

Mechanical Damage Detection of Indonesia Local Citrus Based on Fluorescence Imaging

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Abstract. Citrus experienced physical damage in peel will produce essential oils that contain polymethoxylated flavone. Polymethoxylated flavone is fluorescence substance; thus can be detected by fluorescence imaging. This study aims to study the fluorescence spectra characteristic and to determine the damage region in citrus peel based on fluorescence image. Pulung citrus from Batu district, East Java, as a famous citrus production area in Indonesia, was used in the experiment. It was observed that the image processing could detect the mechanical damage region. Fluorescence imaging can be used to classify the citrus into two categories, sound and defect citruses.

1. Introduction

Indonesia has more than 19 varieties of citrus concentrated in some islands [1], and one superior variety is a Keprok Pulung citrus, which is famous in the country. However, the citrus is subject to damage during handling and transportation. The damaged fruit should be separated as soon as possible to prevent spreading rotten started from the damaged ones. Until now, sorting method of the damaged fruit is manually conducted which is difficult especially at the early stage of damage.

In Indonesia, research on substances flavonoids in citrus peels is benefited to pharmaceutical, with a target of the drug product for anti-proliferative in cancer cells [2]. Until recently, there has been no research on the utilization technology of fluorescence spectroscopy in the field of agricultural engineering in Indonesia. Fluorescence detection method can be applied to detect damaged fruit because the essential oil in citrus peel contains polymethoxylated flavonoid, which is known as a glowing substance under UV light. Recent studies have identified the fluorescence substances in Mandarin [3], and conducted an investigation of wave excitation for fluorescence emission from orange peel that is exposed to UV light [4]. From this research it has been known to fluorescence wavelengths of 15 varieties of oranges grown in Japan are the 300-700 nm. Furthermore, spectra data was used to support the development of machine vision to detect the damage of fruit. Hyperspectral imaging could be used to detect the bruise in apple [5], hyperspectral imaging used for safety inspection of food and agricultural products [6][7]. The study used machine vision to detect the damage of citrus fruit [8][9]. Another research studied the pattern of fluorescence associated with citrus peel defects and had separated the citrus defect in some categories [10].



Fluorescence wavelength is derived from the substance available in citrus peel. Therefore, fluorescence spectroscopy characteristic of the essential oil in citrus peel provide information for the proper lamp used to excite the citrus. The fluorescence image is collected by image acquisition system. The mechanical damage in citrus peel detects from the fluorescence imaging. This study aims to study the fluorescence characteristic of Indonesia local citrus. This study will develop the image acquisition system with proper light to get the fluorescence image. Furthermore, the fluorescence characteristic and the image acquisition system can be used to develop a non-destructive evaluation system for damaged citrus at the early stage which is unseen to human eyes.

2. Materials and methods

2.1. Sample preparation

This experiment used Keprok Pulung citrus (a citrus variety grown in Batu District, East Java Province) as a representative of Indonesian citrus (figure 1). Three groups of samples were prepared, a sound group and two defect groups of scratched fruits caused by swapping rough surface sandpaper (No. 100) and bruised fruits caused by pressing the citrus with rheometer in 19,61 N. The three groups of samples then stored in a room with air conditioning set to 25°C.

Some peel was taken from the sample for extraction. Procedure to prepare peel extract is as follows; citrus peel by weight of 3.1 g was mashed and mixed with 10 mL of pure n-hexane for spectroscopy as a solvent. The extract was stirred and kept for one night at the same temperature as the fruit stored. Citrus peel extract was later used for data retrieval using fluorescence spectrophotometer for absorption, excitation, and fluorescence wavelength observation. Citrus peel extract was placed in quartz cell, and spectra were measured. First, the absorbance spectra were recorded. From spectra curve, peak of absorbance spectra were taken as excitation wavelength for measuring itself. After determining the best excitation wavelength, the fluorescence spectra were measured. Absorbance spectra were recorded on a UV-Vis Spectrophotometer (Ocean Optics, USA). Fluorescence spectra were recorded with USB Fluorescence spectrophotometer (Ocean Optics, USA). Excitation light for spectra analysis was provided by UVGL-58 UV lamp with wavelength at 365 nm.

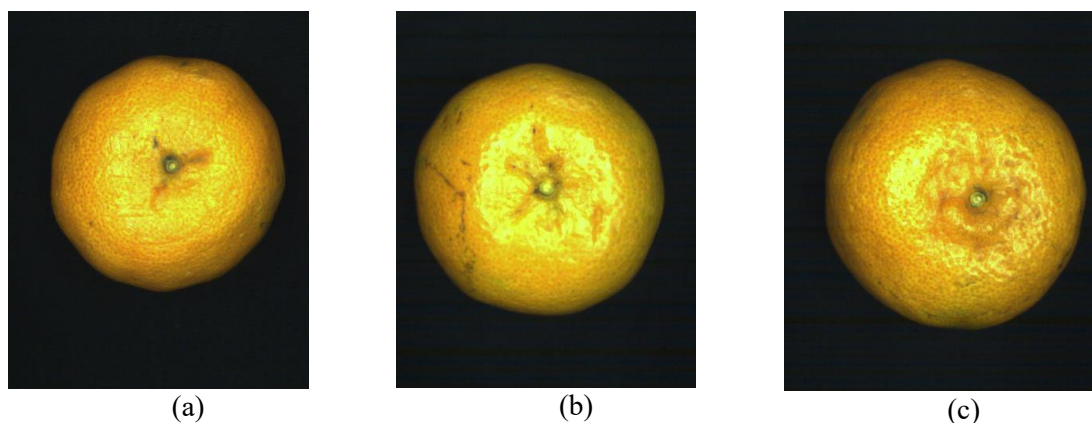


Figure 1. Keprok Pulung Citrus after treatment; (a) sound, (b) scratched, (c) bruised

2.2. Fluorescence image acquisition

Fluorescence images were captured by an image acquisition system that consisted of 4 UV lamps (Sankyo Denky) 15 watt for illuminating the sample with 352 nm and VGA camera (The Image Source) with resolution 744 x 480 pixel. Segmentation process was done to recognize the damage region in citrus. The image acquisition system captured image in red, green, blue (RGB) image. RGB image was less suitable for object recognition. The RGB image was transformed to hue saturation intensity (HSI) image. HSI combined information both color and grayscale of an image. Hue indicated the type of color

or the color pattern where the color was found in the color spectra. It was easier to identify objects with different hue, by giving grey level in hue image. The image processing was conducted by using software Matlab R2013a. The damage region in citrus peel was determined by image processing program. The RGB image was transformed into HSI image. Then segmenting the hue image for a grey level between 150 and 160. The image processing shows in figure 2.

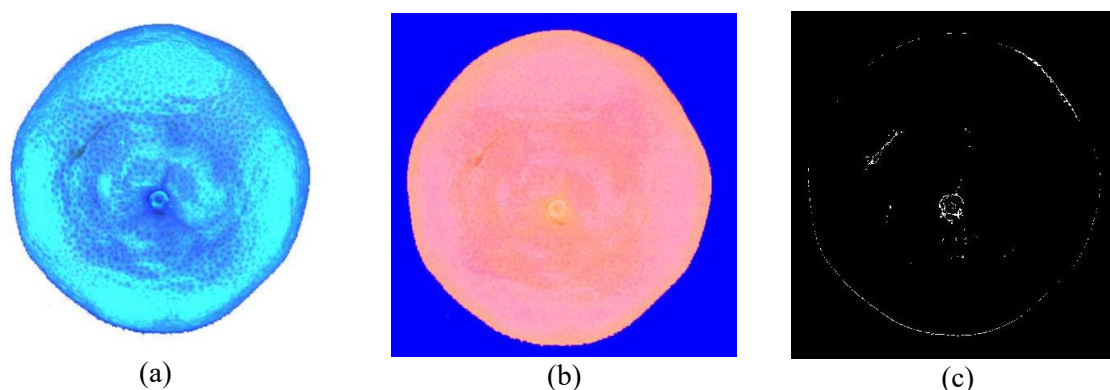


Figure 2. Image Processing ; (a) RGB image, (b) HSI image, (c) segmentation the damage region

3. Results and discussion

3.1. Characteristic of absorbance and fluorescence spectroscopy from Indonesia citrus.

Two dominant peaks were found in the absorbance of the citrus fruit (figure 3). The primary peak appeared at 330 nm to 350 nm. Another peak appeared at 420 nm to 450 nm. It means that there are two substances contain in citrus peel extract. The first peak increased from 310 nm to 330 nm and decreased gradually until 380 nm. The previous study identified that heptamethoxy flavone was one of the major fluorescence substances in rotten citrus fruits and the excitation and fluorescent wavelengths of one of the substances were between 360 nm to 370 nm and between 530 nm to 550 nm, respectively [3]. This information used to select the proper lamp to excite the sample. In this study, the lamp to excite the sample was 365 nm. It was reported that the excitation wavelength of 365 nm provided better fluorescence spectra of eight varieties japanese citrus [11].

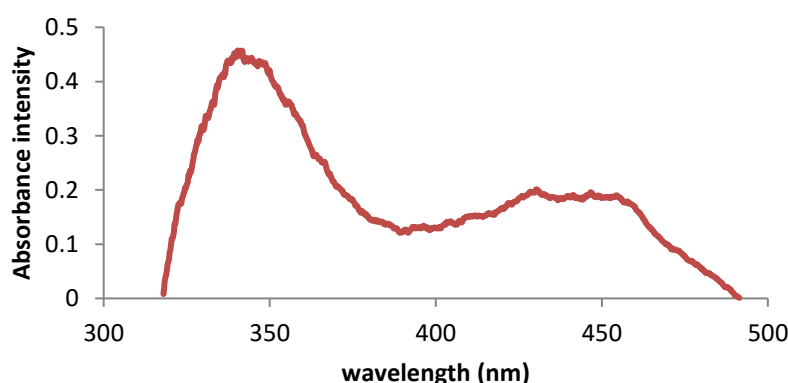


Figure 3. Absorbance spectra

Figure 4 shows the fluorescence spectra of citrus peel extract. The first peak appeared in 500 nm to 520 nm and second was in 740 nm to 750 nm. Mandarin citrus has fluorescence substance that was excited with light from 320 nm to 390 nm and emits the fluorescence of 520 to 570 nm [3]. The fluorescence substance in Mandarin citrus was polyethoxylated flavone. From this literature, the

fluorescence substance from Indonesia citrus supposed to be the same as the mandarin citrus. The first peak at 500 nm to 520 nm should be polymethoxylated flavone. Polymethoxylated flavone could dissolve in n-hexane. This substance will release in the citrus peel when citrus got damage. From this study, the fluorescence method can be applied to be damage detection method of Indonesia citrus.

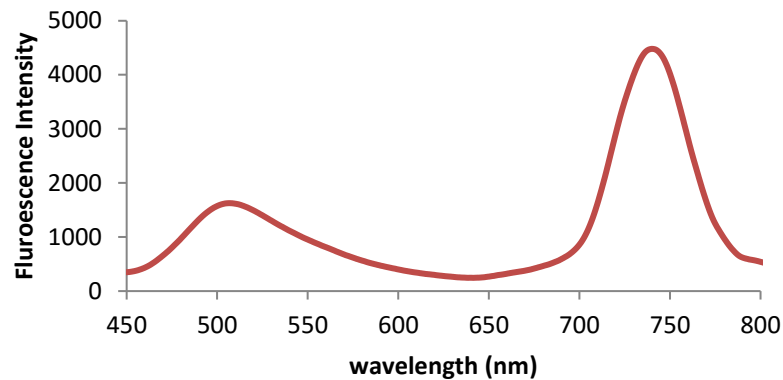


Figure 4. Fluorescence spectra

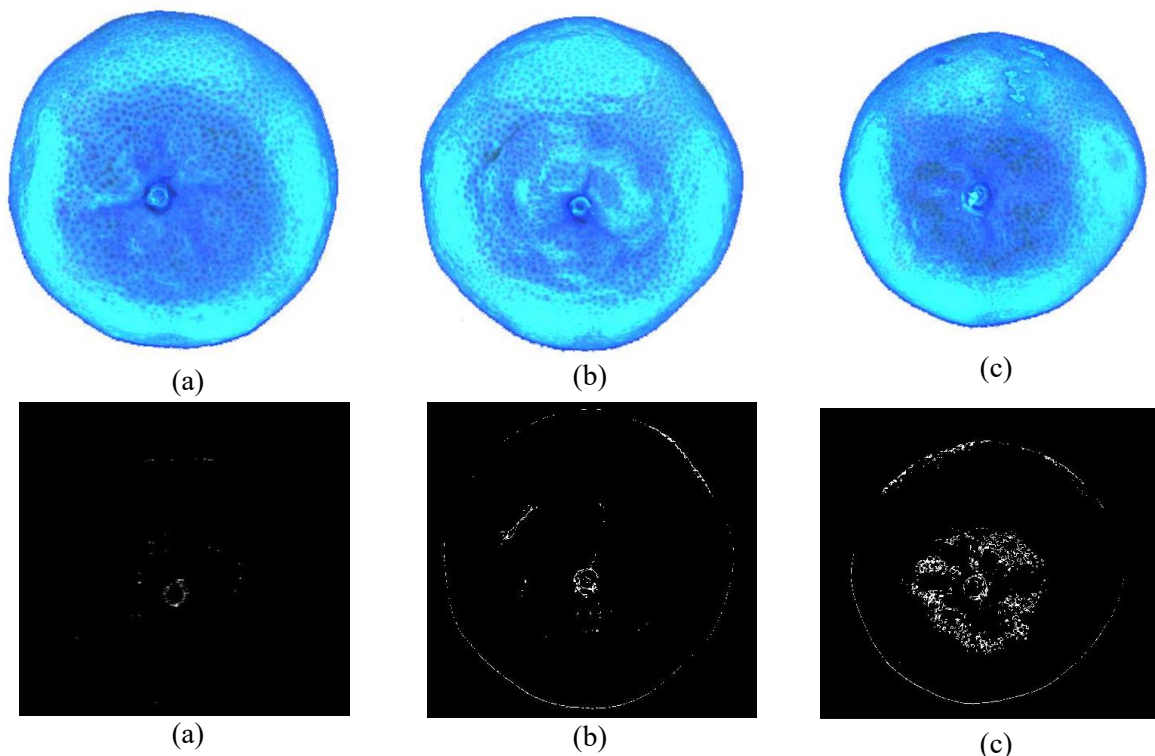


Figure 5. Fluorescence images on the top and process images on the bottom; (a) sound, (b) scratched, (c) bruised

3.2. Fluorescence image processing

Mechanical damage in citrus peel was marked by fluorescence substance that glows under UV light excitation. Based on fluorescence spectra data, the fluorescence wavelength was 500 nm to 520 nm when excited by 365 nm. The fluorescence wavelength was longer than the UV light wavelength. There was the different color region between the sound part and damaged part in citrus peel. Figure 5 shows

the image processing program detected the damage region in citrus peel. White spot associated with the mechanical damage in citrus peel.

Damaged regions in citrus peel had low contrast compare to sound peel. Green color emits because of 352 nm UV light excitation with high intensity could be observed from fluorescence image with low intensity dim. Blue color emits from 352 nm UV light with high intensity effected the green color from fluorescence image with low intensity dim. Figure 6 shows the citrus that marked with green dots as damage region by the program. The region inside black line was the artificial damage region. The image processing program cannot detect the region of the damage peel accurately. Figure 6a should be clear of green dots. But image processing program detected the stem part of citrus as the damage region. The stem part was detected as the damage region for each treatment. The percentage of damage part counted higher because the stem part was recognized as the damage region. Needs to improve the image processing program to separate the stem part from the damage region.

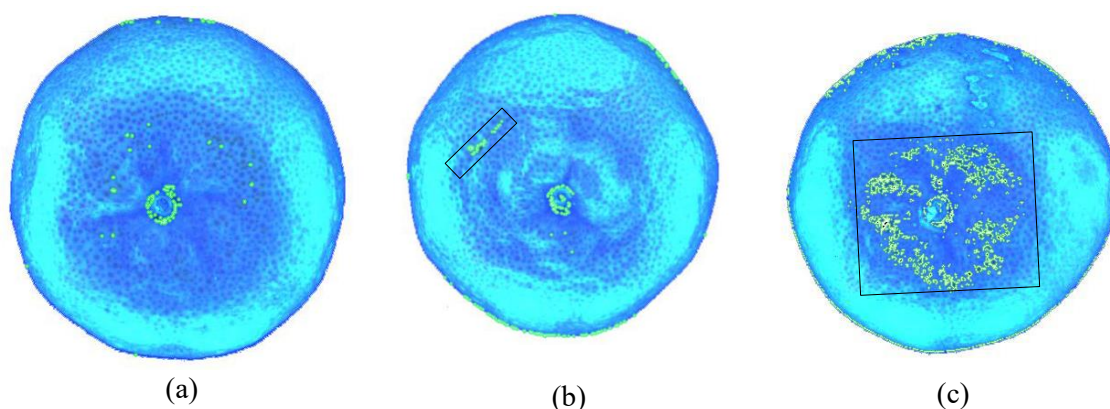


Figure 6. Fluorescence images of citrus marked with damage region for each treatment; (a) sound, (b) scratched, (c) bruised

4. Conclusions

Fluorescence substance in Keprok Pulung citrus has fluorescence wavelength in 500 nm until 520 nm when excited with 365 nm. Fluorescence substance produced by mechanical damage in Keprok Pulung citrus peel can be detected using fluorescence imaging based on machine vision system. The image acquisition set up can detect artificial mechanical damage such as scratched and bruised damage in Keprok Pulung citrus, but recognized the stem part as the damaged region. It requires to develop a better image acquisition system and to improve the image processing program.

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