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Preliminary Study on Detection of Fungal Infection in Stored Paddy Using Thermal Image

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Abstract. Paddy plantation is still threatened by many factors that make rice production become less productive. One of the main factors is paddy infected with fungal. Mycotoxins are toxic substances produced by fungi that grow on seeds or grains in storage and usually will harm human health and animal. Thermal imaging technique is a potential method for the remote detection of abnormality in agricultural products based on temperature changes. In this research, the thermal images of fungal infected paddy were obtained using mid infrared thermal camera after heating for 180s and then cooling in ambient temperature for 30s. Average pixel of the image was used as feature to determine the moisture content. Based on the experiment, fungal infected paddy gave higher average pixel values compared with non-fungal paddy.

Keywords: mycotoxins, image analysis, heat, respiration.

1. Introduction

Paddy is one of the most important commercial crops planted in Malaysia for domestic consumption and continues to be an important source of food in Malaysia. It is a rich source of dietary energy and a good source of amino acids. However, paddy plantation is still threatened by many factors that make rice production become slow and less productive. One of the main factors is paddy infected with fungal. Moisture content is known to be the primary contributing factor in determining the kinds of fungi that invade stored paddy and the degree to which they invade it [1]. The stored paddy at 15.5% until 18.33% of moisture content showed higher fungal infection [2]-[4]. In addition, it also has been reported that high percentages of fungal were observed in cereal seeds, corn and rice at high moisture content levels [2], [3] and [5]. Fungal infection gives effects to paddy production like paddy grain discoloration, odor, toxin contamination and loss in viability will decrease the quality and also market values of paddy grains. These outcomes will make the paddy grain become unfit for human consumption.

Agar plate method was generally used to detect the fungal infection in stored cereal grains [6] and [7]. This method was used to determine relative amount of various fungal species present in a grain mass and was used to measure only certain types of fungi and require a long incubation period up to seven days. High Performance Chromatography (HLPC) method was used to detect fungal growth in grains by measuring the glucosamine level which differs among the fungal species [8]. To detect the extent of fungal invasion of kernel starch, discolored kernels were inspected by scanning electron microscopy (SEM) [9]. Bunches of spherical spores within the cellular boundaries of the black colored rice kernel were observed under SEM. However, the characteristic of the fungal contaminant was not clearly distinguished. Reddy et al. [10] had conducted a research on fungi detection on stored rice paddy during one year of storage from 2008 to 2009. It was stated that different type of fungal will occur with different time. An increase in storage time was conducive for fungal proliferation. Rapid detection of fungi is not possible because all these methods need a long observation time. Therefore, there is a need to develop a technique for rapid detection.

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Thermal imaging is a non-destructive and non-contact infrared sensing technique that record and convert the intensity of radiation pattern of electromagnetic spectrum of an object into a visible image called thermal image [11]. Thermal image allow us to see variations in temperature as the amount of radiation emitted by an object usually increases with temperature. Thermal infrared region is very useful in imaging application that use temperature or heat measurements [12]. Study on thermal imaging for detecting fungal infection in stored wheat [13] has been reported that thermal imaging could be a promising machine vision technique to detect fungal infection in stored wheat. In this paper, thermal imaging technique has been used to identify non-fungal and fungal infected paddy in the storage.

2. Materials and Methods

2.1. Paddy Sample Preparation

In this study, the MR219 paddy grains were collected from commercial rice mills situated in Selangor, Malaysia. To avoid sampling error due to the highly heterogeneous nature of fungal distribution, samples were collected at the same time from one rice mill only. A total of 3kg healthy whole grains paddy were collected from silo storage. The samples were brought to the laboratory and were soaked for 24 hours to ensure the water is equally distributed so that constant moisture content can be gathered. Then, the soaked paddy were filtered and wiped using cloth to remove excess water and were conditioned by drying in oven to get the required moisture content before imaging. Moisture content of paddy was measured using G-7 Grain Moisture Meter. Five samples (25g each) of fungal infected paddy with 17%-19% moisture content and five samples (25g each) of non-infected paddy with 17%-19% moisture content were prepared for imaging with thermal camera.

2.2. Image Acquisition

The instrumental setup is shown in Fig. 1. A FLIR E60 was used in the experiment. It was fixed at a height of 40cm above the paddy sample on a tripod. Ten samples with 25g each (five samples of fungal infected paddy and five samples of non-infected paddy with 17%-19% moisture content) were taken and spread in a round container. Two lamps with 240V power supply, 50Hz frequency and 42W power were used to heat the samples. These lamps were placed 10mm above the sample. Paddy samples were heated for 180s and then cooled for 30s.

Three thermal images were taken for each sample:

- Paddy sample before heating (0s).
- Paddy sample after heating for 180s.
- Paddy sample after cooling for 30s.

Fig. 1: Instrumental setup.

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2.3. Image Analysis

The ‘regionprop’ function in Matlab software was used to measure properties of the paddy image. The ‘MeanIntensity’ has been selected as properties to represent the value of moisture content. The output is the average intensity of the paddy image.

3. Results and Discussion

The thermal images captured at 0s (before heating), 180s (during heating) and 210s (30s after cooling) are shown in Fig. 2. From this figure, it is clearly seen that the color of thermal images changes from time to time during heating and after cooling process. The images of sample before heating are darker compared to the images after heating.

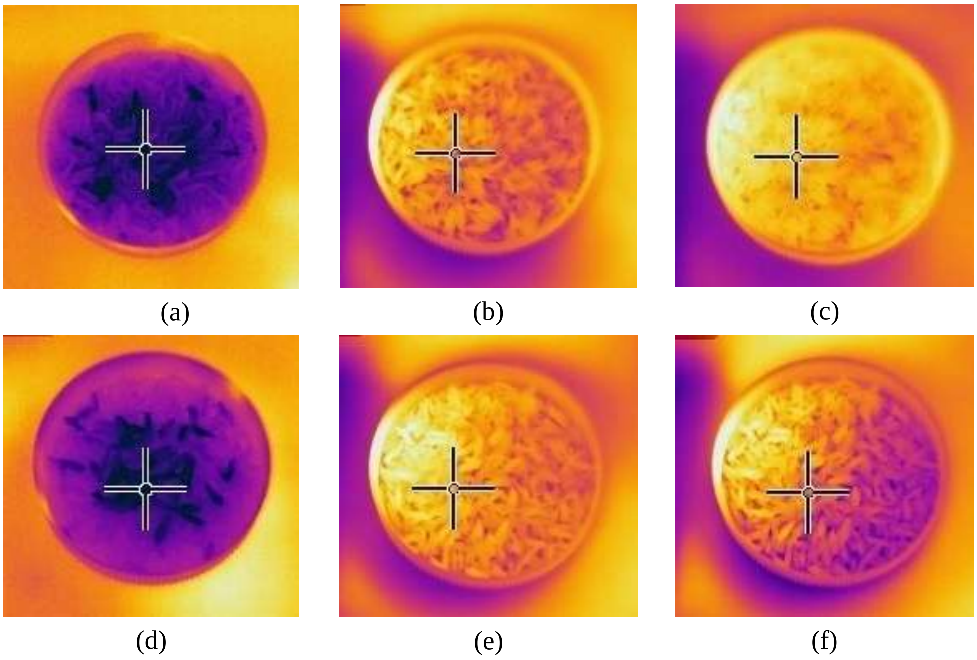

Fig. 2: Example of the thermal image of non-fungal samples at (a) 0s, (b) 180s, (c) 210s and fungal samples at (d) 0s, (e) 180s, (f) 210s.

Table 1. Average pixel values of the non-fungal and fungal infected paddy

Band	Time frame (second)	Average pixel (non-fungal)	Average pixel (fungal)
Thermal	0	41.59	62.78
	180	147.07	161.38
	210	165.65	176.11
RGB	0	181.61	182.32
	180	182.49	176.63
	210	182.69	183.48

Table 1 shows the average pixel of non-fungal and fungal infected paddy in thermal and RGB images. Based on this table, it can be seen that the thermal image gave greater difference of pixel values in different time interval as compared to RGB. Furthermore, it also gave higher difference between fungal and non-fungal infected paddy.

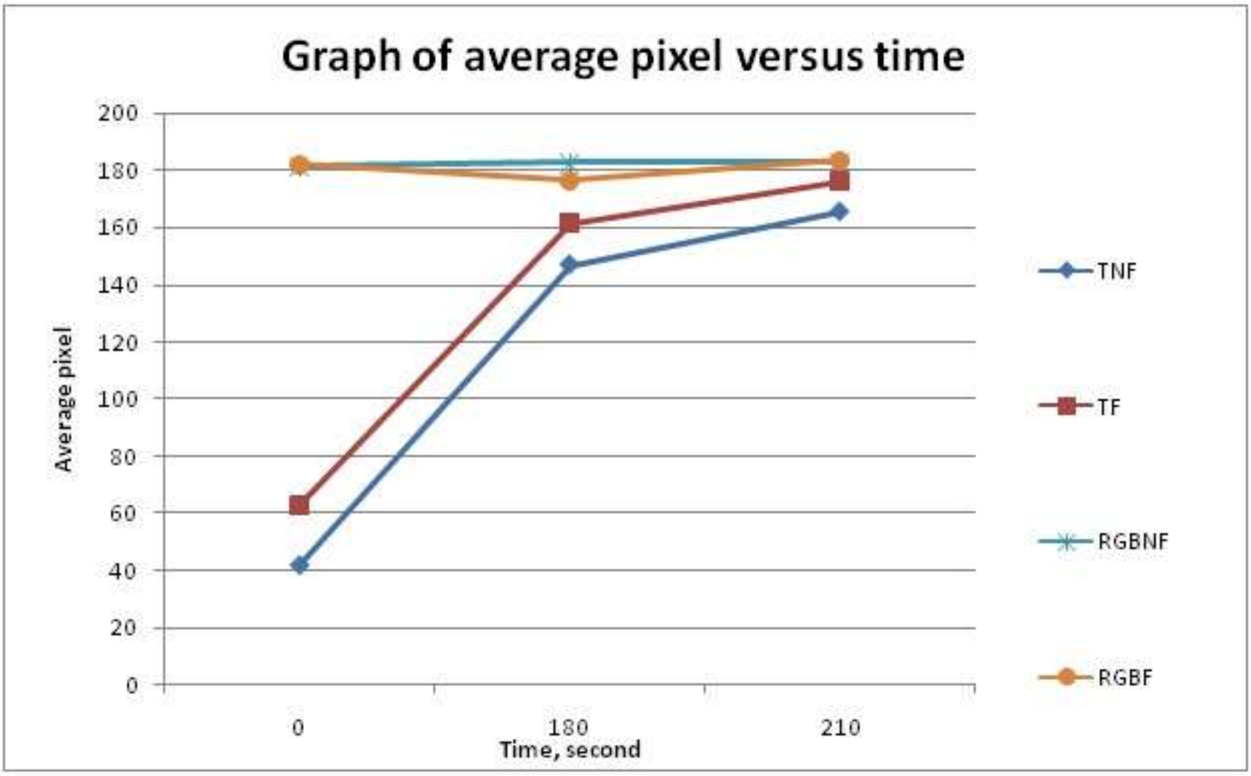

Fig. 3: Graph of average pixel versus time.

Fig. 3 shows trend of the average pixel versus time during 180 seconds heating and 30 seconds cooling, where TNF = thermal image of non-fungal, TF = thermal image of fungal, RGBNF = RGB image of non-fungal and RGBF = RGB image of fungal. From this figure, it is shown that the average pixel is increasing with time in RGBNF, TF and RGBF. Thermal image shows a clear trend of changes, where the average pixel of fungus infected paddy has higher mean pixel value than non-fungus paddy in all conditions. This condition happened because the occurrence of the fungus which caused more heat due to the respiration process. Therefore, the rate of respiration becomes rapid with the expense of chemical constituents. Respiration is the process of oxidizing carbohydrates and producing carbon dioxide and water vapor as well as energy. Respiration was greatly affected by moisture content and temperature. When the respiration increased, the amount of heat will also increase. Moreover, deteriorating grain generates 10.9 times the heat required to evaporate the water generated [14]. When the paddy temperature increased, the average pixel value will be higher. After 30 seconds of cooling, the fungus infected paddy took longer time to lost heat to environment due to high heat produced because of evaporation and transpiration by fungus and paddy during heating. As compared to the RGB image, the thermal images gave higher rate of changes during heating and cooling process. Since paddy and fungal provide some respiration which produced some heat, therefore the changes can be detected using thermal image. It cannot be done by RGB image.

4. Conclusion

In a nutshell, based on the average pixel graph against the time, the characteristic of fungal infection in stored paddy can be determined by using thermal image. The graph shows that there is significant difference between moisture content to mean average pixel for healthy paddy and fungal infected paddy. It would be useful to be used for monitoring fungal infection inside the silo storage which allows on time detection as compared to the current practice which is done based on the scheduled fogging time (once in three months).

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