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Image processing algorithm for area determination of irregularity quality in leafy green salad

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Abstract - The objective of the research was to develop an image processing algorithm for analyzing the color change of leafy green salad using Green Oak as a sample. The research was divided into two parts. The initial step was to construct an image acquisition system. To provide uniform light intensity across the samples, two D65 lamps were mounted 30 cm above the samples at a 45° angle to the sample plane. The second step was to develop an image processing algorithm to analyze the color change of Green Oak salad. For analysis, the algorithm employs the H (hue angle) value. In the image of Green Oak salad, H can be indicated browning. The browning zone is indicated by a H value of 35° to 79°, and the regular color of Green Oak salad is indicated by a H value of 80° to 135°. An experiment with Green Oak salad vegetables stored at 5°, 10°, and 15° revealed that the amount of brown area in the salad vegetables was greater than 9% of the total area. Green Oak salad vegetables are irregular quality, exceeding acceptable limits.

Keywords: Image processing, leafy green salad, green oak, color change

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1. Introduction

Currently, many industries are attempting to implement the Computer Vision Analysis System (CVAS) to help inspect the quality of their products. Due to applying CVAS in quality inspection reduces the amount of human labor required for inspection and helps in increasing the efficiency of the quality inspection process (Lin *et al*., 2023; Frustaci *et al*., 2022; Vijayarekha, 2012). In the agricultural and food industry, the application of CVAS is likely to continue to increase, as evidenced by research studies to apply CVAS knowledge to inspect the quality of many agricultural and food products. In China, CVAS has been applied to inspect and classify green tea leaves (Chen *et al*., 2002). Similarly, apple producing countries have adopted CVAS applied to color sorting (Yang & Marchant, 1995; Dubey *et al*., 2016), as well as to check for defects such as bruises and wounds in apples (Leemans, 1998). Li *et al*. (2017) proposed a method for segmenting the target and background of an apple picking robot in a complex background by combining color, shape, and texture features. The statistical method extracts texture features using gray scale, which is superior to other algorithms. Arjenaki *et al*. (2013) developed an online tomato sorting system based on shape, maturity, size, and surface defects using machine vision. Pereira *et al*. (2018) proposed an approach to predict ripening of papaya fruit using digital image. The color features are used for classifying. The results showed that 94.3% of the classifications. Dorj *et al*. (2017) propose an algorithm that utilize the color features to present an estimate of citrus. To obtain good result automated watershed segmentation is done using distance transform and marker controlled watershed algorithm. The proposed algorithm showed correlation coefficient of 0.93. CVAS has also been applied to inspect the quality of meat (Berg *et al*., 1999; Basset, 2000; Cernadas *et al*., 2005). It is also used to detect changes in the color of chocolate (Briones & Aguilera, 2005).

Although there are many studies that have applied CVAS to inspect the quality of agricultural and food products, as mentioned in the previous paragraph, most research focuses on applications to main products, especially meat and fruit. There are some applications for inspecting the quality of fresh vegetables, but not many because fresh vegetables are products with a short shelf life. Most fresh vegetables are consumed within the country. But at present, the popularity of ready-to-eat processed fresh vegetables in the form of salad tends to increase, leading to the emergence of a salad vegetable production and export industry. (Volkava & Mickiewicz, 2022; Stratton *et al*., 2021). For example, lettuce (*Lactuca sativa L.*) has an annual production value of $3.5 billion in the United States (U.S. Department of Agriculture, 2020), with 24.7lb of lettuce consumed per capita (U.S. Department of Agriculture, 2019). However, it was discovered from the study that the industry's quality control of salad vegetable products, particularly the inspection of human visual quality, such as the quality of color and freshness of vegetables, Currently, quality inspections are still conducted using human labor, which has revealed that there are delays and frequent faults in the operation. Although the use of human labor is problematic, as was already mentioned, there is still a need for human labor in the industrial to inspect quality because there are currently insufficient tools for quality inspection, particularly tools for human vision, a quality characteristic that is directly related to the decision to consume salad vegetable products. For this reason, the author came up with the idea of applying CVAS to inspect the quality of salad vegetables because CVAS can help reduce human labor operations.

This article demonstrates the development of an algorithm for image processing to identify areas with an irregularity in the quality of salad vegetables. The research covers experiments to identify indicators of outstanding irregularity in salad vegetables that can be analyzed using image processing methods. Including the development of an algorithm for analyzing areas of browning in salad vegetables to be accurate in identifying irregularity similar to human identification. The results can be used as a basic guideline for further development and application of the CVAS for commercial salad vegetable quality inspection.

2. Materials and methods

2.1 Sample preparation

Fresh Green Oak were purchased in the morning from a local market, then washed, shredded, centrifuged in a salad spinner for 1 minute to remove excess water, containerized and stored at 5°C, 10°C and 15°C.

2.2 Image acquisition system

The image acquisition system consists of a wood box whose internal walls were painted white to avoid the light and reflection of the room, two fluorescent lights using for illumination (Philips, natural daylight, 18W, length 30 cm, color temperature of 6500 K). The lamps were arranged 30 cm above the samples, at an angle of 45°to the sample plane to give a uniform light intensity over the samples. A digital camera (Nikon D7200) was used for capturing images. The camera was in a vertical position at 25 cm from the samples and at an angle of 45° from the light source. The image was captured at a resolution of 1200×900 pixels, stored in the RGB color model and JPEG format. The images were captured every 24 h for 8 days.

2.3 Developing an image processing program to analyze the overall color changes of salad

The program developed under this research is a program used to analyze irregularities in salad vegetables by analyzing the color obtained from image. The program developed under this research uses C#.Net as the programming language and SharpDevelop version 5.1 as a development tool. The user interface of the program is shown in (Figure 1).

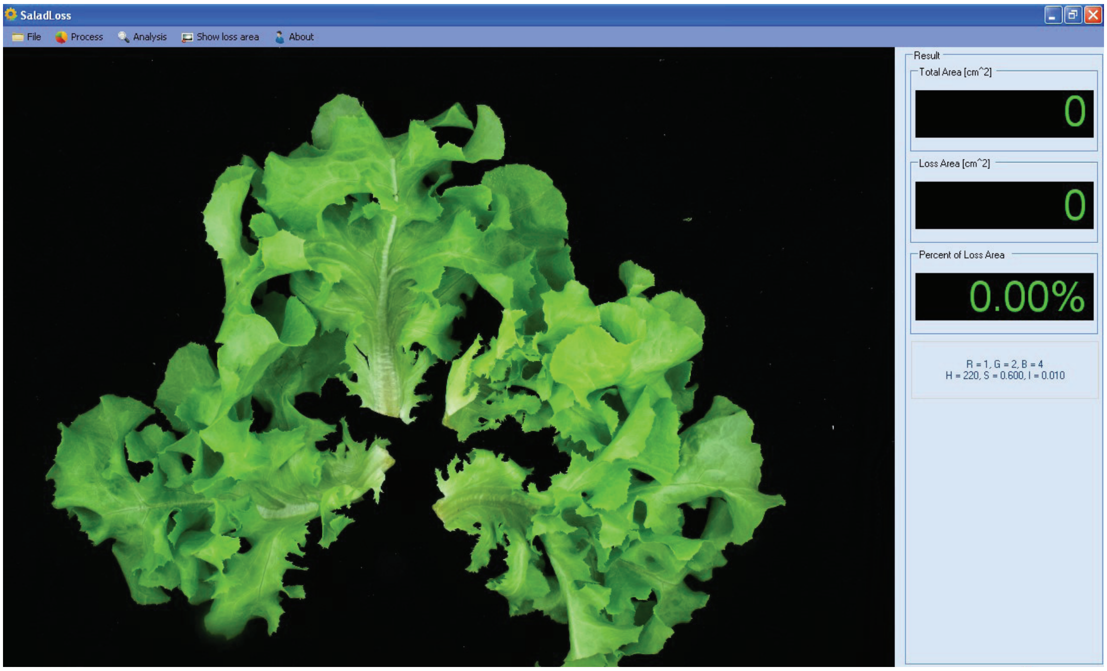


Figure 1. User interface of the program

2.4 Color analysis

Color analysis was performed by converting images of both regular and irregular quality salad vegetables stored in RGB color space to HSI color space according to Equations 1 to 4. Then, the tester trained learn and memorize the outstanding characteristics of salad vegetables until you can distinguish such irregularities from other characteristics of salad vegetables. Sorting and recording the color values of salad vegetables that are of regular quality and those of irregular quality in order to use the color values. The results will be used as an index indicating irregularities in the overall color quality of salad vegetables.

$$\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}\left[(R-G)+(R-B)\right]}{\left[(R-B)^2+(R-B)+(G-B)\right]^{\frac{1}{2}}} \right\} \quad (1)$$

$$H = \begin{cases} \theta & \text{if } B \le G \\ 360-\theta & \text{if } B > G \end{cases} \quad (2)$$

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

$$I = \frac{1}{3}(R+G+B) \quad (4)$$

where the value is the minimum value when comparing the values of R, G, and B.

2.5 Analysis of changes in the overall color value of salad vegetables

Analysis of changes in the overall color value of salad vegetables was done by counting the number of pixels in both regular quality and irregular quality salad images. Then use the obtained values to find the area and calculate the percentage of irregularities in the quality of the salad vegetables.

Calculating the area of the salad vegetables that appear in the image is done by finding the standard value of the number of pixels per average area by counting the number of pixels. This value can be obtained by photographing geometric shapes with a known exact area in the same conditions as photographing salad vegetables. The geometric shapes used in this research are square, rectangular, triangle and circular shape respectively. Then count the number of pixels of each shape. Divide the number of counted pixels by the actual area of the shape to get a standard value for the average number of pixels per area. This value will be used to find the area of the salad that appears in the image.

2.6 Verifying the correctness of the program

Verification of the correctness of the program is done using geometric shapes whose exact area is known in the test. The program calculates the area of the geometric shapes which consist of square, rectangular, triangles and circular shape respectively. Compare the calculation results from the program with the actual area of the shape that was tested for 5 repetitions.

3. Results and discussion

3.1 Analysis of the overall color index of salad vegetables

The results of the analysis of the overall color index of Green Oak salad are divided into two parts: The overall color value of salad vegetables with regular quality and the overall color of salad vegetables irregular quality. The results are shown in (Table 1). The values are similar to the research of Zhou *et al*. (2004), which found that the H value indicating browning of lettuce was between 35 - 50 degrees.

Table 1. Range of H^{o} values for salad vegetables with normal overall color quality and abnormal overall color quality.

Quality characteristics	Range of H values (degrees)
Regular	80 - 135
Irregular	35 - 79

3.2 Results of determining the average number of pixels per average area

The average value of the standard value of pixels per average area calculated using different shapes was 1425 pixels per square centimeter. This value will be used to compute the area of the salad in the image.

3.3 The results of testing the accuracy of the area calculation appear in the image of the image processing program

The development program was validated using images of different geometric shapes. All test results are summarized in (Table 2). According to the test results, the developed program can calculate the area of a given color with high accuracy. However, there were still errors in the calculations. The error values that occur from the program's calculations are caused by lights and shadows around the edges of objects that are not defined by color. This result indicates that the developed program can be used to calculate the abnormal area of salad vegetables by using the color value as an indicator, as evidenced by the very low percentage error (average ±2.98%) shown in (Table 2).

Table 2. Comparison of the results of calculating the geometric area using the developed program with the actual area

Geometric shapes	Actual space (cm^2)	Area calculated from the program (cm^2)	% Error
Square	100.00	96.77	3.23
Square	100.00	99.23	0.77
Square	100.00	97.16	2.84
Square	100.00	98.06	1.94
Square	100.00	100.43	0.43
Rectangle	50.00	48.11	3.78
Rectangle	50.00	47.67	4.66
Rectangle	50.00	47.66	4.68
Rectangle	50.00	48.95	2.10
Rectangle	50.00	49.23	1.54
Circle	78.54	77.14	1.78
Circle	78.54	76.89	2.10
Circle	78.54	77.67	1.11
Circle	78.54	78.27	0.34
Circle	78.54	75.12	4.35
Triangle	25.00	25.23	0.92
Triangle	25.00	26.34	5.36
Triangle	25.00	23.11	7.56
Triangle	25.00	26.09	4.36
Triangle	25.00	26.45	5.80
		Average	**±2.98**

3.4 Analysis of overall color changes of salad vegetables

The variation in the overall color of the salad vegetables is a test of the developed program's ability to analyze and calculate the color values found in the salad vegetable images. (Figure 2) shows the algorithm for analyzing overall color change. (Figure 3) shows the results of the overall color change analysis of Green Oak salad. The results indicate that storage temperature has a significant effect on the rate of quality deterioration. After only 2 days of storage at 15°C, the quality began to deteriorate clearly, with a percentage of the overall area of color change in the irregular quality area equal to 1.61 percent. Meanwhile, vegetables stored at 5°C and 10°C showed no change in color quality, as shown in (Table 3).

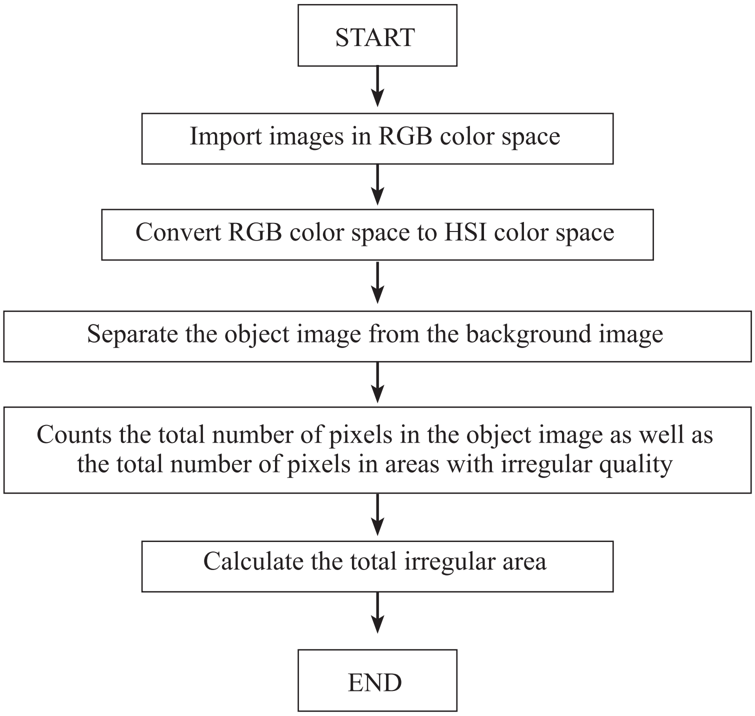


Figure 2. Algorithm for calculating the overall color of salad vegetables irregular quality

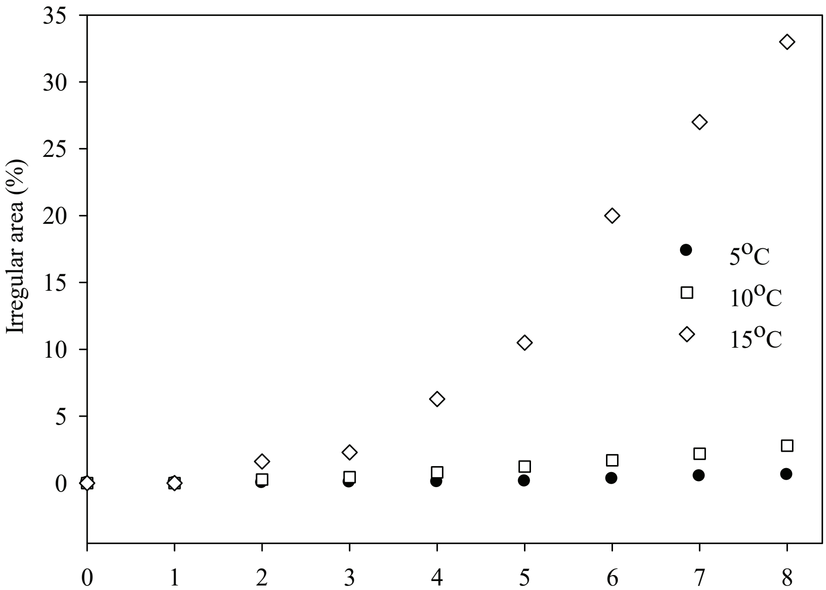
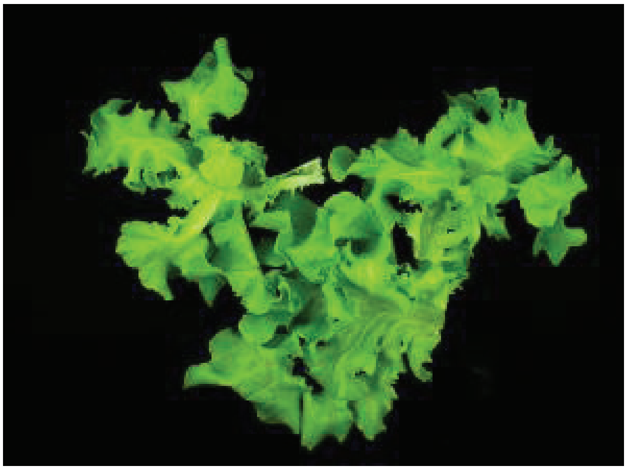
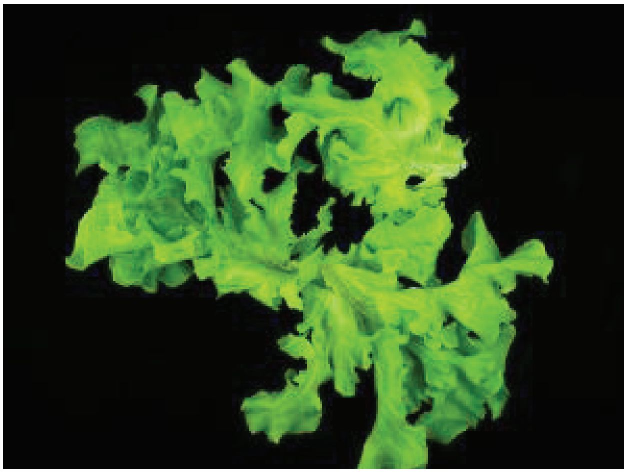
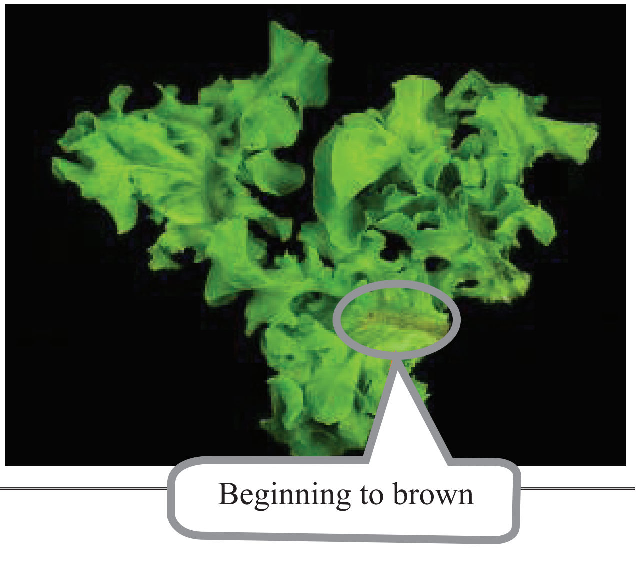


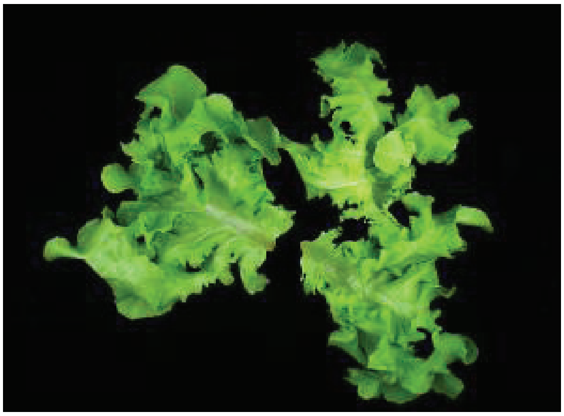
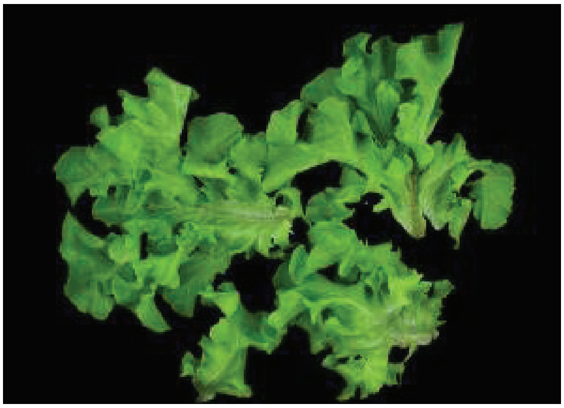
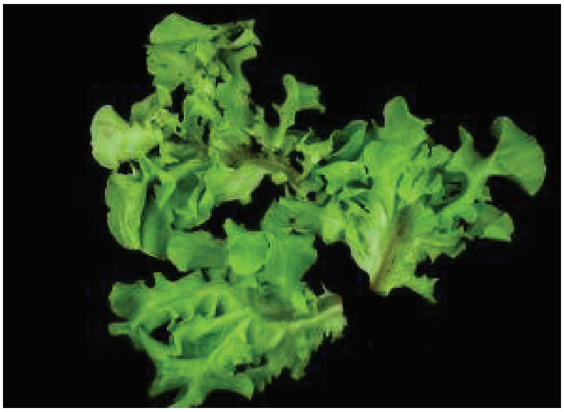
Figure 3. The percentage of total color change area and shelf life at 5°C, 10°C and 15°C, respectively

Table 3. Overall color change of green oat salad vegetables with a shelf life of 2 days at temperatures of 5°C, 10°C and 15°C.

Shelf life is 2 days	Overall color change of Green Oak salad greens
5°C	
10°C	
15°C	

According to (Table 3), the Green Oak salad began to noticeably change in overall color at the storage temperature of 15°C, and when the shelf life reached 3 days, the Green Oak salad at the temperature stored at 15°C had severe quality deterioration, while salad vegetables stored at 5°C and 10°C also began to notice overall color changes, as shown in (Table 4).

Table 4. Overall color change of green oat salad vegetables with a shelf life of 3 days at temperatures of 5°C, 10°C and 15°C.

Shelf life is 3 days	Overall color change of Green Oak salad greens
5°C	
10°C	
15°C	

(Table 4) shows that Green Oak salad stored at 15°C had browning on the leaf petioles and obvious bruising in the leaf areas. The browning of the leaf stalks in Green Oak salad stored at 10°C was found to be more pronounced than in vegetables stored for two days. Browning began to occur on the leaf stalks at 5°C as well, but the appearance was not as pronounced as that of Green Oak salad stored at 10°C and 15°C. When stored further, it was found that Green Oak salad stored at 15°C exhibits severe deterioration in quality or change in overall color. However, green oak salad vegetables stored at 5°C and 10°C showed that the overall color change was not much from the original, as shown in (Table 5).

According to the results in (Table 5), it was found that green oak salad stored at 15°C had severe quality deterioration, such as pronounced browning in the leaf petioles. Including severe bruising around the leaves, etc., when considering the percentage of the overall color change area analyzed from the developed image processing program, it was found to be equal to 6.29 percent, which is similar to existing research reports. It has been previously stated that consumers will not purchase vegetables whose overall color quality has deteriorated by more than 9 percent (Zhou *et al*., 2004). For Green Oak salad stored at 5°C and 10°C, it was found that there were noticeable changes in overall color, such as the brown color of the leaf stalks becoming more intense, etc. Then they were stored. It was further found that at a storage temperature of 15°C, the Green Oak salad had a very severe quality deterioration. Salad vegetables are bruised and rotten in the leaf area. Including the brown color around the leaf stalks has spread more widely. When the images were analyzed with the developed image processing program, it was found that the percentage of the overall color change area was equal to 10.5 percent, consistent with the research of Zhou *et al*. (2004) that previously stated that consumers will not purchase vegetables that have deteriorated in overall color quality by more than 9 percent. The results show that the overall color change analysis algorithm developed in this research can be used to examine the overall color change of Green Oak salad vegetables.

Table 5. Overall color change of green oat salad vegetables with a shelf life of 4 days at temperatures of 5°C, 10°C and 15°C.

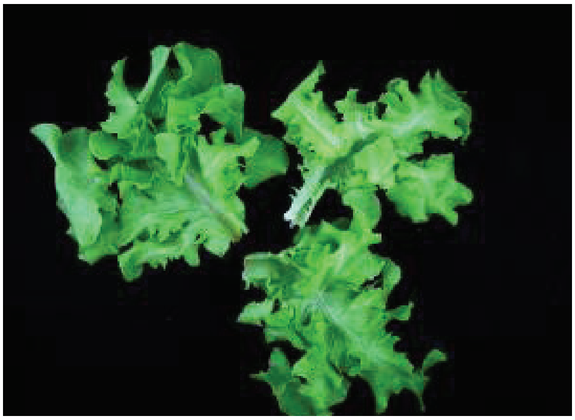
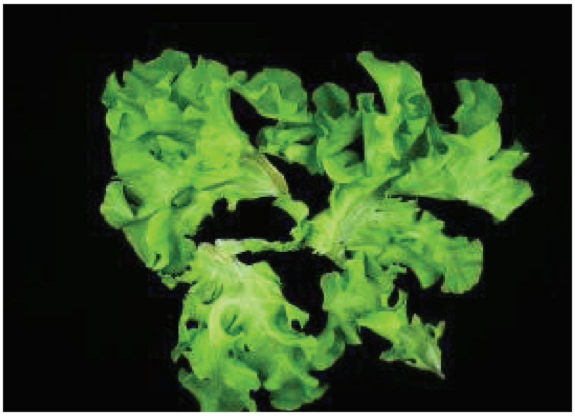
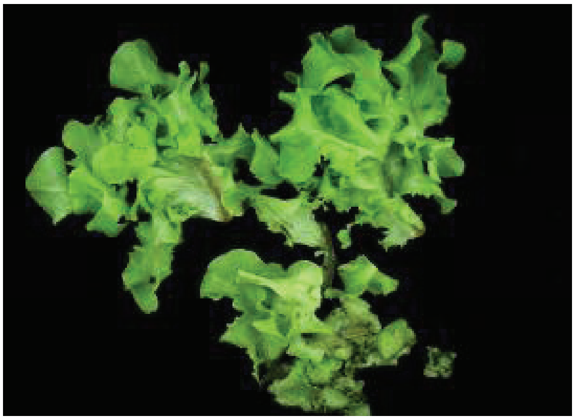
Shelf life is 4 days	**Overall color change of Green Oak salad greens**
5°C	

Table 5. Overall color change of green oat salad vegetables with a shelf life of 4 days at temperatures of 5°C, 10°C and 15°C. (cont.)

Shelf life is 4 days	Overall color change of Green Oak salad greens
10°C	
15°C	

4. Conclusion

The objective of this project is to develop an image processing algorithm to analyze the overall color change of salad vegetables. The findings of this study can be summarized as follows. The image acquisition system consists of two lamps that were positioned 30 cm above the samples, at an angle of 45° to the sample plane to provide a uniform light intensity over the samples. An examination of the amount of brown color in salad vegetables. The method begins by importing an RGB image of salad vegetables, then converting the color space from RGB to HIS color space, and finally using the H value as an index indicating the amount of brown color in salad vegetables. It was discovered that for salad vegetables of regular quality, the H value would be in the 80° - 135° range, indicating both light and dark green color. Salad vegetables with irregular quality will have a H value in the 35° - 79° range, which indicates browning in salad vegetables. According to the results of the analysis, it is considered salad vegetables if the amount of brown area is greater than 9% of the total area of all salad vegetables. Green Oak salad vegetables are irregular quality, exceeding acceptable limits.

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