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Paddy grading using thermal imaging technology

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Abstract

Rice production depends on good quality of paddy. In this research, the capability of thermal imaging to determine the quality of paddy based on the properties used in a Deduction Schedule namely moisture content, immature condition and foreign material is presented. First, the heating and cooling treatment was applied to the samples. FLIR E60 thermal camera was used to acquire images of the sample. Therefore, each samples were represented by a thermal index calculated based on the average value of pixels in the thermal image. Results of the experiment have shown that highly significant relationship were exist between thermal index and maturity stage and moisture content of paddy with r = -0.948 and 0.896, respectively. It also worked well in detecting foreign material (chaff) at 25s after cooling. The method gave accurate results with 92% for moisture content determination, 90% for maturity stage prediction and 100% for chaff detection.

Introduction

Rice (Oryzasativa L.) production not only serves as the primary source of income for nearly one billion people but also provides the staple food for more than half of the world's population (Dawe *et al*., 2011). Based on the world's projection, the demand for rice will grow from seven to nine billion by 2050 and to reach ten billion before 2100. Global demand for rice is expected to increase roughly 35% by 2035 (FOA, 2002), which requires an additional 116 million tons of milled rice (GRiSP, 2010). The increasing demand for rice requires improvements in rice production. There are many factors must be considered to maintain high quality and quantity of rice production. In Malaysia, the paddy has been graded based on the Deduction Schedule according to Malaysian Standard MS 84: 1998. It was used by rice millers to give price to the farmer when purchasing paddy. The total percentage deductions of weight include deduction of moisture content, immature paddy and foreign material. High moisture directly reduces the price of paddy (Belsnio, 1992). Meanwhile, immature paddy caused low milling recovery, high percentage of broken rice, poor grain quality and more chances of disease attack during storage (Hanibah *et al*., 2014). Foreign material can cause the wear and tear of the milling machine. Most of the rice millers rely on their experienced paddy graders to determine how much to deduct by inspecting sample of paddy manually. These manual operations are tedious, time consuming, labour intensive and costly.

Imaging technology can contribute to such quality evaluation of the rice. Thermal imaging is a non-destructive, non-contact system of recording temperature by measuring infrared radiation emitted by a body surface (Arora *et al*., 2008). It is a technique which converts the invisible radiation emitted by an object into visible image without contacting the object. This technique has been widely used in electrical, manufacturing and civil engineering industries (Agerskan, 1975). Traditionally, temperature monitoring has relied on contact methods such as thermocouples, thermometers, and thermistors, which provide limited information (Nott and Hall, 1999). Thermal imaging quantifies the changes in surface temperature with high temporal and spatial resolution compared to single point measurements as in the case of other contact methods by using thermometer or thermocouple (Gowen *et al*., 2010).

Nowadays, thermal imaging has been widely used in agricultural sector. For example, it has been used for better understanding of bruised tissue and automatic bruise sorting. Due to the difference of temperature between healthy and bruised tissue thermal imaging showed the significant difference (Varith *et al*., 2003). Thermal imaging is a potential method for the remote detection of abnormality in agricultural products based on the temperature changes during cooling and heating (Manickavasagan, 2008). Thermal imaging

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allows us to see the variations in temperature because the amount of radiation emitted by an object increases with temperature. It has been used to detect foreign materials in hazelnuts (Meinlschmidt and Margner, 2003) and almond (Ginesu *et al*., 2004). Based on the literature reviews, it can be concluded that with the aid of modern technology, automated device with intelligent computing functions can be used to replace human naked eye in deciding quality of produce. Therefore, this research aimed to analyse the quality of paddy using thermal imaging approach.

Materials and Methods

Moisture content (MC) and maturity index

Paddy type MR220 CL2 was used in this study. It has been released by Malaysia which was derived from cross-breed between the MR220 with rice breed CL1770 that originated from the United States to produce the type of Clearfield rice variety MR220. In this study, the samples were collected from rice granary area located at Sawah Sempadan, Selangor on 92, 94, 96, 98 and 100 Day after Planting (DAP). For each day, the data collection started at 11.30 am. Fifteen samples with 50 grams each were collected at the same point. The process takes 1 ½ hours. The samples were put in the plastic bag and stored in the cooling box to avoid damage to paddy. The moisture content, expressed in percent wet basis (% w.b.), was measured by using moisture analyzer type PM-410. This moisture analyzer can measure the moisture content of paddy in the range between 8.0 to 35.0%. The moisture content was measured for three times and the average was calculated. The values were used to create a relationship between moisture content and its thermal index.

Foreign material

Paddy seed of variety MR219 was taken from one of the Malaysia paddy seed distributors located in Sungai Besar, Selangor. They were taken from paddy silo storage after drying by using an inclined bed dryer. The moisture content of the paddy seed was 12% which is the safe moisture content for paddy seed in silo storage. The sample taken consist of paddy seeds and other foreign materials such as paddy husks, soil, chaff, stones, weed, rice straw, stalks, and insects. An air screen cleaner was used to separate seeds and foreign materials. In this research, only chaff was used to represent the foreign material.

Image acquisition

FLIR E60 thermal camera was used to acquire thermal images of the samples. It was fixed at 40cm height from sample as shown in Figure 1. Thermal images were captured before heating treatment. This was to indicate the initial condition of the sample. For heating treatment, two lamps with 240V and 42W power supply each were used to heat the samples. After that, samples were heated for three minutes (Chelladurai, 2010). Later, samples were cool to the ambient temperature. Thermal videos were recorded during this condition. After that, frame images extracted from FLIR video report player were analysed.

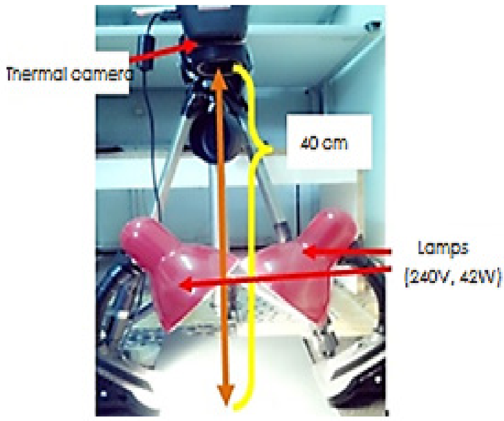
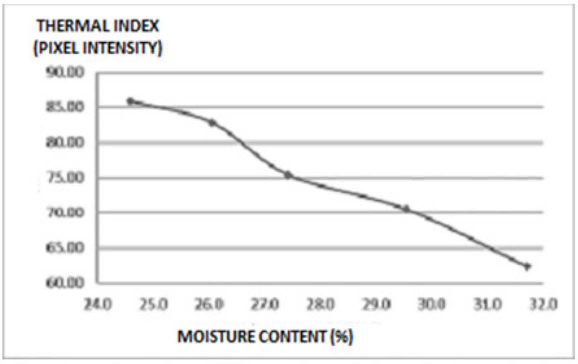


Figure 1. Experimental setup

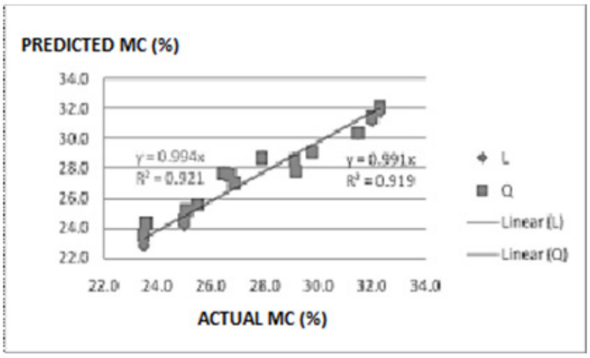
Results and Discussion

Moisture content (MC)

Figure 2(a) shows the average thermal index taken from its gray scale image for each moisture content. From this graph, the value of thermal index (in pixel) was decreasing with increasing value of moisture content. Statistical analysis based on Pearson's correlation coefficient has been done to identify the relationship between thermal index to the moisture content of paddy. Pearson's correlation coefficient assumes that each pair of variables has a bivariate normal distribution. The closer the value of correlation to 1, the closer the two variables to a perfect positive correlation, while the closer the value to -1, the closer the two variables to a perfect negative correlation. Based on the results tabulated in Table 1, thermal index gave high negative correlation with value of paddy moisture content with r = -0.948. The method has been validated using 15 samples of images. As shown in Figure 2(b), the method performs well in predicting the moisture content of paddy with the R^2 value between predicted and actual of 0.919.

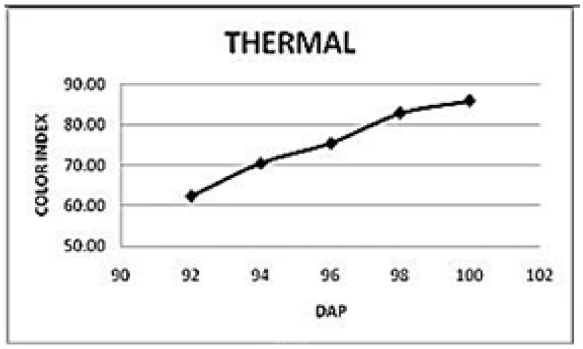


(a)

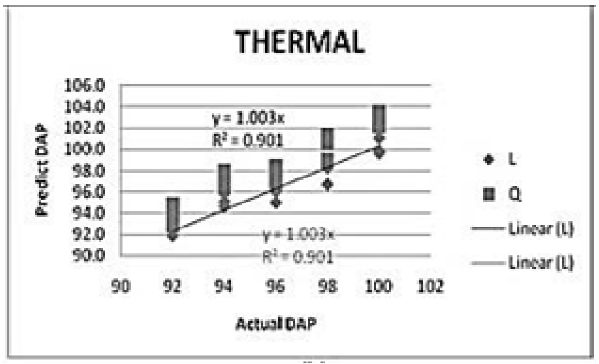


(b)

Figure 2. (a) Average thermal index at different value of moisture content. (b) Scatter plot for predicted moisture content versus actual moisture content



(a)



(b)

Figure 3. (a) Changes of average color index towards maturity stage. (b) Line predicted and actual result of paddy maturity stage determination

Immature condition

The average values of mean for each DAP taken from 60 different samples are shown in Figure 3(a). Based on this figure, it is clearly shown that the value of mean pixel intensity was increasing as the paddy becomes more matured. Results of Pearson correlation as tabulated in Table 1 has also shown that thermal index gave the significant positive relationship at the 0.01 level (2-tailed) with the value of r = 0.896. Therefore, it can be concluded that thermal index can be used to detect the maturity stage of paddy. The method has been validated using 15 samples of images. As shown in Figure 3(b), the method performs well in predicting the maturity stage with the R^2 value between predicted and actual of 0.901.

Table 1 Correlation analysis of thermal index

Properties	r	R^2 (Linear)
Moisture content	-0.948**	0.898
Maturity stage	0.896**	0.803

** Correlation is significant at the 0.01 level (2-tailed).

Foreign material

Trend of average mean pixel values for 100% paddy seeds and 100% chaff from the initial condition until one minute of the cooling treatment is shown in Figure 4. From this graph, it could be observed that average mean pixel values for 100% paddy seeds are greater than 100% chaff through the cooling treatment. At 0s, before the heating treatment, the average mean pixel value for 100% chaff and 100% paddy seeds are 144.32 and 140.71, respectively. These values are almost the same. However, at 1s during the cooling treatment, the average mean pixel value for 100% chaff decreased while value for 100% paddy increased. Then, from 2s to 60s, 100% chaff experienced an increase and a decrease in average mean pixel values. However, the values are not deviate from each other. On the other hand, 100% paddy increase steadily until 35s and decrease slowly from 40s until 60s. The average mean pixel values between husk and paddy have the highest difference at 25s cooling time as compared to the others. Therefore, image of 25s cooling time was used for separation of paddy and chaff. A threshold value was set at 190 to separate the background and object. The method has been tested to detect 40% husk in 50 samples of images and it gave 100% successful detection.

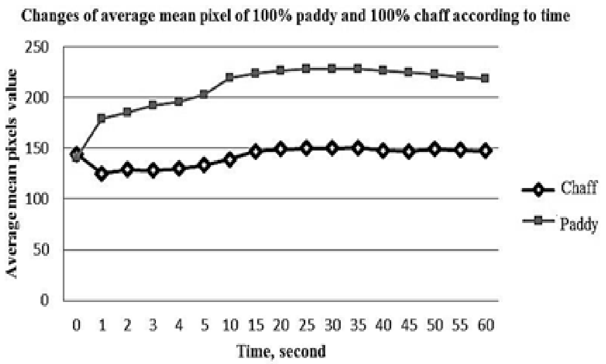


Figure 4. Graph of average mean pixel values of 100% paddy seeds and 100% chaff versus time using thermal camera at initial condition (0s) and during cooling treatment after 180s heating treatment

Conclusion

New techniques of determination of paddy grading parameters namely moisture content, immature condition and foreign material have been presented in this paper. The proposed techniques which used thermal imaging technology gave over 90% accuracy where high moisture content, immature condition and chaff occurrence were indicated by lower pixel values.

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