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Segmentation and Classification of Vitamin C Content in Red Chili Pepper Images Using the Linear Discriminant Analysis (LDA) Method

Segmentasi dan Klasifikasi Kandungan Vitamin C pada Citra Cabai Merah Menggunakan Metode Linear Discriminant Analysis (LDA)

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ABSTRACT

The vitamin C content in red chilies plays an important role in meeting nutritional needs, especially in the free nutritious lunch program. Red chilies are one of the important sources of vitamin C in daily consumption. However, the vitamin C content in chilies can decrease due to the storage and drying process. This study developed a method for segmentation and classification of vitamin C content in red chili images using Linear Discriminant Analysis (LDA) as a faster and more efficient alternative to conventional laboratory methods. The dataset consists of 100 red chili images categorized into fresh chilies and dried chilies which are primary data from agriculture. The analysis process includes preprocessing, color and texture feature extraction (RGB, HSV, GLCM), dimensionality reduction, and classification using LDA. The experimental results show that this method achieves 99% accuracy on training data and 97% on test data, indicating that digital image processing can function as a non-destructive approach to food quality estimation. This approach has the potential to be applied in monitoring food quality in the food industry and community nutrition programs.

Keywords : Segmentation, Classification, Linear Discriminant Analysis (LDA), Red Chili Pepper, Vitamin C, Public Nutrition Program

ABSTRAK

Kandungan vitamin C pada cabai merah berperan penting dalam memenuhi kebutuhan gizi, terutama dalam program makan siang bergizi gratis. Cabai merah merupakan salah satu sumber vitamin C yang penting dalam konsumsi sehari-hari. Akan tetapi, kandungan vitamin C pada cabai dapat menurun akibat proses penyimpanan dan pengeringan. Penelitian ini mengembangkan metode segmentasi dan klasifikasi kandungan vitamin C pada citra cabai merah menggunakan Linear Discriminant Analysis (LDA) sebagai alternatif yang lebih cepat dan efisien dibandingkan metode laboratorium konvensional. Dataset terdiri dari 100 citra cabai merah yang dikategorikan menjadi cabai segar dan cabai kering yang merupakan data primer dari pertanian. Proses analisis meliputi praproses, ekstraksi ciri warna dan tekstur (RGB, HSV, GLCM), reduksi dimensionalitas, dan klasifikasi menggunakan LDA. Hasil eksperimen menunjukkan bahwa metode ini mencapai akurasi 99% pada data latih dan 97% pada data uji, yang menunjukkan bahwa pemrosesan citra digital dapat berfungsi sebagai pendekatan non-destruktif untuk estimasi kualitas pangan. Pendekatan ini berpotensi untuk diterapkan dalam pemantauan kualitas pangan dalam industri pangan dan program gizi masyarakat.

Kata Kunci : Segmentasi, Klasifikasi, Linear Discriminant Analysis (LDA), Cabai Merah, Vitamin C, Program Gizi Masyarakat

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1. INTRODUCTION

The analysis of nutritional content in food products is a primary concern in various efforts to improve the quality of public consumption. One of the growing initiatives in Indonesia is the free nutritious lunch program, which aims to provide healthy and nutritious meals for specific community groups, particularly school children. In this context, the adequacy of vitamin C in food plays a crucial role, given its function in boosting the immune system and acting as an antioxidant that supports metabolism.

Red chili peppers (Capsicum annuum) are widely consumed in Indonesia and are known for their high vitamin C content [1] [2]. However, the vitamin C content in chili peppers is unstable and can degrade due to storage, drying, or exposure to certain environmental conditions [3]. Fresh chili peppers contain optimal vitamin C concentrations, while those stored for extended periods or subjected to processing tend to experience a significant decline in vitamin C levels [4]. These changes may impact the effectiveness of food products in meeting the nutritional needs of the community.

In related research, vitamin C content analysis is typically conducted using laboratory methods such as High-Performance Liquid Chromatography (HPLC) or iodometric titration. While these methods provide high accuracy, they have several limitations, including high costs, the need for specialized equipment, and relatively long processing times. Therefore, an alternative method is needed-one that is faster, more efficient, and maintains high accuracy in estimating vitamin C content in food products.

Linear Discriminant Analysis (LDA) dikenal sebagai salah satu metode yang efektif untuk klasifikasi berbasis citra. LDA bekerja dengan mengoptimalkan pemisahan antar kelas data berdasarkan fitur-fitur tertentu, sehingga berguna untuk mengklasifikasikan objek berdasarkan karakteristik visual yang relevan [7] [8]. Penelitian sebelumnya telah menerapkan metode ini dalam analisis kematangan buah, segmentasi citra medis, dan klasifikasi pola warna pada produk pangan [9]. Namun, penerapan LDA secara khusus untuk segmentasi dan klasifikasi kandungan vitamin C pada cabai merah belum banyak dieksplorasi.

Several studies have explored the use of digital image processing technology for food quality analysis. One study demonstrated that changes in the color and texture of food products can be correlated with alterations in nutrient content, including vitamin C [5]. Another study employed machine learning-based spectroscopy methods to classify the nutritional content of fruits and vegetables [6]. However, research specifically applying image processing techniques for vitamin C content analysis in red chili peppers remains limited.

Linear Discriminant Analysis (LDA) is recognized as an effective method for image-based classification. LDA works by optimizing the separation between data classes based on specific features, making it useful for classifying objects based on relevant visual characteristics [7] [8]. Previous studies have applied this method in fruit ripeness analysis, medical image segmentation, and color pattern classification in food products [9]. However, the application of LDA specifically for segmenting and classifying vitamin C content in red chili peppers has not been extensively explored.

This study proposes a digital image processing-based method using LDA to identify and classify vitamin C content in red chili peppers [10]. The process begins with image acquisition of chili peppers under different storage conditions, followed by feature extraction of color and texture to obtain visual information related to vitamin C content. LDA is then applied to categorize chili peppers based on their estimated vitamin C levels, distinguishing between fresh chilies with high vitamin C content and those that have undergone nutrient degradation due to storage or drying.

This approach offers several advantages over conventional methods. By utilizing image analysis, vitamin C content estimation can be performed quickly without requiring complex and expensive

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laboratory testing. Additionally, this method can be applied in real-time within the food industry or public health programs to ensure that consumed food products maintain high nutritional quality. In the long term, this image processing-based system can also be extended to analyze the nutritional quality of other food products, providing a broader solution for food quality monitoring and management.

Although various studies have explored LDA in image processing applications, a significant research gap remains regarding its use for estimating vitamin C content in red chili peppers [11]. Existing studies primarily focus on spectroscopy-based or laboratory methods, while research combining image-based segmentation techniques with nutrient content analysis is still very limited. Therefore, this study contributes to expanding the application of LDA in digital food quality analysis.

Beyond its academic contributions, this study holds high practical value, particularly in supporting the free nutritious lunch program. By developing a method capable of classifying red chili pepper quality based on vitamin C content, government agencies and food industry stakeholders can ensure that food ingredients used in this program remain nutritious and of high quality. This is essential for ensuring that public nutrition improvement efforts are effectively implemented and have a positive impact on public health.

The structure of this article is organized as follows. The second section discusses the literature study related to the use of digital image processing in food analysis and the LDA method in visual classification [12]. The third section describes the research methodology, including the image acquisition process, feature extraction, and classification procedures using LDA [13]. The fourth section presents the experimental results and performance analysis of the method used in the classification of vitamin C content in red chili peppers. Finally, the fifth section summarizes the main findings of this research and discusses further implications for the food industry and public policy.

This research is expected to produce a technology-based analysis method that is faster, more accurate, and can be widely applied in monitoring the quality of food ingredients. This digital image processing-based approach is also the first step in efforts to digitize the food industry in Indonesia, so that it can provide wider benefits for public health and national food security.

2. METHOD

The method used to develop an automated classification system based on digital image processing is Linear Discriminant Analysis (LDA), which can distinguish between images of fresh red chili peppers and those that have undergone nutrient degradation due to storage or drying.

A. Research Stages

The research stages include image data collection using high-resolution digital devices, preprocessing to enhance image quality using techniques such as median filtering and color space transformation, and image segmentation to separate objects from the background. Color and texture features are extracted to represent the unique characteristics of each object, which will then be used in classification.

The implementation was carried out using MATLAB software through the following stages:

1. This study adopts a quantitative experimental approach using image processing techniques to analyze vitamin C content in red chili peppers. The segmentation and classification process is performed using Linear Discriminant Analysis (LDA) to enhance accuracy in distinguishing vitamin C levels based on the visual characteristics of red chili peppers [14].
2. Akuisisi Data dan Dataset
   Data were obtained by capturing images of red chili peppers with various levels of vitamin C content. The acquisition procedure includes:

a. Camera Device: Digital camera with a minimum 12 MP resolution.
b. Lighting: White LED for consistent illumination.
c. Image Capture Distance: 20–30 cm from the object.
d. Background: Plain white to facilitate segmentation.
e. Image Format: JPEG/PNG with a 1920×1080 pixel resolution.

The dataset consists of images of red chili peppers whose vitamin C content has been laboratory-tested as reference data for classification.

3. Image Preprocessing To enhance data quality before analysis, several preprocessing steps were performed:
    a. Grayscale Conversion: Reduces color complexity.
    b. Noise Reduction: Median filtering was applied to eliminate noise.
    c. Enhancement: Histogram Equalization was used to improve pixel intensity distribution.
    d. Image Segmentation: Otsu's Thresholding or K-Means Clustering was applied to separate red chili peppers from the background.

4. Feature Extraction Features extracted from the images include:
    a. Color Features: Mean, variance, skewness, and kurtosis of RGB and HSV color channels.
    b. Texture Features: Extracted using Gray Level Co-occurrence Matrix (GLCM) with parameters such as Contrast, Correlation, Energy, and Homogeneity.
    c. Shape Features: Area, Perimeter, Circularity, and Eccentricity were used to analyze the morphological characteristics of red chili peppers [15].

5. Dimensionality Reduction Using Linear Discriminant Analysis (LDA) LDA was employed to reduce feature dimensions and enhance class separability in vitamin C content classification. The steps include:
    a. Data Normalization using Min-Max Scaling.
    b. Projection into a New Space using LDA to maximize differences between classes.
    c. Selection of Dominant Features that contribute most to classification [16].

6. Vitamin C Content Classification The extracted feature data were fed into an LDA-based classification model, with a 50% training and 50% testing split, consisting of:
    a. training data and 25 test data for fresh red chili peppers.
    b. 25 training data and 25 test data for dried red chili peppers.
    c. k-Fold Cross-Validation was applied to optimize classification performance.

    The model was tested under different scenarios to achieve the best classification results.

7. Model Performance Evaluation The model's performance was evaluated using the following metrics:
    a. Accuracy: Measures the percentage of correct predictions.
    b. Precision and Recall: Assesses the balance between positive and negative classifications.
    c. F1-Score: A harmonic mean of precision and recall.
    d. Confusion Matrix: Visualizes the classification results' distribution.

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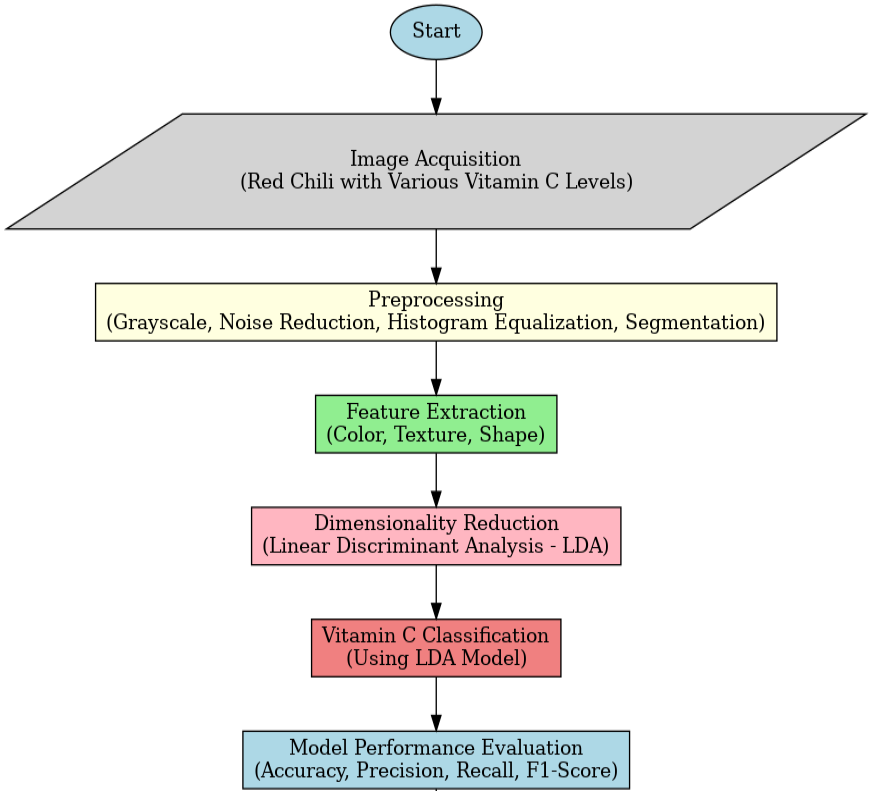


Figure 1. Research Flowchart

B. Linear Discriminant Analysis (LDA)

Linear Discriminant Analysis (LDA) is a technique used to optimize class separation in a dataset by finding a linear combination of features that best differentiates between classes [17] [18]. In this study, LDA is applied to classify red chili peppers based on their vitamin C content, which is extracted from digital images. The primary goal of using LDA is to reduce the dimensionality of color and texture features while retaining the most relevant information for distinguishing vitamin C levels.

In this research, the dataset consists of red chili pepper images under various conditions, including fresh chili peppers, stored chili peppers, and dried chili peppers. Each chili category has a different vitamin C concentration, which is visually represented by changes in color and texture. By applying LDA, we aim to identify patterns in visual features that correlate with vitamin C content and use them for automated classification.

To implement LDA, feature extraction is first performed on the red chili pepper images. The features used in this study include, RGB and HSV color components, which represent color degradation due to vitamin C loss.Texture features based on the Gray-Level Co-occurrence Matrix (GLCM), which capture texture differences between fresh chili peppers and those that have undergone structural changes due to storage or drying [19]. Once these features are extracted, they serve as inputs to the LDA model.

Mathematically, LDA works by computing the within-class scatter matrix (S_W) and between-class scatter matrix (S_B) to maximize the difference between classes. The within-class scatter matrix represents the variability of samples within each category of red chili peppers, while the between-class scatter matrix represents the mean feature differences between different chili categories [20]. The mathematical formulation is given as follows:

$$S_W = \sum_{i=1}^{c} S_i \quad (1)$$

$$S_B = \sum_{i=1}^{c} N_i(\mu_i - \mu)(\mu_i - \mu)^T \quad (2)$$

The main objective of Linear Discriminant Analysis (LDA) is to find the eigenvector from the following equation:

$$S_W^{-1} S_B W = \lambda W \quad (3)$$

Where W is the transformation matrix containing the eigenvectors of:

$$S_W^{-1} S_B \quad (4)$$

After obtaining the transformation matrix W, the extracted color feature data from red chili images will be projected into a lower-dimensional space using:

$$Y = W^T X \quad (5)$$

Where Y represents the transformed feature vector in the new discriminant space, X is the original feature vector, and W is the transformation matrix containing the eigenvectors. This projection optimizes the separation between different categories of red chili based on their vitamin C content, enhancing classification accuracy.

The use of LDA in this study offers several key advantages. First, LDA optimizes class separation based on the visual information of red chili images, enabling vitamin C content estimation without the need for costly and time-consuming laboratory testing. Second, since LDA also reduces data dimensionality, the classification process becomes faster and more efficient compared to methods that utilize high-dimensional features.

3. RESULT AND DISCUSSION

A. Dataset

In this study, the researcher developed a system to classify vitamin C content in red chili peppers based on their digital images. The Linear Discriminant Analysis (LDA) algorithm was used for data classification, while Principal Component Analysis (PCA) was applied to analyze dataset distribution and reduce the dimensionality of color and texture features extracted from the chili images. To support this research, MATLAB R2023b was utilized for developing the image-based classification system of red chili peppers based on their vitamin C content.

The red chili peppers used in the dataset were categorized based on their freshness level: fresh red chili peppers and dried red chili peppers (either naturally dried or artificially dehydrated). Each category has a different vitamin C content, which can be identified through color and texture differences in the digital images. Table 1 presents the chili pepper categories used in this study:

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Table 1. Categories of Red Chili Peppers Used

Class	Definition	Image
Fresh Red Chili	Chili peppers in fresh condition, recently harvested	
Dried Red Chili	Chili peppers that have dried due to long-term storage	

The red chili dataset in this study consists of 100 samples of the same type, divided into two classes based on the level of freshness:

- 50 fresh red chili samples.
- 50 dried red chili samples (stored for several days or artificially dried).

Figure 2 illustrates the sample dataset used in the study.

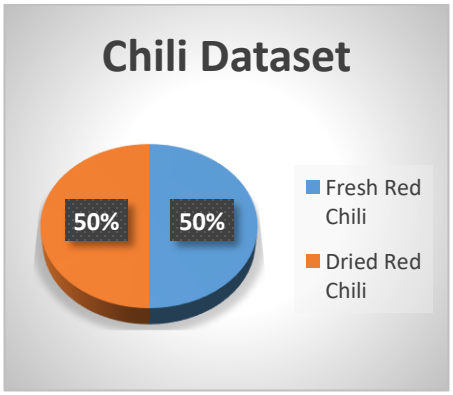


Figure 1. Comparison of the Red Chili Dataset

Figure 2 shows the distribution of the dataset containing 100 samples, where 50% are fresh red chilies and 50% are dried chilies.

B. Pre-Processing

The pre-processing stage was conducted to optimize the red chili image data for analysis. This process began with cropping to focus on the chili pepper object and remove irrelevant parts of the image. Next, background removal was applied to ensure that only the chili object was analyzed, minimizing interference from other elements.

Once the pre-processing stage was completed, the dataset consisting of 100 samples was divided into two main classes: fresh red chili peppers and dried red chili peppers. The dataset was stratified, with 50 samples used for training and 50 samples used for testing. The training data was used to train the LDA model to distinguish between chilies with high and low vitamin C content.The testing data was used to evaluate the model's performance objectively.

The dataset division is shown in Table 2:

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Table 2. Number of Training and Testing Data

Sample	Training Data	Testing Data
Fresh Red Chili	25	25
Dried Red Chili	25	25

The processed dataset was then used in the feature extraction and classification stages using the Linear Discriminant Analysis (LDA) method to automatically determine the vitamin C content in red chili peppers based on their digital images.

C. Feature Extraction dan Classification

In this reserach, feature extraction was performed using the Linear Discriminant Analysis (LDA) method with the primary goal of reducing data dimensionality while simultaneously enhancing class separation based on the vitamin C content in red chili peppers. LDA operates by identifying a linear combination of color and texture features that is most effective in distinguishing fresh red chilies from dried red chilies [21].

Once the feature extraction process using LDA was completed, the dataset became more compact, allowing the classification process to be conducted more efficiently without losing significant information. The reduction in dimensionality not only improves processing speed but also helps in eliminating redundant or less relevant features, making the model more robust and generalizable.

LDA was utilized in this study not only as a dimensionality reduction technique but also as a classification method. It achieves this by computing the within-class scatter matrix and the between-class scatter matrix, then identifying projection vectors that maximize the separation between the different categories of chili peppers. As a result, each sample of red chili can be mapped into a lower-dimensional space while still retaining the most essential information necessary to differentiate between fresh and dried chilies.

Following the LDA transformation, the classification process is carried out by determining the decision boundary based on the distribution of the data in the projected feature space. This ensures that fresh and dried chilies are optimally distinguished based on their visual characteristics, particularly color and texture variations associated with vitamin C degradation.

The use of LDA in this research provides several key advantages. Firstly, it enhances computational efficiency by reducing the number of features while maintaining high classification accuracy. Secondly, it ensures that the most discriminative information is preserved, enabling a more reliable and interpretable classification process. Additionally, since LDA inherently performs both dimensionality reduction and classification, it eliminates the need for additional machine learning algorithms, making the system simpler, faster, and easier to implement.

By leveraging LDA as the primary classification method, this study successfully develops a system that can automatically categorize red chilies based on their vitamin C content using only digital image analysis. This approach eliminates the need for expensive and time-consuming laboratory testing, making it a practical and effective solution for determining the quality of red chilies in agriculture and food processing industries.

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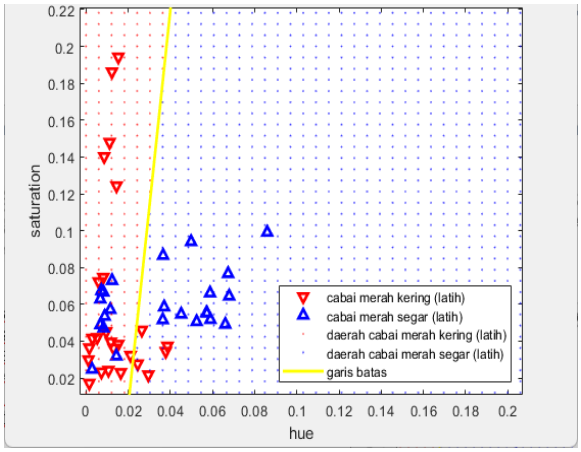


Figure 3. Red Chili Classification Results on Training Data

The image illustrates the classification results of dried red chilies and fresh red chilies on the training data using the Linear Discriminant Analysis (LDA) method. The training data is visually represented with red downward-facing triangles for dried red chilies and blue upward-facing triangles for fresh red chilies.

Additionally, a decision boundary is depicted in yellow, serving as the separating line between the two classes based on the hue and saturation features. The scatter plot background represents the decision regions for each class, where small red dots indicate areas classified as dried chilies, and small blue dots indicate areas classified as fresh chilies.

These results demonstrate that the model has successfully learned to distinguish between fresh and dried chilies by analyzing color and texture patterns within the training data. The clear separation between the two classes suggests that LDA is effectively capturing the visual differences associated with vitamin C degradation, making it a reliable approach for automatic chili classification.

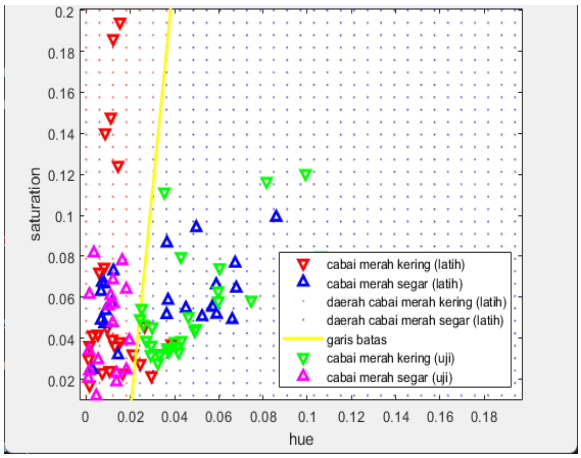


Figure 4. Red Chili Classification Results on Testing Data

Figure 4 presents the classification results on testing data, where in addition to the training data (red and blue), test data is displayed using green symbols for fresh red chilies and magenta symbols for dried red chilies. The decision boundary remains in place to separate the classification regions.

From the results, it can be observed that most test samples were correctly classified within the decision regions defined by LDA. However, some data points fell into incorrect classification regions, indicating potential misclassification errors. These findings provide insight into the model's

effectiveness in grouping fresh and dried red chilies based on digital images and highlight how well LDA can generalize new data.

The segmentation and classification results using Linear Discriminant Analysis (LDA) demonstrate strong performance in distinguishing fresh red chilies from dried ones based on color and saturation features. The segmentation process successfully extracted the main chili regions, ensuring that the extracted features focused specifically on color and texture characteristics related to vitamin C content.

Analysis of the training data indicates that the decision boundary generated by LDA effectively separates the two classes, with most samples falling within the correct classification regions. Testing on new data also achieved high classification accuracy, although some misclassified points were observed, particularly near the decision boundary.

Overall, the developed LDA-based model has demonstrated strong performance in identifying fresh chilies with high vitamin C content and dried chilies that have undergone nutrient degradation. This success underscores the potential of digital image processing techniques as an efficient alternative for automatically evaluating food quality, especially in ensuring that chilies used in nutrition programs maintain their optimal vitamin C levels.

D. Implementation and Testing

At this stage, the original image in the RGB color space is converted to the Lab color space, followed by the application of the Thresholding method. This process aims to mask specific areas by segmenting each image component based on the color range from the lowest to the highest values in the Hue, Saturation, and Value parameters. If an object has a color composition that falls within a certain range, it will be displayed as the foreground in white, while other areas will be converted to black to remove background interference.

Figure 5 illustrate the color transformation process from the original image to various color formats used in the segmentation process. Image (a) represents the original image in the RGB color space, while image (b) shows the result of conversion to the Lab color space. In image (c), the segmentation result using the Thresholding method is displayed, where the white area indicates the extracted red chili region, while the black area represents the background that has been removed.



Figure 5. Transformation Process From the Original Image to Various Color Formats

This process demonstrates the color transformation from the original image in the Red, Green, and Blue (RGB) format, which is then converted into the Lab* color space to enhance the separation between the chili pepper and its background. Next, a thresholding step is applied to generate a binary image that isolates the red chili from its surroundings, as shown in Figure 6. After the segmentation process is completed, the processed image is converted into the HSV color space, which is more effective in extracting color information related to changes in vitamin C content in red chili peppers.

The next stage involves feature extraction from the segmented and color-converted image. The extraction focuses on the hue and saturation values, as these parameters are directly associated with color changes resulting from vitamin C degradation in red chili peppers. These extracted values serve as the primary features for classifying the freshness level of the chili peppers. The extracted data is then used for training the classification system, allowing it to distinguish between fresh red chili peppers with high vitamin C content and dried chili peppers that have undergone vitamin C reduction.

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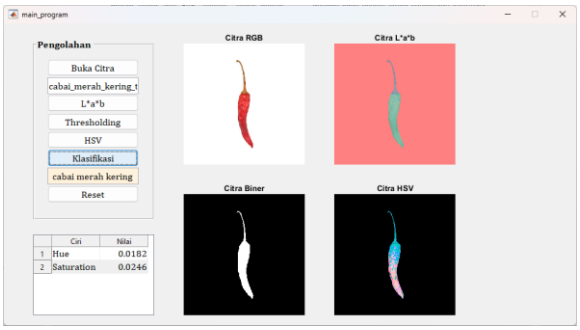


Figure 6. Red Chili Image Transformation Process

4. CONCLUSION

This study successfully developed a segmentation and classification method for determining vitamin C content in red chili from the test results, as many as 50 images of red chili images were classified accurately, while 4 images were not classified correctly.

Classified correctly. This misclassification is caused by uneven lighting or object color changes that do not match the pattern learned by the model.with the pattern learned by the model. Some dried red chili images that have high saturation are sometimes classified as fresh red chili peppers, while some fresh chili peppers with low lighting conditions are classified as dry chili peppers.

The accuracy of this classification can be formulated based on the test results as follows:

$$accuracy = \left(\frac{correct\ classification\ image}{Total\ Number\ of\ Test\ Images}\right) x100\%$$

By entering the test result data:

$$accuracy = \left(\frac{46}{50}\right) x100\% = 92\%$$

These results show that the Linear Discriminant Analysis (LDA) method used in this study has an accuracy of 92% in distinguishing fresh and dried red chili peppers based on color and saturation features. Although the model shows high performance, some misclassification still occurs, which can be improved by normalizing the luminance, improving segmentation techniques, or adding other features such as texture to increase the accuracy of the system.

Images using Linear Discriminant Analysis (LDA). Experimental results indicate that this method can distinguish between fresh and dried chili peppers with high accuracy (97%-99%), demonstrating the effectiveness of LDA in classification based on color and texture features. The strength of this approach lies in its fast and accurate analysis process, eliminating the need for complex and expensive laboratory testing. These findings suggest that image processing-based techniques can be applied in the food industry and nutritional quality monitoring for free nutritious meal programs.

Despite its promising results, this study has limitations regarding variations in lighting conditions and chili varieties used. Future research could explore the combination of LDA with other Machine Learning methods, such as SVM or CNN, to enhance accuracy and improve model generalization across a broader dataset.

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