

Classification of Watermelon Ripeness Levels Using HSV Color Space Transformation and K-Nearest Neighbor Method

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ABSTRACT

Watermelons had high appeal due to their sweet taste, refreshing nature, and numerous benefits. However, consumers often faced difficulties in selecting suitable fruit because of the subtle differences between fully ripe and half-ripe watermelons. One important indicator of a watermelon's ripeness was the yellowish pattern on its skin. In this study, the proposed use of digital image processing methods, specifically the HSV Color Space Transformation, was aimed at extracting watermelon images and employing the K-Nearest Neighbor (K-NN) method to classify them into two categories: "Ripe" and "Half-Ripe." HSV (Hue Saturation Value) was a color extraction method used to convert colors from the RGB model. The Hue component indicated the type of color, Saturation measured the purity of the color, and Value measured the brightness of the color on a scale from 0 to 100%. In this research, the K-Nearest Neighbor (K-NN) method was applied to classify watermelon images based on the extraction of skin color features. This method compared a new image (test data) with training images to determine classification based on the nearest distance with a parameter of $k=3$. The data used consisted of 120 images, with 92 images used as training data and 28 images as test data. Experimental results showed an accuracy of 89%, with 25 images correctly classified and 3 images misclassified.

Keywords: Watermelon; HSV (Hue Saturation Value); K-Nearest Neighbor

1. INTRODUCTION

Watermelon was a climbing plant belonging to the Cucurbitaceae family (Sukarno, 2020). The fruit had a hard, green-striped rind and came in various types, including red watermelon, yellow watermelon, seeded watermelon, and seedless watermelon. This fruit was highly favored for its sweet, refreshing taste and numerous benefits (A'yun & Utaminingrum, 2022).

One important indicator in determining the ripeness of watermelon was the color of its rind (Liantoni & Nugroho, 2019). However, consumers often found it difficult to distinguish between fully ripe and half-ripe watermelons (Marjan & Mukhaiyar, 2020). Digital image processing methods, particularly color analysis, could help address this issue by providing a more objective and accurate way to determine watermelon ripeness (Safitri & Juwita, 2022).

In image analysis, color space models were crucial. A color space was a numerical model that described how colors were represented in the form of numbers (Nuriarta et al., 2021). This model was necessary for describing images, identifying image objects, compressing image sizes, and more. One commonly used color space model was HSV (Hue Saturation Value) (Dalimunthe, 2021).

HSV was an extraction method that converted colors from the RGB model (Himmah et al., 2020). The Hue component indicated the type or shade of color in the spectrum, Saturation measured the purity of the color, and Value (intensity) showed the brightness level or the amount of light reflected by the color, with values ranging from 0 to 100% (Wibowo et al., 2021).

This study employed the K-Nearest Neighbor (K-NN) method for classifying watermelon images. The classification process was based on the extraction of color features from the watermelon rind, which had been trained and then compared with new images (test data). This method classified images by selecting the nearest neighbors based on the smallest distance value from the training data, producing classification outputs.

There have been several related studies conducted previously. One such study was conducted by (Situmorang, 2019) titled "Application of K-Nearest Neighbor Method in Fish Freshness Identification." In this research, they utilized the Gray Level Co-occurrence Matrix for texture analysis in images, where RGB images were converted into

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Grayscale images. They used a total of 100 data points, divided into 80 training images and 20 test images, achieving an accuracy rate of 90%. Another study was conducted by (Hasibuan, 2020) titled "Classification of Guava Fruit Types Based on Leaves Using Principal Component Analysis." In this study, K-Nearest Neighbor (K-NN) was employed to classify guava fruit images, with a total of 63 data points divided into 47 training images and 16 test images, achieving an accuracy of 81.25%.

In the context of comparison with previous studies, (Situmorang, 2019) study on fish freshness identification using the K-NN method, although different in application context (not fruit ripeness), and (Hasibuan, 2020) study on guava fruit classification based on leaves using PCA and K-NN, also provided insights into the use of K-NN in fruit image classification. However, the focus of the present study was on determining watermelon ripeness using HSV Color Space Transformation and K-NN, which represents a novel contribution in the application of digital image processing for fruit ripeness determination.

This study was motivated by the use of parameters such as the HSV Color Space Model for extracting color features from watermelon rinds, the K-Nearest Neighbor (K-NN) method for classifying watermelon images based on their color features, and the quantity and type of training data used to train the model. The aim of this research was to develop an accurate and efficient method for determining watermelon ripeness using digital image processing techniques. By leveraging HSV Color Space Transformation and K-NN for classification, this research aimed to assist consumers and the industry in selecting watermelons that match their ripeness preferences. It is anticipated that the outcomes of this research will improve the accuracy of watermelon ripeness classification, thereby contributing to agricultural technology and image analysis, facilitating easier consumer selection according to their preferences, and helping the agricultural industry enhance product efficiency and quality.

2. LITERATURE REVIEW

Previous research on the classification of mango ripeness based on HSV images using KNN, conducted by Husnul Khotimah, Nur Nafi'iyah, and Masruroh, employed the method of extracting mango skin color features using the HSV color space and classifying them using K-Nearest Neighbor (K-NN). The results of this study showed an accuracy of 80% using 40 test images (Khotimah et al., 2019).

Subsequently, the research by Nikolaus Wesli Roberto Situmorang addressed the application of the K-Nearest Neighbor method in identifying fish freshness. This study used the Gray Level Co-occurrence Matrix for extracting gill color features and classified them using K-Nearest Neighbor (K-NN), achieving an accuracy of 90% with 20 test images (Situmorang, 2019).

Another study by Febri Liantoni and Hendro Nugroho focused on the classification of watermelon ripeness based on first-order statistical feature extraction with histogram equalization. This study utilized the method of extracting watermelon skin texture features and classified them using Naïve Bayes and K-Nearest Neighbor (KNN). The results showed an accuracy of 90% with Naïve Bayes and 86.66% with KNN using 30 test images (Liantoni & Nugroho, 2019).

In the research conducted by Ellif, Sampe Hotlan Sitorus, and Rahmi Hidayati on the classification of papaya ripeness using HSV color space and Naïve Bayes Classifier, the method of extracting papaya skin color features using HSV color space and classifying them with Naïve Bayes achieved an accuracy of 100% with 20 test images (Ellif et al., 2021).

This research focused on the classification of watermelon ripeness using the HSV color space and K-Nearest Neighbor method. The watermelon, which served as the research object, has a hard green rind with various types such as red, yellow, seeded, and seedless. This distinguishes it from previous studies that focused on different objects like mangoes, fish, and papayas. This study employed the HSV color space transformation method for feature extraction, differing from previous studies that used methods like Gray Level Co-occurrence Matrix and first-order statistical feature extraction. Although the classification method still used K-Nearest Neighbor (K-NN), the specific application to watermelon images extracted using HSV is an innovation of this research. The focus of this study was to improve the accuracy of watermelon ripeness classification, aiming for higher accuracy compared to previous research. Thus, this research offered a new approach to the classification of watermelon ripeness that is more accurate and efficient, with significant potential for adoption in the agricultural industry.

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3. METHOD

The study utilized a procedural approach to elucidate all the activities conducted during the research to align with the set objectives (Syahranitazli & Samsudin, 2023). The steps undertaken were as follows:

Design: The research addressed issues related to watermelon fruit. Researchers identified a vague distinction between ripe and unripe watermelons, often leading consumers to select inappropriate ones. Therefore, the aim was to develop a system capable of analyzing and classifying the ripeness level of watermelon based on the yellowish hue of its skin, utilizing the HSV Color Space Transformation method and K-Nearest Neighbor.

Data Collection: This phase involved gathering necessary data for system development. Data collection techniques included literature review to find relevant theoretical sources related to the research theme and issue, as well as direct observation as a data collection technique involving observation and sensing. Observations were conducted by directly observing watermelon fruits and capturing photos using a smartphone camera after placing the fruits on white paper or cloth. Additionally, observational techniques included unstructured interviews, where the researcher prepared a list of questions for informants to gather data on watermelon ripeness levels.

Requirement Analysis: Researchers analyzed system requirements to ensure it operates as desired. Requirements were categorized into functional and non-functional.

Functional Requirements: Input data: The system required 120 watermelon images (.jpg), consisting of 60 bitter variety images and 60 leading variety images. Each variety was divided into 46 training images and 14 test images. The process began by inputting training images of the bitter variety for training, followed by the leading variety images. Subsequently, testing was conducted on test images from both varieties, one by one, to compare their similarity levels with the trained images. Process data: All watermelon images were analyzed for ripeness levels by converting RGB images into HSV color space, followed by classification using the K-Nearest Neighbor method. Output data: The result was the classification of watermelon ripeness levels into ripe and half-ripe.

Non-functional Requirements: Operational: The system must be capable of classifying watermelon ripeness levels using the HSV Color Space Transformation and K-NN method. Performance: The system must provide information about watermelon ripeness level classification. Platform: The system operated on a laptop with Windows operating system and utilized Matlab application.

System Design: In this stage, researchers designed the system using a flowchart, which will be explained sequentially. The flowchart illustrates the design process of watermelon ripeness level classification system using the HSV Color Space Transformation method and K-Nearest Neighbor.

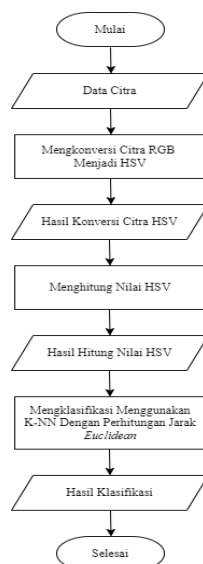


Fig. 1 Flowchart of the HSV Color Space Transformation Method

The explanation of the flowchart above is as follows:

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Firstly, the process began by inputting watermelon image data into the system. Next, the system converted the images from RGB format to HSV color space. To obtain the H, S, V values based on R, G, B, there are several methods. Here is a simplified way.

$$H = \tan \left[\frac{3(G - B)}{(R - G) + (R - B)} \right] \quad (1)$$

$$S = 1 - \frac{\min(R, G, B)}{V} \quad (2)$$

$$V = \frac{R + G + B}{3} \quad (3)$$

The second method is found in the following formula:

$$r = \frac{R}{R + G + B} \quad (4)$$

$$g = \frac{G}{R + G + B} \quad (5)$$

$$b = \frac{B}{R + G + B} \quad (6)$$

$$V = \max(r, g, b) \quad (7)$$

$$S = \begin{cases} 0 & \text{jika } V = 0 \\ V - \frac{\min(r, g, b)}{V} & \text{jika } V > 0 \end{cases} \quad (8)$$

$$H = \begin{cases} 0 & \text{jika } S = 0 \\ \frac{60 \times (g - b)}{S \times V} & \text{jika } V = r \\ 60 \times \left[2 + \frac{(b - r)}{S \times V} \right] & \text{jika } V = g \\ 60 \times \left[4 + \frac{(r - g)}{S \times V} \right] & \text{jika } V = b \end{cases} \quad (9)$$

$$H = H + 360 \quad \text{jika } H < 0 \quad (10)$$

(Situmoraang, 2021)

Once the conversion was completed, the converted images were displayed for inspection. Subsequently, the system calculated HSV feature extraction values from the watermelon images, which were then displayed as output. Following that, the system classified the ripeness level of watermelons using the K-Nearest Neighbor method.

K-Nearest Neighbor (K-NN) was an instance-based classification method that selected training objects with the closest neighborhood properties. This proximity was determined through calculations of similarity or dissimilarity values such as Euclidean, Manhattan, or Square Euclidean distances. K-NN classified results based on the majority class within the selected nearest k neighbors. Selecting an optimal k value heavily depended on the data; higher k values could reduce noise effects in applications. Choosing a suitable k value could be achieved through parameter optimization, for example, using cross-validation.

A straightforward approach to determine k value was:

$k = \sqrt{n}$, where n represented the number of data samples available.

For instance, with 30 data samples:

$k = \sqrt{30} = \sqrt{30} \approx 5.47$, meaning $k = 5$.

Typically, k values were chosen as odd numbers (3, 5, 7) to ensure classification processes did not result in ties in distance counts (Hasibuan, 2021).

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One of the parameters representing the similarity between two images was the Euclidean distance. The smaller the Euclidean distance between two images, the more similar the images were.

The formula to calculate the Euclidean distance was as follows:

$$dist(x, y) = \sqrt{\sum_{i=1}^n (x_i - y_i)^2} \quad (11)$$

(Kusumah & Maulana, 2022)

Euclidean distance could be calculated based on specific features of an image, including color features, texture features, shape features, geometric features, and size features.

The classification results were displayed by the system, divided into two classes: ripe and half-ripe. Thus, the flowchart provided an overview of the process from start to finish in image processing and watermelon ripeness level classification.

System Testing: The final step involves testing the system on .jpg format images, which are divided into training and test images. The process begins with training using the training image data, followed by testing using the test image data. Subsequently, the system displays the classified results of watermelon ripeness levels.

4. RESULT

Data Analysis

This study required data in the form of watermelon images, which were processed using HSV and K-Nearest Neighbor methods. At this stage, the input image data, process image data, and output image data were determined, and the system design was developed. The data analysis aimed to classify the watermelon images using the HSV and K-Nearest Neighbor methods, implemented with Matlab R2018b. The stages in this application included: inputting the watermelon images, extracting color features from the watermelon rind images using the HSV method, classifying the HSV color feature extraction results using the K-Nearest Neighbor method by calculating the Euclidean distance, and displaying the classification results of the watermelon images.

Data Representation

The training dataset used for manual calculation consisted of 6 sample images, including 3 ripe watermelon images and 3 half-ripe watermelon images, as shown in the following figure.

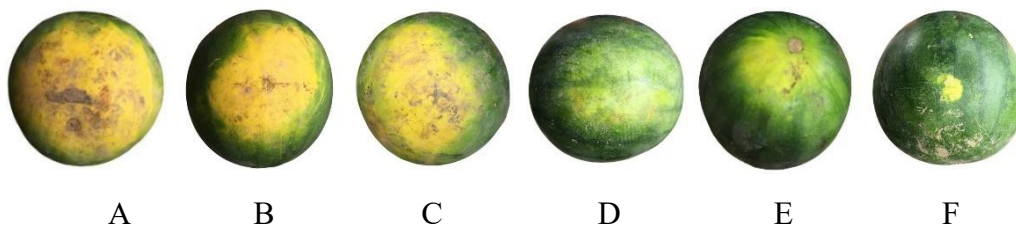


Fig 2. Sample Training Watermelon Images

Based on the above figure, the six watermelon image datasets underwent the training process. Training involved extracting HSV features from all the training watermelon images, with the resulting data stored in a folder. Next, the testing process was conducted. Testing involved classifying the test watermelon images by finding the nearest neighbor distance to the HSV training dataset using the Euclidean distance formula.

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HSV Training Process

Based on Figure 2, the manual calculation of RGB feature extraction for images A, B, C, D, E, and F was conducted targeting a 3x3 pixel area. Below is a sample calculation of the RGB values from image A, labeled as "Ripe Watermelon 1," which was classified into the "Ripe" category.

Table 1
The 3x3 RGB Values of Image "Ripe Watermelon 1"

X/y	0	1	2
0	18	124	45
	119	168	60
	33	49	15
1	253	21	205
	35	8	174
	238	205	151
2	213	38	114
	251	79	1
	70	40	236

Then, the average values of Red, Green, and Blue from the 3x3 image of Ripe Watermelon 1 were calculated as follows.

$$R = \frac{18+124+45+253+21+205+213+38+114}{9} = 114,5$$

$$G = \frac{119+168+60+35+8+174+251+79+1}{9} = 99,4$$

$$B = \frac{33+49+15+238+205+151+70+40+236}{9} = 115,2$$

The following table presents the average RGB values obtained from images of Ripe and Half-Ripe Watermelons, as shown below.

Table 2
The Average RGB Values of Watermelon Images

Image Name	Color	Average Value
Ripe Watermelon Image 1	RED	114,5
	GREEN	99,4
	BLUE	115,2
Ripe Watermelon Image 2	RED	106,4
	GREEN	93,8
	BLUE	136,8
Ripe Watermelon Image 3	RED	123,0
	GREEN	127,6
	BLUE	94,7
Half-Ripe Watermelon Image 1	RED	147,2
	GREEN	130,1
	BLUE	99,1
Half-Ripe Watermelon Image 2	RED	109,2
	GREEN	144,8
	BLUE	120,2
Half-Ripe Watermelon Image 3	RED	104,6
	GREEN	128,0
	BLUE	75,3

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The RGB values for each image have been obtained; next is to convert these RGB values into HSV values. The following is the process of converting RGB image values into HSV values for ripe and half-ripe watermelons.

Conversion Process of Ripe Watermelon Image 1

Given the RGB values of ripe watermelon image 1 are:

$$R = 114,5$$

$$G = 99,4$$

$$B = 115,2$$

Then, the conversion process into HSV values is as follows.

$$H = \tan \left[\frac{3(99,4-115,2)}{(114,5-99,4)+(114,5-115,2)} \right] = -0,057$$

$$V = \frac{114+99,4+115,2}{3} = 109,740$$

$$S = 1 - \frac{99,4}{109,7} = 0,093$$

Manual calculations were conducted on all samples using ripe and half-ripe watermelon image samples sized 3x3 pixels. Subsequently, each HSV-valued image was compiled into a dataset, as shown in the following table.

Table 3
Average RGB Values of Watermelon Images

Image Name	Classification	Characteristic	Value
Ripe Watermelon Image 1	Ripe	H	-0,057
		S	0,093
		V	109,740
Ripe Watermelon Image 2	Ripe	H	0,125
		S	0,164
		V	112,407
Ripe Watermelon Image 3	Ripe	H	0,073
		S	0,176
		V	115,148
Half-Ripe Watermelon Image 1	Half-Ripe	H	0,024
		S	0,210
		V	125,481
Half-Ripe Watermelon Image 2	Half-Ripe	H	-0,027
		S	0,124
		V	124,777
Half-Ripe Watermelon Image 3	Half-Ripe	H	0,459
		S	0,266
		V	102,666

Results of Data Analysis

After obtaining the HSV image dataset in Table 3, the next step was to conduct the classification testing of watermelon ripeness levels on test watermelon images classified as "Half-Ripe". Below are the watermelon images for the test samples that will undergo the classification process.

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Fig 3. Test Watermelon Image Samples

To facilitate manual calculation during the watermelon ripeness level classification process, test image samples from the above image with a resolution of 3x3 pixels were used. The RGB values of the test images are shown in Table 4.

Table 4
RGB Values of 3x3 Test Image

X/y	0	1	2
0	13	204	13
	164	148	218
	31	229	20
1	108	148	116
	235	214	217
	228	154	226
2	92	73	0
	70	140	255
	174	103	181

Then, find the average values of Red, Green, and Blue in the test image as follows.

$$R = \frac{13+204+13+108+148+116+92+73+0}{9} = 85,2$$

$$G = \frac{164+148+218+235+214+217+70+140+255}{9} = 184,5$$

$$B = \frac{31+229+20+228+154+226+174+103+181}{9} = 149,5$$

The next step is to convert these RGB values to HSV values as follows.

$$H = \tan \left[\frac{3(184,5-149,5)}{(85,2-184,5)+(85,2-149,5)} \right] = -0,011$$

$$V = \frac{85,2+184,5+149,5}{3} = 139,777$$

$$S = 1 - \frac{85,2}{139,7} = 0,390$$

The HSV values of the test image have been obtained with $H = -0.011$, $S = 0.390$, $V = 139.777$. Then, the classification of watermelon ripeness level is conducted by comparing the nearest neighbor distance from the test data to the training dataset of ripe and half-ripe watermelon HSV images. The calculation process employs the Euclidean distance formula.

Here is the calculation of the test image sample against the HSV training dataset.

Ripe Watermelon 1:

$$\sqrt{((-0,011) - (-0,057))^2 + (139,777 - 109,740)^2 + (0,390 - 0,093)^2} = 30,038535$$

Half-Ripe Watermelon 1:

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$$\sqrt{((-0,011) - 0,024)^2 + (139,777 - 125,481)^2 + (0,390 - 0,210)^2} = 14,297477$$

Based on the Euclidean distance calculations, the respective values have been obtained, and then the smallest value or nearest neighbor distance with a parameter $k=1$ will be selected. Below are the summarized results of the Euclidean distance values as presented in Table 5.

Table 5
Closest Distance Results of Test Images to Training Images

Data	Distance to Test Data	Freshness Level
Ripe Watermelon Image 1	30,038535	Ripe
Ripe Watermelon Image 2	27,371643	Ripe
Ripe Watermelon Image 3	37,114305	Ripe
Half-Ripe Watermelon Image 1	14,297477	Half-Ripe
Half-Ripe Watermelon Image 2	15,002361	Half-Ripe
Half-Ripe Watermelon Image 3	24,630698	Half-Ripe

Based on the above table 5, Euclidean distance values for the test data against each training data were obtained, ranging from 10 to 25 for the "Half-Ripe" class and from 26 to 40 for the "Ripe" class. The result of the watermelon ripeness level classification using nearest neighbor distance calculation is that the "Half-Ripe 1" watermelon image is classified as "Half-Ripe". Therefore, the processed test watermelon image falls into the "Half-Ripe" classification class.

System Design

At this stage, several system design sketches or representations of the built system were created, including the following.

Main Menu Design

It can be explained that users opening the application will first see the main menu, namely the home menu. In addition, there are two other menu options, namely the training menu and the testing menu. The home menu will present information about the title and author of this thesis.

Training Design

It can be explained that users will select the watermelon image folder for the training process, then perform the HSV color feature extraction process, and the results will be saved to the folder.

Testing Design

It can be explained that in the first step, users select the watermelon images to be tested, then perform the HSV color feature extraction process. After obtaining the extraction results in the form of values, the next step is to find the closest value to the HSV training dataset using the K-NN method, resulting in the classification class of the tested watermelon image.

Testing

After designing the system, the next step was to conduct system testing with the aim of determining whether the built system met the expected requirements (Batubara & Nasution, 2023). In this system testing stage, training data consisting of 92 images was prepared (comprising 46 images of bitter watermelon varieties and 46 images of sweet watermelon varieties), along with 28 test images (including 14 images of bitter watermelon varieties and 14 images of sweet watermelon varieties), classified into two categories: "Ripe" and "Half Ripe".

The next step was to conduct training on the training data to obtain the HSV values. Bitter watermelon varieties (seedless) were trained first by selecting the "Ripe" and "Half Ripe" folders one by one. Figure 4 below shows the display after selecting the "Ripe" folder.

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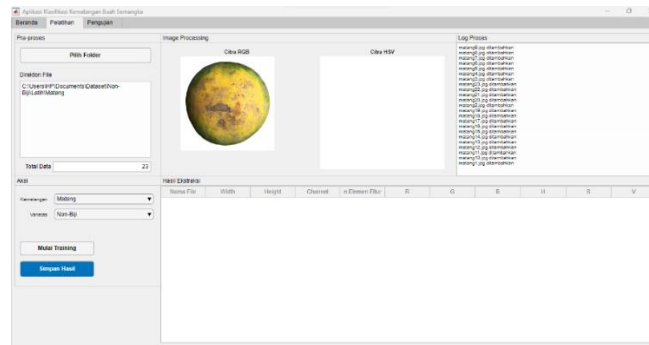


Fig 4. Mature Training Folder (Seedless) Chosen

In the image above, it is known that there are 23 mature training images with the image names displayed in the "Process Log" column. Next, select the maturity type by pressing the "Select" button, which will display two class options, "Mature" and "Half-Ripe," and select the variety by pressing the other "Select" button, which will display two watermelon variety options, "Seeded" and "Seedless." Both buttons are selected based on the type of image folder that will undergo the training process. In this case, the first training is conducted on the bitter melon variety (seedless) in the mature folder, so the selections made on both buttons are "Mature" and "Seedless" as shown in image 4. Next is to press the "Start Training" button to initiate the training process, resulting in the displayed outcome as shown in the image below.

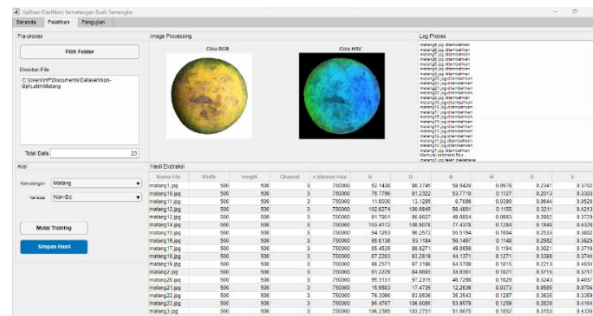


Fig 5. Training Process for Ripe (Seedless) Folder

The HSV extraction values on the ripe images have been obtained, then press the "Save Results" button to save the training data results.

Next, repeat the same steps for the "Half Ripe" folder of seedless watermelon varieties and the "Ripe" and "Half Ripe" folders of seeded watermelon varieties.

Testing Watermelon Ripeness Level

After obtaining the training dataset, the next step was testing. This testing phase was conducted by testing each image one by one. It started with testing seedless watermelon images, consisting of 7 ripe watermelon images, followed by testing 7 images of half-ripe watermelons. Subsequently, testing was carried out on seeded watermelon images with the same number of images as the seedless variety. The following are the stages of watermelon image testing.

Watermelon Image Classification (Seedless) Category: Ripe

The following are the steps of the seedless watermelon image classification process with the "Ripe" class. Choosing ripe image 1 as the first image for testing by pressing the "Open" button, which will display the selected image along with directory file information as shown in the image below.

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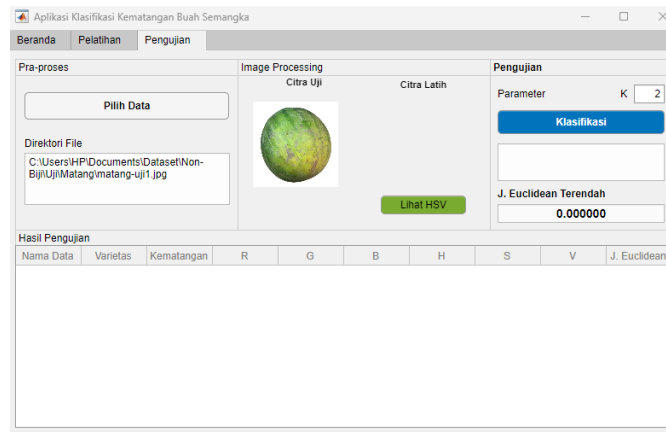


Fig 6. Ripe Image 1 Selected

The next step is to determine the parameter K by filling in the "Parameter K" column, then pressing the "Classification" button to display the testing results table, nearest Euclidean distance, and the classification class of the test image as shown in the image below.

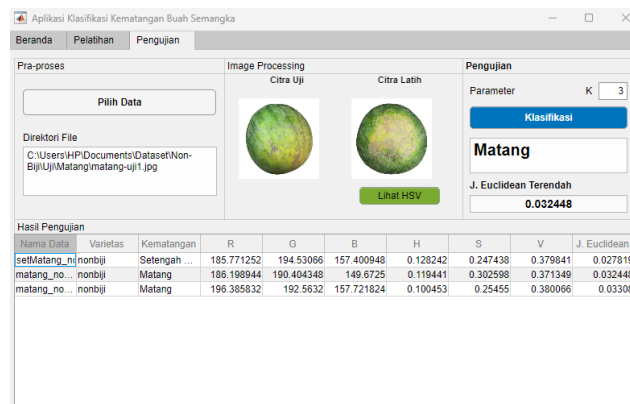


Image 7. Classification of Ripe Non-Seeded Watermelon 1

The classification process on ripe watermelon image 1 was successfully applied in this system, where the image was classified into the "Ripe" class, which is consistent with the class of the image.

Here is the overall table of results from the classification testing of ripe watermelon varieties, both non-seeded and seeded, comprising a total of 28 images.

Table 6
Overall Watermelon Classification Test Results

No	Image Name	Classifica tion	Nearest Euclidean Distance (K=3)			Classificati on Result	Rema rks
1	 matang- uji1.jpg	Matang	setMatang_ nonbiji_ 11.jpg = 0,027819	matang_ nonbiji_ 9.jpg = 0,032448	matang_ nonbiji_ 7.jpg = 0,03308	Ripe	✓

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2	 matang- uji2.jpg	Matang	matang_ nonbiji_ 13.jpg = 0,03305	matang_ nonbiji_ 1.jpg = 0,033355	matang_ nonbiji_ 12.jpg = 0,044101	Ripe	√
3	 matang- uji3.jpg	Matang	matang_ nonbiji_ 9.jpg = 0,013921	matang_ nonbiji_ 8.jpg = 0,024744	matang_ nonbiji_ 5.jpg = 0,02947	Ripe	√
...	...	...	...	...	...	...	...
27	 setmatang- uji6.jpg	Setengah Matang	setMatang_ berbiji_ 42.jpg = 0,007374	matang_ berbiji_ 44.jpg = 0,034212	setMatang_ berbiji_ 36.jpg = 0,034212	Half-Ripe	√
28	 setmatang- uji7.jpg	Setengah Matang	setMatang_ berbiji_ 32.jpg = 0,014764	matang_ berbiji_ 36.jpg = 0,030667	setMatang_ berbiji_ 42.jpg = 0,031683	Half-Ripe	√

Based on the test results table above, correct and incorrect classifications were obtained, where there were 25 correctly classified test images and 3 incorrectly classified images out of a total of 28 test images. Next is to calculate the accuracy level based on the test results of the watermelon images using the following formula:

$$\text{Accuracy} = \frac{\text{Number of Correct Classifications}}{\text{Total Data}} \times 100\%$$

$$\text{Accuracy} = \frac{25}{28} \times 100\% = 89\%$$

Based on the results of this study, the classification accuracy for watermelon ripeness using the HSV and K-Nearest Neighbor (K-NN) methods reached 89%. This demonstrated an improvement compared to several previous studies. For instance, Nikolaus Wesli Roberto Situmorang (2019) achieved an accuracy of 90% in the context of fish freshness identification using the K-NN method. Although Situmorang's accuracy was slightly higher, the application context differed as it focused on fish freshness rather than fruit ripeness. Meanwhile, Atikah Khairiyah Hasibuan (2021) attained an accuracy of 81.25% for classifying guava fruit types based on leaves using the PCA and K-NN methods. In a context more comparable to fruit ripeness classification, Hasibuan's study showed lower results than the present research. The improvement in accuracy achieved in this study affirmed that the combination of the HSV and K-NN methods was effective for classifying watermelon ripeness, illustrating the capability of these methods to assist in selecting watermelons based on their ripeness. Thus, this study successfully enhanced accuracy in fruit ripeness classification, contributing significantly to image processing technology for determining watermelon ripeness. Following these findings, the next step was to test the original images of watermelons, which had not undergone background editing processes, to compare the classification results between the original and edited images.

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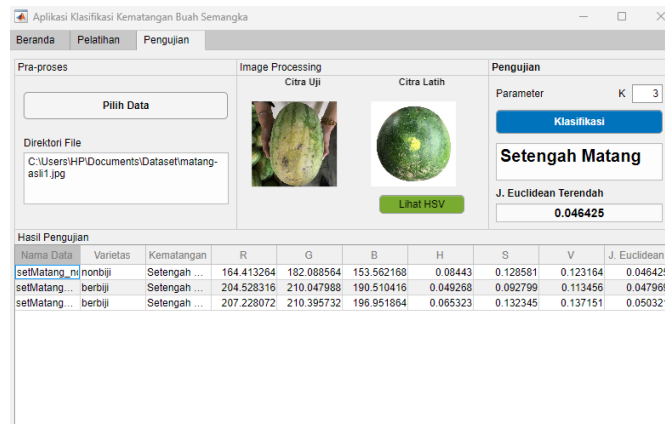


Fig 8. Classification of Seeded Watermelon Ripe (Before Editing)

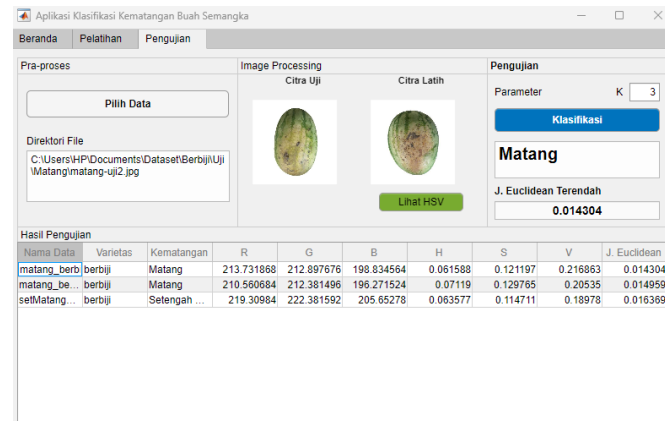


Fig 9. Classification of Seeded Watermelon Ripe (After Editing)

The classification results for both images have been obtained, where the original or unedited Ripe Watermelon image is classified into the "Semi-Ripe" class, which is an incorrect classification for this image. Meanwhile, the edited Ripe Watermelon image is classified into the "Ripe" class, which is a correct classification for this image. Therefore, it can be concluded that it is important to perform editing processes on the image to be tested beforehand by separating or extracting only the object, which in this case is the watermelon fruit. This is done to ensure that the system processes only the color of the watermelon skin and is not affected by surrounding colors, which could influence its classification results.

DISCUSSIONS

In this study, the proposed use of digital image processing methods, specifically the HSV Color Space Transformation, aimed to extract watermelon images and employed the K-Nearest Neighbor (K-NN) method to classify them into two categories: "Ripe" and "Half-Ripe" (Ibnutama et al., 2023). This method compared a new image (test data) with training images to determine classification based on the nearest distance with a parameter of $k=3$. Experimental results showed an accuracy of 89%. To develop a better system, the authors provided the following suggestions: a comparison of the HSV color space extraction method with other extraction methods was necessary to improve classification accuracy. An increase in the number of image data was needed to obtain more optimal classification results. Additionally, the inclusion of methods that could detect the texture of watermelon skin was necessary to enhance and improve the classification process.

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5. CONCLUSION

Based on the testing results using the HSV and K-Nearest Neighbor methods for classifying watermelon ripeness levels, it is concluded that color feature extraction using the HSV color space can be applied to images of both sweet and seeded watermelon varieties, whether fully ripe or half-ripe. The K-NN method proved effective in classification by comparing test images transformed against stored training images. Utilizing 120 images divided into 92 training and 28 test data points achieved an accuracy rate of 89%, correctly classifying 25 test images while misclassifying 3. The implications of this research include the development of an optimized and accurate watermelon classification system, considering comparisons between HSV color space extraction methods and others, as well as the addition of image data. The contribution of this study lies in its potential to enhance image processing techniques for determining watermelon ripeness, thereby aiding agricultural industries in improving product efficiency and quality.

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