CHAPTER I
BACKGROUND

This chapter introduces the problem of chicken meat freshness evaluation, a process that is commonly conducted through visual inspection by humans. To provide a more objective assessment method, this research applies a classification framework based on digital image processing using HSV color features and GLCM-LBP texture characteristics. Model performance is further improved by integrating Bayesian Optimization and cross-validation into the LightGBM algorithm, enabling more accurate classification of chicken meat freshness.

1.1 Background

The demand for animal-based protein among the Indonesian population has continued to increase annually. This trend is influenced by population growth, lifestyle changes, and increasing public awareness regarding the importance of maintaining a balanced nutritional intake. To fulfill these nutritional needs, various types of meat are widely consumed as sources of animal protein. Among the available options, chicken meat remains the most preferred commodity due to its high protein content and relatively affordable price. As a result, the level of chicken meat consumption within the community has significantly increased [1]. According to data reported by Pusdatin (2024), national chicken consumption rose from 3.96 kg per capita in 2014 to 7.46 kg per capita in 2023. When consumption from industrial and other service sectors is also considered, the figure reaches 12.58 kg per capita [2].

The increasing consumption of chicken meat has not been accompanied by optimal quality control practices. During the distribution and marketing process, inadequate refrigeration systems and poor sanitation facilities are still commonly encountered, causing chicken meat to deteriorate more rapidly. This condition is closely related to the characteristics of chicken meat, which contains high levels of water and protein, making it highly vulnerable to the growth of spoilage microorganisms [3]. The potential for spoilage becomes even greater when the meat is left at room temperature for prolonged periods. Within approximately 12 hours after slaughter, alterations in acidity levels and reductions in the water-holding capacity of muscle tissues may occur, leading to both physical and chemical degradation that ultimately renders the meat unsuitable for consumption [4]. Therefore, freshness evaluation is considered an essential aspect, as freshness represents the primary indicator used to determine the suitability of chicken meat for consumption [5].

Despite these concerns, the evaluation of chicken meat freshness is still largely performed using conventional methods, particularly through direct observation of color, texture, and odor. Such approaches make it difficult to identify subtle variations in freshness levels, are highly influenced by external conditions, and often require considerable time and human effort [6]. These limitations indicate the necessity for an automated evaluation system that offers greater consistency, efficiency, and practicality. One promising alternative is digital image processing, as it enables the visual characteristics of objects to be analyzed quantitatively, thereby minimizing the subjectivity associated with manual inspection. Although deep learning techniques have been extensively implemented in food image classification studies, the selection of an appropriate method should still consider factors such as data characteristics, dataset size, and computational complexity. In situations where data availability remains limited and image variations are relatively constrained, approaches based on color and texture feature extraction combined with machine learning algorithms continue to be highly relevant. Such methods are generally more computationally efficient, require lighter training processes, and are still capable of achieving reliable classification performance [7].

This research focuses on color and texture information because changes in chicken meat freshness can generally be observed through visual characteristics on the meat surface. Fresh chicken meat typically exhibits a brighter appearance and a firmer texture, whereas deterioration in freshness causes the color to become paler or darker and alters the surface texture as a result of microbial activity and chemical reactions occurring during storage. Therefore, color and texture attributes are considered important indicators for distinguishing different levels of chicken meat freshness. To represent color information, the Hue, Saturation, and Value (HSV) color space is utilized because it aligns well with human visual perception and can effectively describe variations in surface color characteristics [8]. Texture information is extracted using Gray Level Co-occurrence Matrix (GLCM) and

Local Binary Pattern (LBP), which are capable of capturing statistical texture properties, contrast, regularity, and local structural patterns from image data. These descriptors provide meaningful information regarding the condition of the meat surface and support the classification process. Feature extraction methods based on handcrafted descriptors remain widely applied because they can convert visual information into numerical features while requiring lower computational costs than deep learning approaches. Previous research [9] demonstrated that the implementation of HSV, GLCM, and LBP features for classifying the quality of cayenne peppers produced promising results, with the HSV feature achieving the highest classification accuracy of 98.92%. Another study [10] reported that the integration of SHAPE and GLCM features using an Artificial Neural Network (ANN) classifier achieved a classification accuracy of 95.5%. The study highlighted the effectiveness of GLCM in capturing texture-related information that supports the recognition of visual characteristics within image data. These results indicate that texture descriptors can enhance the ability of classification models to distinguish object conditions more accurately. Building upon findings from previous studies, this research integrates HSV, GLCM, and LBP features to capture complementary color and texture information, thereby generating a richer representation of chicken meat characteristics for freshness classification.

To improve classification performance, this research employs the Light Gradient Boosting Machine (LightGBM) algorithm because of its capability to identify complex relationships among features associated with changes in chicken meat freshness. Previous research [11] reported that freshness indicators in chicken meat, including L, a, and b color values, pH levels, as well as H_2S and NH_3 gas concentrations, generally remain relatively stable during the early storage period before increasing significantly at later stages. These observations indicate that the deterioration process is associated with the combined influence of multiple factors that interact in a non-linear manner. Therefore, a classification model capable of learning complex relationships is required to accurately represent such conditions. LightGBM was selected due to its gradient boosting decision tree framework, which enables efficient learning of non-linear feature interactions and complex data patterns. In addition, study [12] demonstrated that LightGBM provides competitive classification performance while offering faster training times compared to several other boosting-based algorithms, making it computationally efficient. Another study [13] reported that LightGBM achieved an accuracy rate of 98.5% on structured datasets. Similarly, research [14] showed that LightGBM achieved the highest performance among 16 machine learning algorithms due to its capability to effectively capture non-linear relationships and its strong generalization ability.

An optimization framework integrating Bayesian Optimization and cross validation was implemented to identify hyperparameter settings that could improve the overall effectiveness of the classification model. This method was chosen because it offers a structured and efficient approach for searching optimal hyperparameter values compared with conventional tuning techniques. According to [12], Bayesian Optimization delivered favorable results in classification accuracy, training efficiency, and tuning effectiveness, demonstrating its suitability for determining optimal model configurations. The use of cross-validation further supports a more dependable and stable evaluation process while reducing the risk of overfitting. Furthermore, previous research [15] reported that the integration of LightGBM with Bayesian Optimization was able to enhance classification performance, achieving an accuracy of up to 96.99%.

Previous studies related to both the research topic and methodological framework have provided valuable references for this work. Study [16] proposed a chicken meat freshness detection method by integrating color and texture features. Several machine learning models were tested, and the PSO-SVM algorithm achieved the best performance with an accuracy of 98.67%. The study concluded that integrating color and texture information contributes positively to the accuracy of freshness classification. In another study [17] developed a classification model for five rhizome spice categories using HSV color features and the LightGBM algorithm on a dataset of 2,250 images. The model parameters were optimized through Grid Search, resulting in an accuracy of 82.67%. The findings suggest that HSV features combined with LightGBM can effectively capture color-related information contained in image data.

Based on the review of previous studies, several research gaps can still be identified. The use of combined HSV, GLCM, and LBP features for chicken meat freshness classification has received limited attention in existing literature. Likewise, the application of the LightGBM algorithm in this field remains relatively underexplored. Studies investigating the use of Bayesian Optimization for improving chicken meat freshness classification performance, particularly through the optimization of LightGBM hyperparameters, are also still limited. Therefore, this research investigates the classification of chicken meat freshness by integrating HSV color features with GLCM and LBP texture features and employing LightGBM as the classification algorithm. To improve model performance, Bayesian Optimization and Cross Validation are applied during the optimization process. In addition, this study utilizes both primary and secondary datasets to increase data diversity and evaluates model performance under several data partitioning scenarios to identify the most stable and effective classification model. The model with the highest performance is then implemented in a web-based application that enables users to classify chicken meat freshness through uploaded images. Through this approach, the study is expected to provide a deeper understanding of the effectiveness of combining HSV, GLCM, and LBP features with the LightGBM algorithm for chicken meat freshness classification in a more objective and efficient manner.

1.2 Research Questions

Considering the research background and the identified gaps in previous studies, the following research questions are proposed:

1. How can color and texture features be effectively extracted from digital images of chicken meat to identify different levels of freshness?
2. How can the implementation of the LightGBM algorithm, combined with hyperparameter optimization using Bayesian Optimization and Cross-Validation, improve the accuracy and stability of chicken meat freshness classification?
3. What is the impact of combining color and texture features on the effectiveness of the LightGBM model in distinguishing chicken meat freshness levels??
4. How can the best-performing classification model be implemented into a website based system for practical chicken meat freshness classification?

1.3 Research Objectives

To address the questions raised in this research, the following objectives are established:

1. To extract and combine HSV based color information with GLCM and LBP texture descriptors from digital chicken meat images for freshness level classification.
2. To examine the contribution of Bayesian Optimization and Cross Validation in improving the predictive capability of the LightGBM classifier through hyperparameter adjustment.
3. To determine the most appropriate feature fusion strategy and dataset splitting configuration by comparing classification results obtained from the LightGBM model across different freshness categories.
4. To develop a website based system utilizing the LightGBM model to support practical and automated classification of chicken meat freshness levels.

1.4 Benefits of the Research

The outcomes of this research are anticipated to offer valuable contributions in several areas, including:

1. Supporting advancements in digital image processing applications, particularly for assessing chicken meat freshness through the integration of HSV color features with GLCM and LBP texture descriptors.
2. Providing additional scientific references for future studies related to image-based classification, especially those involving color and texture feature extraction techniques and the application of LightGBM combined with hyperparameter optimization methods.
3. Expanding the understanding of readers, researchers, and industry professionals regarding the use of LightGBM for chicken meat freshness classification, including its potential implementation within web-based applications to facilitate a more practical, efficient, and accessible evaluation process.

1.5 Scope of the Study

To maintain consistency with the objectives established in this research, the study is conducted within the following boundaries:

1. The classification algorithm applied in this study is LightGBM, with the primary focus directed toward comparing the performance between the baseline LightGBM model and the LightGBM model optimized using Bayesian Optimization combined with Cross Validation.
2. Feature extraction is carried out using color and texture information. Color characteristics are represented through the HSV color model, while texture characteristics are extracted using the GLCM and LBP methods.
3. Both primary and secondary datasets are used in this study. The secondary dataset was obtained from Kaggle and originated from the study entitled, "Sistem Pendeteksi Tingkat Kesegaran Daging Ayam Menggunakan CNN Berbasis Android." Meanwhile, the primary dataset was collected from chicken meat purchased at a traditional chicken market located in Pambon Village, Lamongan. The chicken meat samples were subsequently cleaned and divided into several parts prior to the image acquisition process.
4. The proposed classification system is designed specifically to identify the freshness level of broiler chicken meat. Within this study, freshness is represented by three class labels: Fresh, Less Fresh, and Rotten.
5. The object of this study is broiler chicken meat, with the entire analysis focused on determining the condition of the meat based on visual characteristics extracted from digital images. The analyzed samples include several chicken body parts, such as thighs, wings, breasts, and other sections, in order to represent the visual diversity of chicken meat within the classification process.
6. The outputs of this research include the classification results of chicken meat freshness using a combination of color and texture features optimized through Bayesian Optimization and Cross Validation on the LightGBM model, along with performance evaluation results measured using the Confusion Matrix, Classification Report, and Area Under the Curve (AUC).