN), Gading, Playen, Gunung Kidul, Yogyakarta 55861, Indonesia

[4]Department of Animal Husbandry, University of Jambi, Jambi, Indonesia

**Corresponding author:dirpan@unhas.ac.id*

***Abstract*—Quality and shelf-life extension are major concerns in the development of meat packaging systems. The purpose of this study was to determine the effectiveness of absorbent food pads combined with intelligent packaging as well as to determine the correlation between active packaging and smart indicator labels. The active packaging applied absorbent food pads as carriers of active ingredients from basil and lemongrass, which are expected to extend the shelf life of chicken meat and maintain its quality. Meanwhile, intelligent packaging employs Whatman paper treated with Phenol Red (PR), providing real-time information on the quality of chicken meat. Various chicken meat spoilage test parameters such as thiobarbituric acid (TBA), total volatile base nitrogen (TVBN), total bacteria of total plate Count (TPC), and pH were tested at chiller temperature (4°C) every 3 × 24 hours. The results of this study indicated that absorbent food pad with lemongrass essential oil can extend the shelf life of chicken meat by 3 days while, the intelligent indication label's color profile changed from yellow at the beginning of application to red during chicken spoilage. Therefore, smart packaging from a combination of an absorbent food pad as active packaging and phenol red indicator label as intelligent packaging can potentially extend the shelf life of chicken and monitor the condition of chicken meat during storage.**

***Keywords*— Chicken Meat, Absorbent Food Pad, Smart Packaging.**

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I. INTRODUCTION

Chicken meat is one of the most favoured meats, appreciated for its economical pricing and nutritional richness owing to the presence of high-quality protein, low amount of fat, high amount of unsaturated fatty acids, and relatively less saturated fatty acids [1]. Chicken meat and its derivatives are highly perishable. Therefore, extending the shelf life of raw meat in retail packaging is a major concern [2].

Quality and shelf-life extension are major concerns in the development of packaging systems for meat [2,3]. One way to control food quality and safety is to implement a new packaging system, which includes active packaging and smart packaging [4].

Active packaging is a new technology designed to incorporate material components in packaging that release or absorb substances from or into packaged food or the surrounding environment to extend shelf life and maintain or improve the condition of packaged food [5]. The incorporated substances can be either active compounds that are released into the atmosphere of the packer or packaged food (antimicrobials or antioxidants) or components that can absorb unwanted substances from the packer's headspace (scavengers). Among the natural antioxidant compounds, essential oils have been extensively studied for the development of active films [5–7]. An example of an active packaging system is an absorbent food pad.

Absorbent food pads in the meat industry are still limited in their ability to absorb liquids from meat products [8]. Absorbent food pads containing a combination of basil oil and lemongrass oil have the potential to be applied to chicken meat products because they are thought to maintain quality and extend shelf life by inhibiting pathogenic microbial activity (*Escherichia coli* and *Staphylococcus aureus*).

Smart packaging is the development of conventional packaging, which can monitor the freshness of food in real time and provide information on its quality, safety, and freshness. Materials added to the packaging can detect changes in properties such as pH, humidity, oxygen levels, or microbial contamination [9] In some studies, the material used to carry the spoilage detection material in packaged meat is Whatman paper [10,11] In this study, Whatman paper was used as a medium to carry Phenol Red (PR), and as a material that is expected to detect damage that occurs in packaged chicken meat.

Various studies on absorbent food pads have been conducted, including the combination of absorbent food pads with black cumin oil on fish fillets [12], use of N-alanine compounds in absorbent food pads [13], utilization of bacteriophages incorporated in absorbent food pads [14], and utilization of linolenic acid and sodium dodecyl sulfate in combination with absorbent food pads [15]. However, no study has reported the use of absorbent food pads combined with basil and lemongrass essential oils for chicken meat storage.

In this study, we used absorbent food pads as carriers of active ingredients from basil and lemongrass, which are expected to extend the shelf life of chicken meat and maintain its quality, and combined them with smart packaging, namely Whatman paper that has been given Phenol Red (PR), which can provide real-time information on the quality of chicken meat.

II. MATERIAL AND METHODS

A. Material

The materials used in this study were fresh broiler meat (chicken breast) obtained from Hafiz Talassalapang Makassar, basil and lemongrass oil, absorbent food pads (Poultry Absorbent), LDPE plastic wrap, Styrofoam, Whatman paper, and phenol red (PR).

This research also uses nutrient agar, Escherichia coli, Staphylococcus aureus, aquades, 4 N hydrochloric acid, 0.02 N hydrochloric acid, TBA reagent, 7% TCA, 3% boric acid, carbonic acid, Conway indicator, and 70% alcohol.

B. Methods

Active Packaging Preparation

Extracts of basil and lemongrass essential oils (according to treatment) in absorbent food pads at different concentrations, namely A0: Control (without active compound treatment), A1: Basil essential oil extract (50%) + lemongrass extract (50%), A2: Basil essential oil extract (75%) + lemongrass extract (25%), A3: Basil essential oil extract (25%) + lemongrass extract (75%), A4: Basil essential oil extract (100%), and A5: Lemongrass extract (100%). The best treatment for active packaging from the microbial inhibition test results and the best smart paper label in the test with chicken meat will be combined and used in the follow-up observation of the cold/chiller temperature (4°C).

Smart Paper Preparation

The activated paper was made using Whatman paper no. 1 by cutting small pieces (2 cm × 4 cm). The paper was then soaked in a phenol red indicator solution set at pH 2.66 for 24 h at room temperature. After 24 h, the paper was dried using a hair dryer [10].

Bacteria Inhibition Zone Test

A bacterial inhibition test was used to assess the ability of the extracts or natural compounds to kill or inhibit the growth of microorganisms. This test aimed to determine the ability of basil and lemongrass oil extracts incorporated into absorbent food pads to inhibit the growth of microbes. The microbes used are common spoilage organisms found in chicken meat, namely, *Escherichia coli* (representing gram-negative bacteria) and *Staphylococcus aureus* (gram-positive bacteria).

For the bacterial inhibition test, each sample was cut into 1x1 cm squares. Three squares were placed on a plate that had been smeared with bacteria (0.1 mL per plate). There were 2 plates for 1 type of bacteria. The agar plates were incubated at 37 °C for 24 h, and a clear zone (zone of inhibition) formed around the samples. The zone was measured using a caliper in millimeters [16].

Smart Packaging Application on Chicken Meat

Chicken meat was obtained from *Hafiz Talassalapang abattoir* in Makassar City. and then packaged in plastic containers (polypropylene) and placed into the cooler. Next, the sterile sample was prepared into 100 g pieces/packages. The pieces of meat were then packed in Styrofoam (1.05 g/cm^3) covered with an active paper-absorbent food pad that filled the entire base of the Styrofoam. Next, an indicator label was placed on the package by sticking it to the surface of the Low-Density Polyethylene (LDPE) film (0.9g/cm^3) used as a cover, as shown in **Figure 1**. The samples were stored at a cool temperature (4°C) and observed every 3 × 24 h.

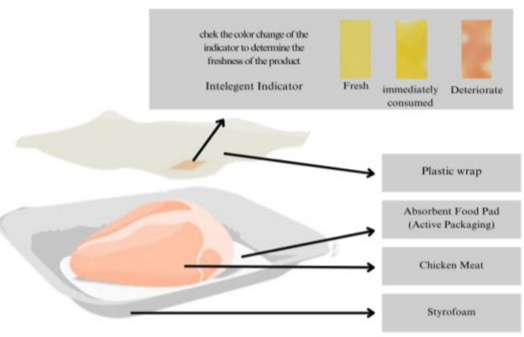

Fig. 1. Design of the intelligent and active packaging system

C. *Parameter Observation*

Parameter observations were made on the chemical characteristics of chicken meat, including pH using a pH meter [17], Total Volatile Basic Nitrogen using the Conway method, total bacteria with the Total Plate Count method, and Thiobarbituric Acid (TBA). Each analysis was conducted with three replications, processed using the Statistical Package for the Social Sciences (SPSS) analysis of variance (ANOVA) data, and further tested with Duncan's test. Furthermore, significant treatment differences were indicated by $p < 0.05$. The observation parameters for smart paper are color measurements of smart packaging indicators. The observation parameters of smart packaging indicators include the analysis of the level of relationship (correlation) between test parameters using Sigma Plot version 15.0.

III. Result and Discussion

A. *Bacteria Inhibition Zone Test*

Inhibition zone assessment was carried out on *Staphylococcus aureus* and *Escherichia coli* bacteria, both frequently associated with meat. The test results in T**able 1** show that the absorbent food pad with the addition of 100% lemongrass essential oil had the best inhibition zone compared to the control and the combination treatment with the two essential oils.

TABLE 1
ZONE OF INHIBITION OF BACTERIAL GROWTH ON ABSORBENT FOOD PAD. THE MEAN VALUE FOLLOWED BY VARIOUS LETTERS INDICATES A SIGNIFICANT DIFFERENCE

Sample	Sample Zone of Inhibition (mm)	
	S. aureus	*E. coli*
Control (without active compound treatment)	0.25±0.02^{a}	0.95±0.03^{a}
Basil essential oil extract (50%) + lemongrass extract (50%)	10.4±0.15^{b}	6,35±0,04^{c}
Basil essential oil extract (75%) + lemongrass extract (25%)	10.3±0.10^{c}	8.3±0.11^{b}
Basil essential oil extract (25%) + lemongrass extract (75%)	9.25±0.15^{d}	9.65±0.15^{c}
Basil essential oil extract (100%)	12.95±0.34^{f}	10.65±0.15^{d}
Lemongrass essential oil extract (100%)	13.05±0.10^{g}	10.9±0.15^{d}

According to Pan et al., [18] the zone of antibacterial inhibition was divided into three categories: inhibition greater than 6.00 mm (strong), 3-5 mm (medium), and less than 3 mm (weak). The addition of 100% lemongrass essential oil at 100% concentration inhibited *S. aureus* and *Escherichia coli* bacteria at 13.05 mm and 10.9 mm, respectively which fall to strong category. The high inhibition zone is due to the content of lemongrass essential oils, such as citral, including geranial (α-citral) and neral (β-citral) isomers, which are antimicrobial compounds [19].

B. *Smart Indicator Label Color Change Response*

Observations showed that the smart indicator labels applied to chicken meat changed in color during storage. The changes in smart indicators are shown in **Figure 2**. The °Hue value can be used as a benchmark to observe changes in the color of the indicator from the beginning of chicken meat storage until the meat enters the spoilage phase. The data obtained showed no change in the values from the initial storage to day 3. The color of the indicator began to change on day 6 of storage, and obvious changes were observed on days 9 and 12. Changes in the color of the indicator that have a significant difference, namely, at the beginning of the application, is yellow, then shows a color change on day 6 to yellow to orange, and turns red on day 12 of storage. This is in accordance with the results of Hidayat's research [10] which states that there is a linear correlation between the length of meat storage and changes in indicator color the longer the meat storage time, the clearer the color change in the packaging indicator.

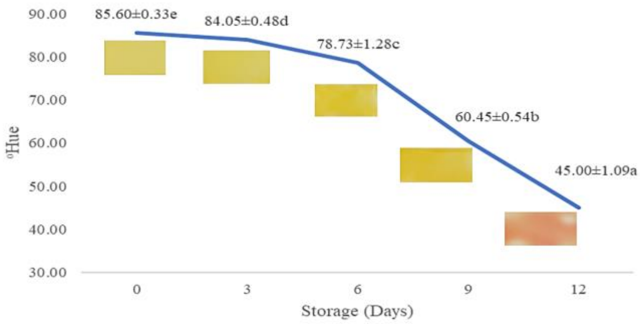

Fig. 2. Color change profile of smart indicator labels. The mean value followed by various letters indicates a significant difference

C. *Total bacteria value (TPC method)*

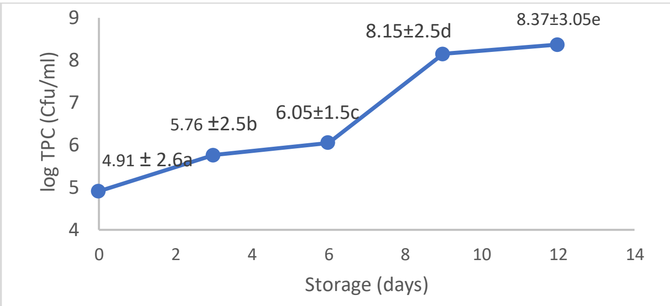

Fig. 3. Total plate count (TPC) of packaged meat stored at a cold temperature for 12 days. The mean value followed by various letters indicates a significant difference.

Based on the Indonesian National Standard (SNI) document number 7388:2009 concerning the maximum microbial contamination in food, the microbial limit in chicken meat is 1 × 10^6 CFU/g. The results in **Figure 3** show that chicken meat did not meet the criteria on day 6 of storage, which was 6.05 log CFU/gram. A significant increase in TPC occurred on day 9 reaching 8.15 log CFU/gram, which was above the SNI maximum threshold. This indicates that microbial growth started rapidly. The highest total bacterial count on Day 12 was 8.37 log CFU/gram. The total bacteria exceeded the SNI on days 9 and 12, which exceeded the safe threshold for chicken meat indicating that the chicken meat has already experienced deterioration.

D. Analysis of pH value of chicken meat

The degree of acidity (pH) can be used to determine the freshness of chicken meat. In **Figure 4**, The pH values of the chicken meat samples during storage are presented.

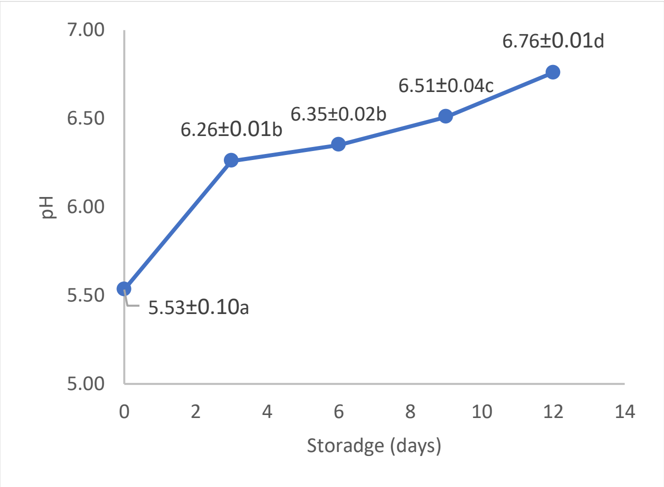

Fig. 4. pH value of packaged chicken meat samples kept in cold storage for 12 days. The mean value followed by various letters indicates a significant difference.

Based on this observation, the pH of the fresh chicken meat was 5.53. This value is included in the pH value category, which is in accordance with the pH of chicken meat 0-12 hours after slaughter. The pH value increased along with the increase of the storage time. On day 3, the pH rose to 6.26 and then continued to increase over time. On the 12th day, the pH reached its maximum value of 6.76. This indicates that the chicken underwent a change towards alkaline conditions during storage. This is in accordance with the results of research by Mupalla *et., al.*, [19], who concluded that fresh chicken has a pH of approximately 5.5, and that an increase in pH to above 6 occurs during decay [20].

E. Analysis of the TVBN value of chicken meat

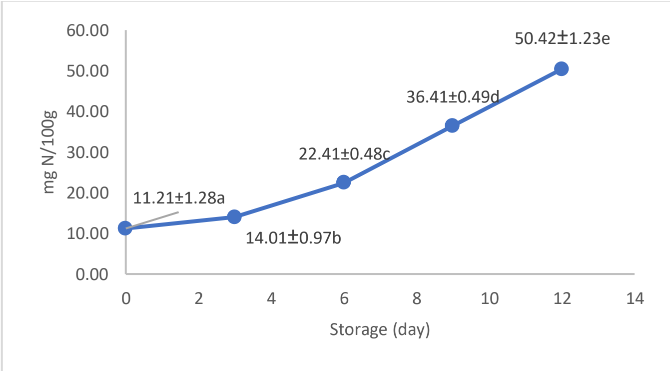

Fig. 5. The TVBN value of packaged chicken meat samples kept in cold storage for 12 days. The mean value followed by various letters indicates a significant difference.

The TVBN value of chicken meat increased with increasing storage time (**Figure 5**). The TVBN value of the fresh chicken meat was 11.21 mg N/100g. Based on the TVBN value standard from the Korean Ministry of Agriculture and Forestry, meat can be categorized as rotten at >20 mg N/100 g [21]. However, the TVBN value increased significantly over time. On day 6, the TVBN value reached 22.41 and continued to increase until it reached 50.42 on day 12. The meat was categorized rotten by looking at the TVBN content on day 6 of storage, which was 22.41 mg N/100g. The increase in TVBN value in the sample is a part of the enzymatic activity and microbial growth in the product [22].

F. Analysis of Thiobarbituric Acid (TBA) Value in Chicken Meat

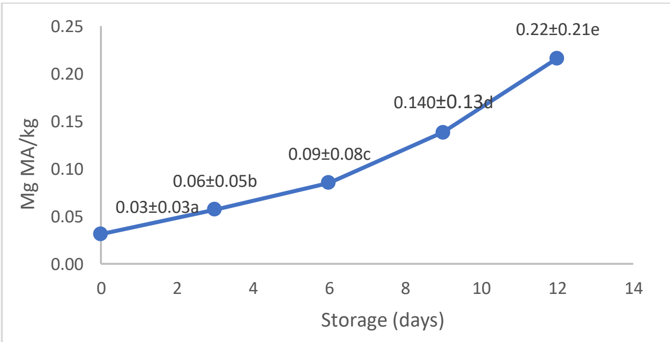

Fig. 6 The TBA value of packaged chicken meat samples kept in cold storage for 12 days. The mean value followed by various letters indicates a significant difference.

The results in **Figure 6** show that the TBA value on day 0 was 0.03, indicating that the chicken meat was still fresh. Until the 3rd day, the TBA value remained low at 0.06. This indicated that chicken meat is still suitable for consumption. The increase in the TBA value began to appear significant after the 9th day of storage (0.14). The highest TBA value was found on the 12th day of storage (0.22). This indicates that chicken meat experienced high rancidity. This demonstrates that there is an increase in fat oxidation in chicken meat with increasing storage time. An increase in the TBA value indicates a decrease in the quality of chicken meat owing to prolonged storage. The increase in TBA value in chicken meat is due to an increase in the oxidation of unsaturated fatty acids during storage [23].

G. Correlation Level of Smart Indicator Label Sensor Response with Various Parameters of Chicken Meat Quality Decline

The change in color of the indicator label correlated with all observed parameters, as shown in **Figure 7**. The results showed that the decrease in °Hue was followed by an increase in other parameter values. The graph of the total bacteria value, TVBN value, and TBA value crossed the threshold on day 6, which was in line with the change in the oHue value of the indicator. An increase in the TBA value correlated with an increase in the TVBN value. Both indicate the decomposition and deterioration of organic matter (fat and protein) owing to microbial activity [24]. An increase in TVBN value was also correlated with an increase in pH value. Alkaline compounds produced by protein decay cause the pH of chicken meat to become more alkaline. The sharp increase in total bacteria after day 6 was correlated with a significant increase in TBA and TVBN values after the same day. Bacterial growth causes the decomposition of fat and proteins. With an increase in microbes, the nutritional components decomposed by microbes are also greater and produce volatile alkaline compounds that increase the pH value of the meat during storage [25].

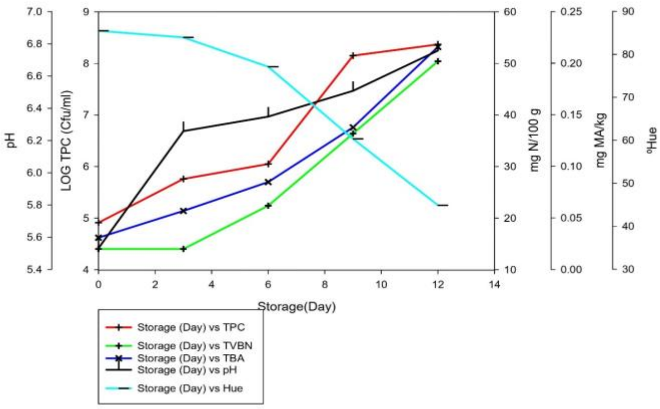

Fig. 7. Correlation of smart indicator label colour change with all chicken meat parameters.

Overall, the data showed that the quality of chicken meat decreased drastically after the 6th day of storage, characterized by an increase in TBA, TVBN, pH, and total bacteria. Chicken meat is not recommended for consumption after the 9th day of storage. The use of lemongrass essential oil as an active ingredient can extend the shelf-life of chicken meat during cold storage. The use of plant extracts can extend shelf life and improve the health-related characteristics of fresh meat and meat products [26]. The lemongrass content slowed down the rate of decay of chicken meat until day 6. This is in accordance with the results of a study by Latief [27] concluded that the content of citronella oil provides the best effect in slowing the rate of product decay [27] the results of research by [28] concluded that lemongrass essential oil has good antimicrobial activity against many microorganisms.

IV. Conclusion

The results of this study indicate that smart packaging from a combination of absorbent food pad with lemongrass essential oil as active packaging and phenol red indicator label as smart packaging can extend the shelf life of chicken meat by 3 days at chiller temperature (4°C) and monitor the chicken meat condition during storage. The phenol red indicator changed from yellow at the beginning of the application to red during chicken meat spoilage.

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