Examination system of chicken meat quality based on hyperspectral imaging

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Abstract. The freshness of the chicken meat will be degraded due to microbiological and chemical processes and will affect the quality of the chicken's meat. Measurements of freshness were done by a laboratory test that usually destructively and takes a long time. In this study, a VNIR imaging system was built with a wavelength range of 400-1000 nm to determine the freshness of broiler chicken meat. The freshness of the chicken meat was analyzed by using the organoleptic and pH measurement approach. Classification using Random Forest (RF) modeling has been developed to predict the freshness of chicken meat. The freshness of chicken meat was evaluated by using the correction value of 85.5%. The Partial Least Square Regression (PLSR) algorithm was successfully used to determine the pH. The pH measurement system for fresh chicken meat was evaluated using a correlation coefficient of 0.80 and RMSE 0.16. Meanwhile, for the spoiled chicken meat, pH was measured using a correlation coefficient of 0.84 and RMSE of 0.18. Both classification and regression methods indicate that this measurement system is adequate for predicting the quality of chicken meat.

1. Introduction

Chicken meat is tender and more digestible than red meats [1]. The growth of the global poultry industry has been demanding more attention to the quality and safety of broiler chickens [2]. One of the critical quality attributes of chicken meat is pH. The acidity of the pH value change after slaughtered. In traditional markets, the quality of the chicken meat was improved through this method. First, if the chicken was not sold on the same day, the chicken meat will be resold the next day. This results in a decrease in the quality of the chicken meat. Biologically more meat damage is caused by microbial growth which is increased by the storage factor of temperature, time, the availability of oxygen and water content, and pollution.

On an industrial scale, chicken meat quality is also considered. Some food industries, such as the meat industry, need a method to test the quality and safety in producing large scale meat. The method provides time and energy efficiency. The need for a system to detect chicken meat quality can be done quickly, efficiently, accurately, and non-destructive.

In recent years, non-destructive techniques, such as odor imaging, magnetic resonance imaging, visible and near-infrared (Vis/NIR) spectroscopy, Raman spectroscopy, and hyperspectral imaging (HIS) have been well developed to measure chemical compositions in meat and meat product [3]. The development of optical technology based on a hyperspectral image produces a chicken meat quality testing system comprehensively in analyzing the nature and characteristics of the meat being tested.
Hyperspectral imaging is a non-destructive method for the sample and the results obtained are outstanding and accurate. This gives an exclusive feature for the hyperspectral imaging technology. Hyperspectral imaging is an emerging platform that combines imaging and spectroscopic technology. This method is rapidly gaining ground as a non-destructive, real-time detection tool for food quality and safety assessment [4]. Hyperspectral imaging is able to attain both spectral and spatial information called the hypercube three-dimensional data cube which is essential information for analyzed physical and chemical properties sample. From this hypercube, the pertinent qualitative and quantitative information can be obtained to facilitate the determination of the chemical composition of several samples besides visualizing chemical distribution within the same sample [5].

In this research, the quality of broiler chicken-based meat will be tested using hyperspectral imaging. The hyperspectral imaging system integrates the imaging technique and spectroscopy in the form of three dimensions, namely two dimensions of space, and one is the spectral dimension known as the data cube or hypercube. This hyperspectral technology consists of some hardware and software. System design is carried out to obtain an image that presents spectral information at each subsequent spatial pixel processed using image processing methods that are implemented into MATLAB. Image processing consists of several stages, namely image correction, image processing and then to the feature extraction and regression model process. Some of these processing results are analyzed based on the parameters that were set by one of them, namely, to determine the freshness of chicken meat and to determine the pH value of chicken meat. The classification of chicken meat was done using the organoleptic approach. The quality of chicken meat was tested through physical and chemical tests, and to get the pH value, it was done using a pH meter. PH value which is generated, was used as information in analyzing the hyperspectral image system.

2. Materials and methods

2.1. Preparation of chicken samples
The chicken that was used is a live chicken which then slaughtered for a total of 16 chicken carcasses. In this study, chicken breast meat samples were taken from the carcasses of broiler chicken meat from the Kemiri traditional market in Depok, West Java, Indonesia. The chicken was then filled on the chest and brought to the Bio-Nano Technology Laboratory in the Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok, Indonesia. Once arrived at the laboratory, the chicken breast was cleaned and measured the weight. Each chicken breast was ready to be measured for the pH value while using hyperspectral imaging.

2.2. Measurement of quality parameters
For the first time, chicken breasts were tested using an organoleptic approach based on smell, flexibility, and color. The next step was to measure the pH value. The left and right breast fillets of the carcass were used to measure the pH values (pH meter CT-6020A) and using hyperspectral imaging for 1h, 2h, 3h, 4h, 6h, 8h, 10h, 12h, 24h, and 48h.

2.3. Hyperspectral imaging system
This research used a push broom method, in the reflectance range of 400-1000 nm (VIS/NIR) hyperspectral imaging system to acquire the sample image from the chicken breast with four 150 W halogen lamps, slider, and personal computer as shown in Figure 1.

The measurement of the quality parameter was used as a reference value for constructing the optimal wavelength band. Regression model and measuring the model performance to predict the freshness and pH chicken breast. Flow chart of freshness and pH of the chicken breast by using hyperspectral imaging, as shown in Figure 2.

Model development and model evaluation for classification was the Random Forest (RF) modeling. It has been developed to predict the freshness of chicken meat. The Partial Least Square Regression
(PLSR) algorithm was used to determine the pH value. PLSR is widely used as it can avoid collinearity problems and allow the number of variables higher than the number of samples [6].

![Figure 1. Hyperspectral Imaging System](image1)

![Figure 2. Image Processing Flowchart](image2)

To make the measurement system model, it is necessary to train the measurement system model. The measurement system model that has been trained will be tested with the type of data testing. From these tests, it has obtained an error value from testing the measurement system model. The error value used as a reference for the validation of this hyperspectral system data is the root mean square error (RMSE). The resulting error value is a parameter used to measure the difference between the predicted value.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_{\text{pred}} - y_{\text{act}})^2}{n}}$$

(1)
Correlation coefficient (R) used for analysis and evaluation. The correlation coefficient is a correlation measure between two predictive variables and a reference value with a value of 1.

\[
R = \sqrt{1 - \frac{\sum_{i=1}^{n} (y_{pred} - y_{act})^2}{\sum_{i=1}^{n} (y_{act} - y_{mean})^2}}
\]  

(2)

Where \( n \) is the number of samples, \( y_{act} \) is the real value, \( y_{pred} \) is the predicted value, \( y_{mean} \) is the mean value.

3. Results and discussion

3.1. A statistical distribution of organoleptic and pH values

All the chicken breast with a total of 16 was measured after being slaughtered with measurement time at 1h, 2h, 3h, 4h, 6h, 8h, 10h, 12h, 24h, and 48h and has obtained for a total measurement data of 91. Overall of the statistical data has been classified into 64 raw chicken data and 27 spoiled (unfresh) chicken meat data. The average, the standard deviation (SD), and the maximum and minimum values of pH of the fresh chicken were 5.98, 0.24, 6.62 and 5.62, respectively. Also, the values of the pH of the unfresh chicken were 6.02, 0.26, 6.68 and 5.65, respectively.

3.2. Hyperspectral characteristics of chicken

Figure 3 shows the mean of the spectral characteristics of the fresh and unfresh chicken breast. The results show that significant differences in the spectral reflectance where the fresh chicken breast has a higher wavelength than the unfresh chicken breast. In wavelength 400-650 nm, this range of spectra mainly represents the information of color, this may indicate that the pH value has some relationship with chicken meat color [2].

![Figure 3. Spectral profiles of the fresh and the spoiled chicken meat](image)

3.3. Model of classification

Table 1 shows a confusion matrix random forest (RF) of the chicken breast. Based on the evaluation of RF classification models using the confusion matrix method with three parameters for the overall model assessment, accuracy, precision and recall were obtained 85.5%, 84.5%, and 98%, respectively.
Table 1. Random Forest (RF) Confusion Matrix for the chicken meat.

| Real class | Predicted class | Fresh | Unfresh |
|------------|----------------|-------|---------|
| Fresh      | Fresh          | 49    | 1       |
| Unfresh    | Fresh          | 9     | 10      |

3.4. The measurement model of pH value

This research used Partial Least Square Regression (PLSR) for pH value for all chicken meat. The optimal principle component was selected as the input of the calibration model. Relationship of percent variance and number of principal components for fresh and spoiled chickens as shown in Figure 4 and Figure 6. All variance data could represent more than 90% when the number of PLS components is 25. The graph shows the percentage variation in the number of components as much as 25. Visible performance becomes stable by using as many as 25 components. A large number of components produce many dimensions in the new domain which has an impact on increasing the performance of the model.

The pH measurement system for fresh chicken meat was evaluated using a correlation coefficient of 0.80 and root mean square error (RMSE) 0.16. Overall result from the correlation coefficient and mean square error show good value. Linearity between the predicted and measured value of the pH of the fresh chicken using reflectance mode is shown in Figure 5.

Figure 4. The percent of variance explained for moisture content of fresh chicken

Figure 5. The testing set for pH value of fresh chicken

Meanwhile, for the spoiled chicken meat, pH was measured using the correlation coefficient of 0.84 and RMSE of 0.18. Linearity between the predicted and measured value of pH fresh chicken using reflectance model as shown in Figure 7.
Figure 6. The percent of variance explained for moisture content of unfresh chicken

Figure 7. The testing set for pH value of unfresh chicken

4. Conclusions
This research shows the prediction of chicken meat quality using the hyperspectral imaging system in the NIR spectral region of 400-1000 nm. The non-destructive technique can be used to predict the quality of chicken meat using random forest modeling and was evaluated using the correction value of 85.5%. The pH measurement system for fresh and spoiled chicken meat was evaluated using a correlation coefficient of 0.80 and 0.84. Root mean square error (RMSE) for fresh and spoiled chicken is 0.16 and 0.18.

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