Current Technological Approach for Chicken Meat Freshness Evaluation: A Review

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Abstract. Chicken meat is the most widely consumed commodity by the public because it contains high protein and low fat. The freshness of food needs to be considered by producers and consumers. Therefore, many people have difficulty determining the freshness of chicken meat. Freshness assessment using conventional methods is usually based on chemical, physical, and microbiological parameters analysis. Some disadvantages of freshness assessment using traditional methods are time-consuming, expensive, and destructive. In recent decades, the development and implementation of meat quality analysis methods have increased. This paper aims to examine various methods of non-destructive detection of chicken meat freshness which have several advantages, including requiring quick time analysis, less sample preparation, low cost, and non-destructive measurements. In this paper, we explain various principles and technological applications used in assessing the freshness of chicken meat, including smart packaging, digital imaging, electronic nose and gas sensors, and spectroscopy. Ultimately, developing chicken meat freshness evaluation technology will help all customers and stakeholders monitor the product more effectively and efficiently.
Keyword: Chicken meat freshness, Non-destructive detection, Smart packaging, Digital imaging, Gas sensors

1 Introduction

Broiler chicken meat is a source of affordable protein and is easy to obtain in the market. Besides that, broiler chicken meat can be processed into various food preparations. It is highly preferred for household and restaurant consumption because it has soft and thick meat [1]. Brewer [2] and Alexandrakis et al. [3] stated that chicken meat is crucial in a healthy diet because it contains essential compounds such as protein, amino acids, fats, minerals, and vitamins. Chicken meat is a good source of protein because it has a low-calorie value, so it is perfect for maintaining health and weight. Nastiti [4] explain that the demand for broiler chicken meat continues to increase in Indonesia. Based on data from

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the Socio-Economic Survey (SUSENAS), consumption of broiler chicken meat in the community has tended to increase over the last ten years by 7.39% per year [1].

Xiong et al. [5] said the current income and economic increase had increased public awareness of obtaining good quality meat. Therefore, it is essential to know and evaluate the quality and freshness of chicken meat. Lonergan et al. [6] explained that blood circulation would stop after slaughtering the animal. Thus, the respiration process will stop resulting in an anaerobic glycolysis reaction and producing lactic acid. Furthermore, the meat will undergo chemical and biochemical changes such as protein solubility, water-holding capacity, and muscle tissue. Fu et al. [7] stated that the glycolysis process would cause the meat to experience a change in pH and protein degradation into amino acids so that the meat is vulnerable to spoilage microorganisms. Microorganisms that spoil meat will produce proteases and enzymes that can decompose meat to form chemical compounds such as ammonia gas, hydrogen sulfide, total volatile base nitrogen (TVB-N), and biogenic amines [8].

Microorganisms that contaminate products can pose a severe health threat, so product quality is an essential concern because it relates to consumer food safety. A technological innovation that can be used to analyze quickly and accurately is needed to evaluate the freshness of chicken meat non-destructively. Generally, meat has three quality parameters: physical, chemical, and microbiological. Several meat quality parameters include texture, pH, color, tenderness, and microbiology [9]. The level of freshness can determine the quality and safety of chicken meat. Consumers usually know the degree of freshness of meat based on external parameters such as color and texture [10]. This method has drawbacks because it is subjective and unstable. Therefore, many studies have been developed to objectively, efficiently, and measurably detect meat freshness. Several innovations were created using digital and sensor approaches to determine the freshness of chicken meat. This paper aims to describe some recent technologies that can determine the freshness and quality of chicken meat non-destructively.

2 Methode

2.1 Imaging technique

Agricultural technology is currently growing rapidly. Various technological approaches have been developed and applied to the agricultural industry. One of the technologies that can be used to evaluate the freshness and quality of chicken meat is digital imaging techniques. Li et al. [11] explained that digital imaging techniques could evaluate food quality from several parameters such as texture, color, shape, and size. This technology is widely applied because it has several advantages, including reducing labor costs and saving time. Furthermore, digital imaging techniques require more straightforward and less destructive sample preparation. This approach provides a measurable assessment compared to traditional subjective methods.

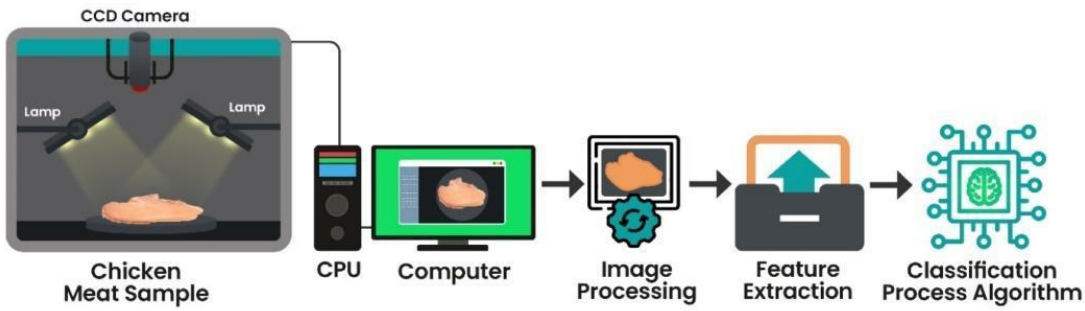

Fig 1. Digital imaging technique for chicken meat

Digital imaging techniques have two objectives, namely (a) to improve image quality so that more detailed information can be obtained and (b) to extract information that becomes an object parameter numerically [12]. According to Raj et al. [13], digital imaging techniques consist of several processes, including image acquisition and image analysis, to determine the objective value of the quality of agricultural products. Therefore, digital imaging techniques have been widely implemented to evaluate various agricultural commodities such as vegetables, fruit and meat. Digital imaging consists of 4 main steps: digital image acquisition, image processing and interpretation, feature extraction, and image classification. Figure 1 describes the stages of a digital imaging technique.

An image is a set of dots (pixels) of an image that contains color information. The dots in the image represent coordinate positions and indicate the image's color. Digital images can be obtained with a computer acquisition device whose elements can explain the light intensity value at a discrete set of points [12]. An analysis process is required to obtain information from digital images, as described in Figure 1. The first stage is retrieving digital image data, usually using a CCD camera. In the data acquisition process, paying attention to the camera resolution, lighting technique, the distance between the sample and the camera, and the angle at which the image is taken [14]. The captured image will be displayed on the computer screen and can be saved in JPG and PNG formats. The second stage is digital image processing. Raj et al. [13] explained that image processing aims to (a) observe objects that cannot be seen, (b) improve the quality of digital images, (c) to know the pattern recognition in images, (d) image retrieval, and (e) image recognition. Several processes that can be used for image processing are cutting, thresholding, image smoothing, and image restoration. The third stage is feature extraction which is a process to obtain the numerical attribute value of an image. Extracted features or information can be in the form of RGB (Red, Green, Blue), HSV (Hue, Saturation, Value), GLCM (Gray Level Co-Occurrence Matrices), L*a*b values, and other image scoring systems [15]. The fourth stage is the classification of digital images. The classification process is carried out to obtain a model that can explain an object's quality class [13]. Classification of chicken meat freshness can be determined by using artificial intelligence classification algorithms such as convolutional neural network (CNN), artificial neural network (ANN), genetic algorithm (GA), support vector machine (SVM), and naïve Bayes [16].

2.2 Electronic nose

Freshness is one of the parameters of the quality of chicken meat. Chicken meat is usually sold in open conditions and without good sanitation. Moreover, chicken meat is also very susceptible to spoilage microorganisms because it undergoes an anaerobic glycolysis process [4]. Smolander et al. [17] explained that the decomposition process can decompose meat to produce volatile components in the form of hydrogen sulfide (H_2S) and ammonia

(NH_3). Therefore, the presence of volatile components produced by chicken meat can be used as a parameter of meat freshness. Conventional methods are usually utilized using the Eber Test to identify the spoilage process of chicken meat. The Eber method requires complicated sample preparation because it requires HCl to break down amino acids and is not real-time [18]. Nowadays, the development of meat testing methods that are fast, non-destructive, inexpensive, and portable. Using an electronic nose is one technology that can make the data analysis process faster. The advantages of electronic noses in the analysis of food products include requiring minimum sample preparation, faster data analysis, and cheaper.

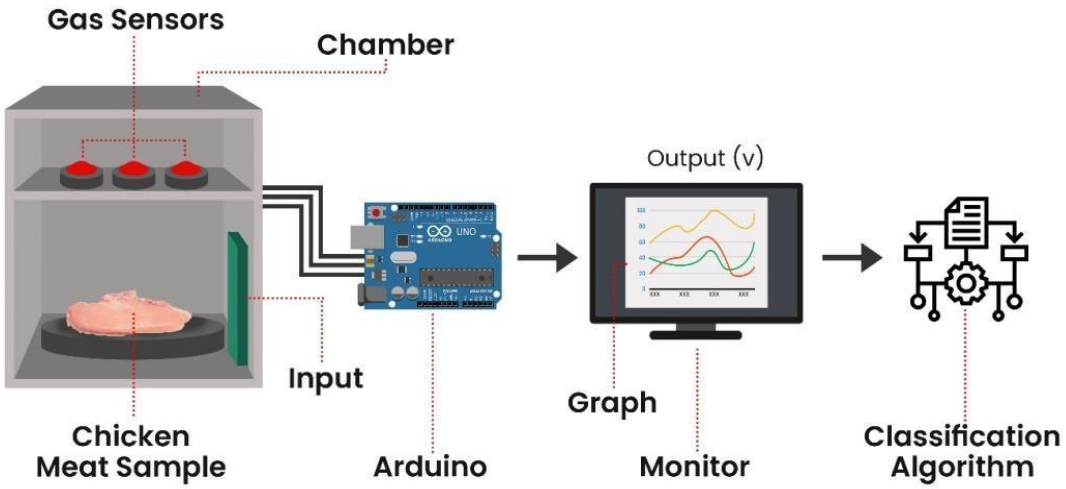

Fig 2. Illustration of an electronic nose for chicken meat quality evaluation

The electronic nose is a system used to detect specific gases in agricultural commodities. This technology has been developed in the agricultural and food sector because it has several functions, including (a) process monitoring, (b) determining product shelf life, (c) as a quality control system, (d) monitoring food product damage, and (e) determine the toxicity of food products. In chicken meat samples, usually, the sample will be placed in a chamber equipped with a specific gas sensor. The sensor will respond to the gas of the chicken meat release resulting in a voltage change on the device [4]. Generally, the process of detecting the freshness of chicken meat with an electronic nose is presented in Figure 2. Several studies regarding the evaluation of the freshness and quality of chicken meat have been carried out by several researchers. Nastiti et al. [4] succeeded in developing a detection system to determine the quality of chicken meat during storage using MQ135 and MQ136 by detecting ammonia and hydrogen sulfide gases in products stored for 24 hours. Astuti et al. [18] developed a freshness classification system for chicken meat contaminated with Escherichia coli using a metal oxide semiconductor (MOS) sensor. The MOS sensor will produce a suitable potential difference by changing the resistance of the material in the sensor so that the output voltage can be measured. The output voltage value will be the gas concentration value in an environment or chamber. Some of the sensors used in Astuti et al. [18] research to develop an electronic nose include MQ2, MQ3, and MQ. Furthermore, chicken meat freshness was classified using two algorithms, namely random forest and support vector machine. Trimson et al. [19] also developed an electronic nose using a metal oxide semiconductor sensor to detect a decrease in the quality of chicken meat. Machine learning using the principal component analysis (PCA) method can be used to classify the quality of chicken meat during storage. Implementing artificial intelligence also gives good

results; artificial neural networks (ANN) algorithms can classify the quality of chicken meat with a success rate of 97.92%.

3 Results and discussion

3.1 Smart Packaging

Currently, the technology to evaluate the quality and freshness of chicken meat is needed by stakeholders because consumer demand for fresh chicken meat is continuously increasing. Chun et al. [20] explained that quality evaluations carried out by consumers usually use the senses through the eyes and smell. Consumers usually also pay attention to product expiration dates to evaluate freshness. Kuswandi et al. [10] explained that monitoring the freshness of packaged products is done by observing the results of metabolites in the form of gases produced, such as ammonia, carbon dioxide, oxygen, hydrogen sulfide, dimethylamine, and trimethylamine. Therefore, smart packaging technology can be developed to evaluate chicken meat quality. Smart packaging is a technology that can be used to detect and monitor the quality of chicken meat during storage as a guide to determine shelf life [21]. Smart packaging has a sensor as an intelligent label as a Food Quality Indicator (FQI) [22]. This label is an acid-base indicator resulting in a color change due to a change in pH. Lee et al. [23] explained that a decrease in the quality of chicken meat could be identified through changes in the color of the pH indicator due to the volatile components produced by the product.

Freshness indicators on smart packaging usually have three layers, namely (1) a semi-permeable layer that functions for the exchange of metabolite gases, (2) a color-changing layer that is an indicator of freshness, and (3) a protective layer [24]. Studies to develop smart packaging to detect deterioration in the quality of chicken meat have been carried out by several researchers. Kim et al. [24] developed a colorimetric bromocresol purple (BCP)-based pH indicator label on chicken breast meat stored at low temperature for 12 days. The results showed that the pH indicator label changed color from yellow to purple, which indicated spoilage of chicken meat during storage. The color change on the indicator label is due to changes in pH during chicken meat storage. Furthermore, during storage, it will produce a volatile component in the form of nitrogen gas, an indicator of meat spoilage. The development of pH indicator labels for smart packaging shows promising results for evaluating meat quality so that consumers can detect them visually.

Lee et al. [25] developed a colorimetric-based pH indicator with bromocresol green (BCG) to determine the freshness of chicken meat. The pH indicator embedded in chicken meat packaging consists of three layers: a semi-permeable membrane in the form of Tyvek tape, a layer of color indicators, and a protective layer in the form of low-density polyethylene (LDPE). The development of pH indicators to evaluate the freshness of chicken meat can also use other indicators such as bromophenol blue (BPB), cresol red (CR), bromothymol blue (BTB), thymol blue (TB), and curcumin using a semi-permeable membrane in the form of polyether block amide (PEBA) film and a protective layer in the form of a polyethylene terephthalate (PET) film [23]. Implementing a pH indicator on smart packaging for fresh chicken meat can detect changes in the quality and freshness of the meat because there is a change in the indicator's color which describes an increase in the nitrogen content and microorganisms in the product. Lee et al. [23] explained that the manufacture of smart packaging starts from making dye solutions, coating tape or paper with coloring solutions, drying indicator layers, cutting indicator layers, indicator

lamination and protective films with semi-permeable membranes, cutting indicators and installing indicators on the packaging. The procedure for creating smart packaging is presented in Figure 3.

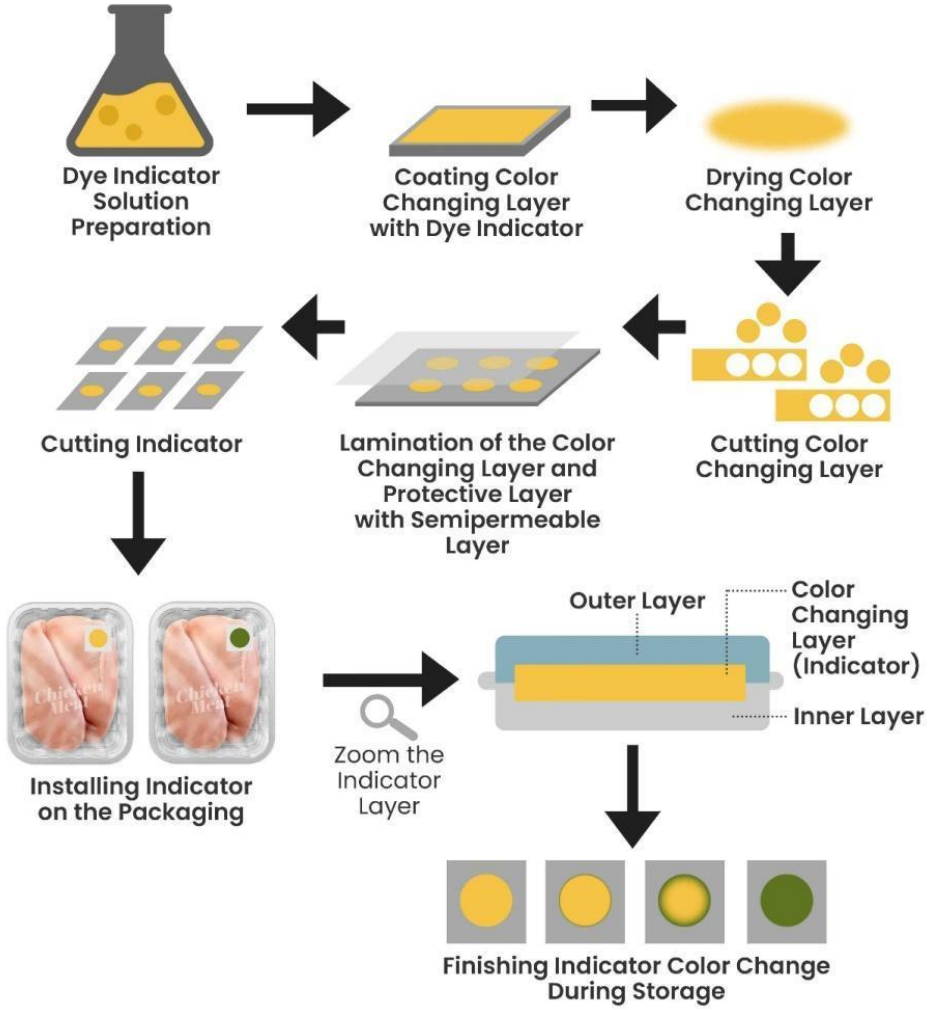

Fig 3. Smart packaging production with freshness indicator (Synthesized and modified from Lee et al. [23, 25])

Smart packaging for food products with a color change indicator label during storage can be called a Time Temperature Indicator (TTI). Khairunnisa et al. [26] explained that TTI is a smart packaging technology that can provide information on changes in product quality in real time during storage. The development of TTI technology based on gas diffusion will provide information that more extended product storage at a certain temperature will decrease quality and freshness. TTI-based smart packaging technology is usually developed for fresh food products that are easily damaged and stored at low temperatures. Changing the color of the freshness indicator label will make it easier for consumers to visually identify the quality and freshness of food products to make the right decision. Food freshness indicators based on color changes can be developed in two types, namely synthetic dye indicators and natural dye indicators. Synthetic dye indicators that can be used include phenol red, bromophenol blue, bromocresol violet, methyl red, and others [27]. Natural dyes are usually obtained from anthocyanin extracts from agricultural commodities such as turmeric, grapes, black rice, and other agricultural commodities [28]. Synthetic dye indicators have advantages compared to natural dyes because they provide

suitable color response and stability [27]. TTI-based smart packaging technology development has drawbacks because it requires enormous costs and time.

3.2 Spectroscopy

Risks related to quality and food safety may occur during production. The existence of food contamination and adulteration raises concerns among consumers [29]. Fresh products such as meat can also be contaminated or decrease in freshness due to long storage time. Meat quality and freshness testing are carried out in a laboratory destructively with microbiological and chemical tests. This test has drawbacks because it requires a long time, complex sample preparation, and is expensive. Non-destructive methods to support product testing more quickly and efficiently have been developed. One of the technologies that can be used to assess the quality and freshness of meat is spectroscopy. Spectroscopy technology consists of several types depending on the wavelength of the light used, such as (1) visible light spectroscopy (UV-VIS), which has a wavelength between 200 – 780 nm, (2) near-infrared (NIR) with a wavelength of 780 – 2500 nm, and (3) mid-infrared (MIR) with a wavelength of 2500 – 10000 nm [30,31].

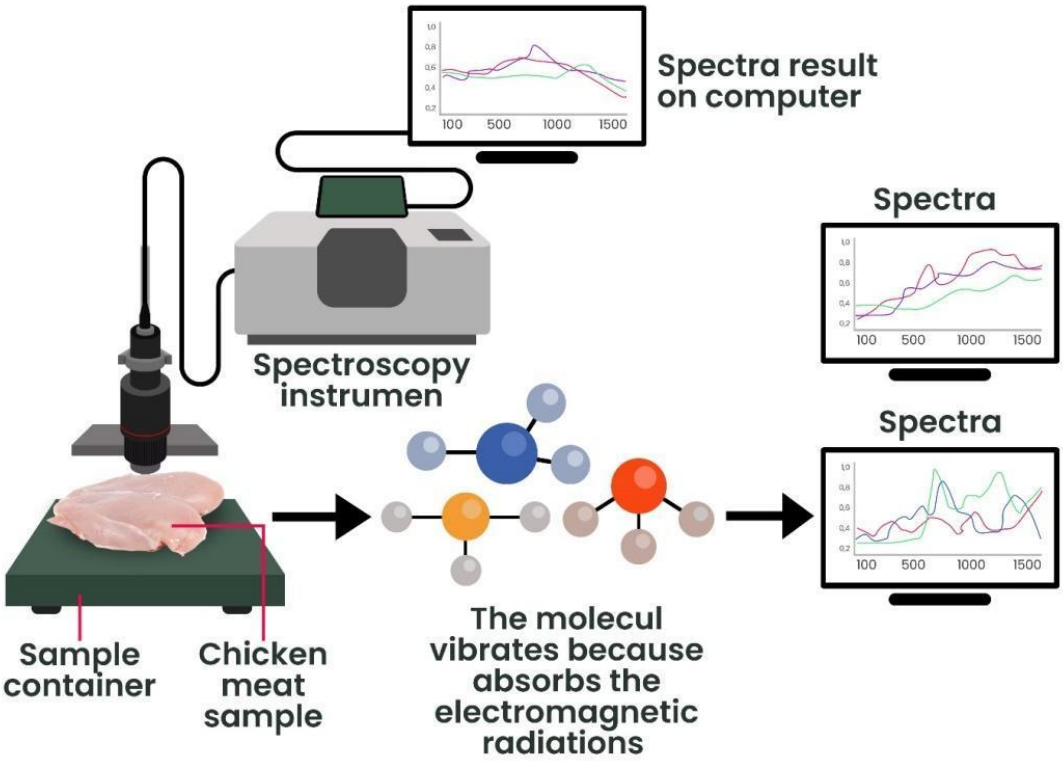

Fig 4. Spectroscopic principles for quality evaluation

Based on Figure 4, the principle of spectroscopy technology is that when waves of electromagnetic radiation are generated and hit food products, some of the wave energy will be reflected, some will be transmitted, and some will be absorbed by the chemical molecules contained in the material and used to vibrate [32]. Chen and He [33] explained that the energy of vibrating chemical molecules would be converted into spectra. A spectroscopy instrument consists of two primary devices, a detector and a light source arranged at a certain distance. Spectroscopic instruments are also in portable handhelds with a specific wavelength and instrument software [34]. In meat, samples can be cut first or

directly shot by a light source so that the detector can capture the spectrum. The spectra generated by the instrument can be used to evaluate the quality of food products [34].

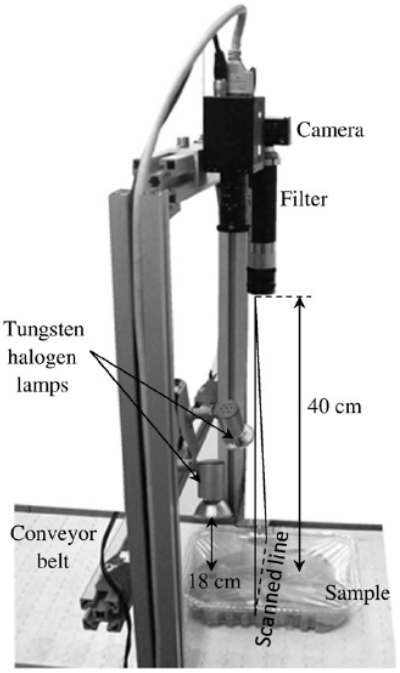

Fig 4. Acquisition of NIR spectrum data on chicken meat
(Source: Grau et al. [35])

One of the most widely used spectroscopic technologies in the evaluation of chicken meat is near-infrared (NIR). Grau et al. [35] developed a technology to predict the freshness of chicken meat using a short wavelength near infrared at 400 – 1000 nm. Barbin et al. [36] developed a model for predicting the quality of chicken meat using NIR at a wavelength of 400 – 2500 nm. Parastar et al. [37] monitored the quality of chicken meat using a handheld NIR combined with machine learning. The results of measurements using NIR will produce a spectral dataset that can be used for analysis and other research. Spectral datasets can be analyzed using statistical methods or machine learning to improve the results of evaluating the freshness of chicken meat. Several analytical methods that can be used to evaluate the quality and freshness of chicken meat include principal component analysis (PCA), partial least squares (PLS), and linear discriminant analysis (LDA). Artificial intelligence can also be applied to spectroscopy by using artificial neural networks and support vector machines for a classification system for the quality and freshness of chicken meat [37]. Nonetheless, research in the field of spectroscopy is expected to have more samples used. Thus, the dataset obtained is also increasing so that the prediction accuracy of the freshness and quality of chicken meat uses a combination of statistical methods and machine learning [37].

4 Conclusion

Monitoring chicken meat's freshness and quality is a significant concern. Many technologies have been developed to assist the process of monitoring freshness and quality. Several technologies that have been developed include digital imaging techniques, electronic noses, smart packaging, and spectroscopy. Non-destructive evaluation of the freshness and quality of chicken meat has the advantage of being fast, effective and

accurate. These conditions will help consumers and all stakeholders maintain the quality of food products along the supply chain.

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