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Rice Quality Assessment Using Fluorescence Imaging Technique

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Abstract

Grain rice quality is defined by various parameters including physical, biochemical and physiochemical properties. Most of the technology that have been developed only measure one quality characteristics at one time. More capability such as assessment of multiple quality parameters in one system is desirable. In this research, a machine vision with double lighting system has been developed to incorporate more features for the quality evaluation. The proposed machine vision system has the capability to obtain information related with morphological features and fluorescence color information of the rice simultaneously. Those features extracted from the image set were used to separate between non-white core, white core, chalky and dead sake rice with different freshness condition. This system shows promising result for separating difference type of rice with different freshness. These results provide an alternative way for quality grading technology for rice.

Keywords: Double Lighting, Freshness, Fluoresence, Rice Quality

Introduction

In Japan, the quality of rice as an ingredient of sake depends on several physicochemical properties, such as protein content, water absorbability of grain, the weight of 1000 grains (around 25 to 30 g), moisture content, and the most important characteristic for sake brewery the presence of the white core at the center of the rice grain. In addition, for all rice varieties, both table or sake rice, freshness is also an important factor of quality evaluation. Moreover, these physiochemical and physiological characteristics will change during storage (Hachiya et al., 2009). Chrastil et al. (1990) explains the changes in functional properties associated with aging on the rice.

In this study we will focus on two main qualities for sake rice: freshness and the occurrence of white core (type of sake rice). White core refers to an opaque region in the endorsperm of the rice grain, which is called Shinpaku in Japanese. Rice grains with white core can absorb water quickly and steam well; a desirable characteristic of sake rice grain. The white core is very important because it helps to increase the ability to gelatinize during steaming, has a softer center for Aspergillus Oryzae (koji), a filamentous fungus (a mold) (Aramaki et al., 2004; Kamara et al., 2009), to invade once it breaks through the firmer outer layer, and is more readily converted by the koji enzymes. It is used to saccharify the rice, breaking down the complex carbohydrates into monosaccharide components.

This structure scatters light and causes what is often seen as a white core at the center of large grains. But amongst the harvested sake rice grains, not all the rice will have the desired white core. Other rice grains can have a chalky appearance, which is associated with the development of numerous air space between the loosely packed starch granules; resulting in changes in light reflection (Tashiro and Wardlaw, 1991).

Recently, Ultraviolet (UV) imaging, including fluorescence imaging, has begun to be explored and used for some non-destructive applications. The fluorescence material absorbs the UV excitation, then reradiates at a longer wavelength (Richards, 2006). Non-destructive approaches have been proposed by Hachiya et al., (2009) to evaluate freshness of rice using fluorescence imaging with UV-Excitation (Hachiya et al., 2009). They found that the old rice has a higher fluorescence intensity compared to new rice in the emission wavelength region of 440 – 500 nm, which is related to the chemical oxidation of the rice. However, the color information their system obtains is restricted to the red region of visible spectrum, since they are applying a short pass filter to the camera. As a consequence, original RGB information that may also useful for freshness discrimination has not been explored thoroughly in previous research.

This study develops novel ideas for evaluating rice quality appearance using a unique machine vision system. A double lighting system is developed, which consists of frontlighting and backlighting and a RGB camera for image acquisition. In addition, UV LEDs with a specific narrow bandwidth for inducing visible fluorescence and a backlighting system with white LED were develop to acquire transmittance images of the rice. These two sets of images were then used to extract features related to morphological properties and the fluorescence properties of the rice. These extracted features were then used to discriminate between rice grain types and freshness levels.

Materials and methods

1. *Rice samples*

A total of 536 rice grains (Yamadanishiku) harvested in 2011 and 2016 in Hyogo Prefecture, Japan with a moisture content of 15.4% were used. In each year sampled the rice grains consisted of the 4 type of sake rice grain: non-white core (translucent) rice (67 samples), white core rice (67 samples), chalky rice (milky white rice) (67 samples) and dead rice (67 samples). Images of the different types of rice grains are shown in Figure 1.

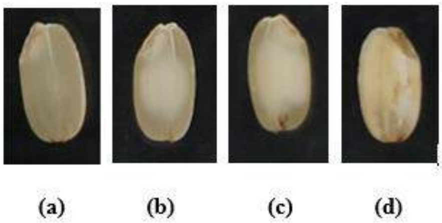

Figure 1: Images of (a) non-white core (translucent) rice (b) white core (c) chalky rice (milky white) (d) dead rice

In translucent rice the starch granules are tightly packed into the cell, which will allows the transmission of scattered light (Yamada et al. 2002). Whereas in the white core rice there is space between the starch granules in the cell, which are small and disorganized thus preventing the transmission of scattered light (Yamada et al., 2002). Moreover these white core rice normally have an opaque region in the central region of endosperm, while in the chalky (milky white) rice the opaque region is in the ventral part or entire endosperm (Yoshizawa and Kishi, 1994), but both the white core and milky white rice grains are larger in length, width and thickness, but lower in length/width ratio than the non-white core rice.

2. *Machine vision system setup*

The machine vision system consisted of a camera, two lighting arrangements: frontlighting and backlighting, and a glass plate for placing the samples on. The images were captured using a Digital Single Lens (DSLR) camera (Canon EOS Kiss X7, Canon, Japan) with PL filter. For the frontlighting, we constructed a UV LED lighting system (365 nm) with PL filter (Y-49, Japan). Then, for the backlighting, we used square type white LED (CCS Co., Ltd., type:LFX2-75SW) as backlight and a power unit (PD2-3024-2, CCS Co., Ltd., Japan.) to control brightness for both lighting devices. At the time of measurement the grain sample was placed on the smooth surface of the glass plate. This system is a modification of the double lighting system previously reported in detail elsewhere (Jahari et al., 2015; Mahirah et al., 2017). The schematic layout of the developed machine vision system is shown in Figure 4.

Before acquiring the images, the camera operation parameters were optimized for high quality image capture. EOS Utility Software（Canon Inc.）was used for acquiring the images and setting the parameters of the camera. Appropriate combinations of shutter speed, ISO, focal length and F-number were adjusted to ensure objects could be easily distinguished from the background. After the white balance setting, both lighting systems were two set-up optimal lighting.

The sample was then subsequently sub-sampled for ease of image acquisition. The image acquisition device is compact necessitating the sample be of small size to avoid problems with overlapping of grains and other material in this experiment, the sample was placed manually on the object plate.

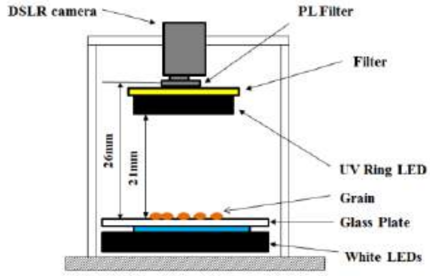

Figure2: Double lighting machine vision setup

3. *Image processing and analysis*

Images captured by the UV LED frontlighting were then processed by extracting the color features, such as Red, Green, Blue (RGB) of the rice grains using Matlab R2013a (MathWorks, Natick, USA). For the images from the backlighting system, the morphological properties of the grains were extracted using ImageJ2 (ImageJ developers). In this study, we used 3 features parameters as below:

$$\boldsymbol{Ratio\ (Perimeter\ with\ area) = \frac{Perimeter\ of\ opaque}{Area}} \quad (1)$$

$$\boldsymbol{Ratio\ (Opaque\ area\ with\ full\ area) = \frac{Area\ of\ opaque}{Area\ of\ full\ grain}} \quad (2)$$

$$\boldsymbol{Distance\ of\ centroid\ (opaque\ and\ full) = \sqrt{(x1 - x2)^2 + (y1 - y2)^2}} \quad (3)$$

where

(i) perimeter is defined as the distance around the boundary of the region

(ii) area is defined as the actual number of pixels in the region

(iii) centroid is defined as the center point of the region which is the average of the x and y coordinates of all of the pixels.

Figure 3 shows the flowchart of the image processing and feature extraction for the backlighting image.

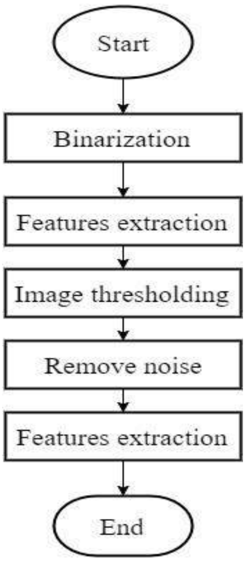

Figure 3 Flowchart of backlighting image processing

4. Classification of sake rice

A two-way ANOVA was used to compare the mean differences between groups. The primary purpose of the two-way ANOVA was to understand if there was any interaction between the two independent variables on the dependent variables. In this study, we observed interactions between color and morphological overview of the similarities and differences among the samples.

Results and discussion

Images of sample grains for the different sake rice grain types and different year of harvest (2011 & 2016) obtained by the double lighting system (frontlight and backlight) with the same orientation are shown in Figure 4.

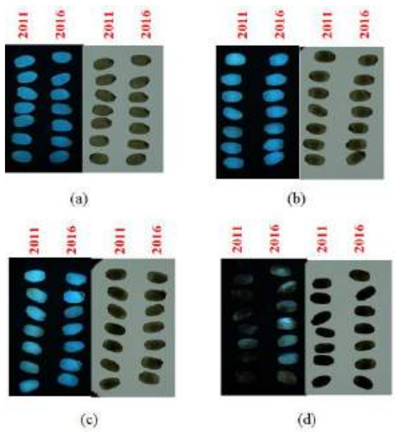

Figure 4 : Image of samples harvested in different years taken using double lighting image system (the left side is the frontlight image taken using UV LEDs and the right side is the backlight image taken using white LEDs (a) non-white core (translucent) rice (b) white core (c) chalky rice (milky white) (d) dead rice
The old rice (2011) has a higher intensity of RGB compared to the new rice.

Table 1 shows average and variance for each type of rice in different years followed by the two-way ANOVA results for the RGB. This result confirms that the color information from the UV-imaging is promising for separating the rice with difference of the year. Even though it also gives a difference for different type of the rice, but it doesn't shows a same pattern for all type of rice.

Table 1 The average, variance and two way ANOVA results for RGB color channel

		Non-white core		White core		Chalky		Dead	
		2011	2016	2011	2016	2011	2016	2011	2016
R	Average	26.37	18.40	27.79	20.76	41.90	22.50	41.09	23.04
	Variance	15.60	7.07	22.75	7.66	37.29	10.65	79.74	23.92
G	Average	110.51	95.64	115.12	108.88	126.24	102.21	86.61	38.55
	Variance	123.80	109.93	129.01	107.76	248.76	204.03	683.08	143.63
B	Average	145.94	135.43	151.08	153.09	152.83	141.33	93.54	42.74
	Variance	183.21	223.84	191.01	192.51	420.37	446.51	1109.52	273.94

Two way ANOVA

Source of Variance	SS[1]	df[2]	MS[3]	F[4]	P-value	$F_{critical}$
Type of rice	700521.2	7	100074.5	480.7818	0.0001	2.01535
RGB	2792623.0	2	1396312	6708.218	0.0001	3.001405
Interaction	398343.7	14	26453.12	136.6957	3.2E-260	1.698016
Within	329708.6	1584	208.1494			
Total	4221197	1607				

[1]Sum of squares [2]Degree of freedom [3]Mean squares [4]The test statistics

The results in Table 1 show that the F value is greater than the F critical and the P value is less than 0.05. The within rice type p value was 0.001 ($p<0.05$), while for the RGB colors the P value was also 0.001 and the P value for the interaction between these < 0.005. Therefore, the results obtained show a significant difference between rice types in different year, and also between the RGB colors (Table 1). Next the potential of backlighting images to separate rice types is examined. The morphology characteristics were extracted from the binary and the threshold images. Table 2 shows the two way ANOVA results. These three physical properties were chosen based on a preliminary. A T-test shows that these three parameters are significantly different between each type of rice.

Table 2: The two way ANOVA

Two way ANOVA

Source of Variance	SS	df	MS	F	P-value	F crit
Type of rice	109928.6	7	15704.08	49.08295	2.18E-63	2.01535
Morphology	332256	2	166128	519.2312	3.9E-174	3.001405
Interaction	226648.4	14	16189.17	50.59908	2.2E-116	1.698016
Within	506800.6	1584	319.9499			
Total	1175634	1607				
Total	5299566					

[1]Sum of squares [2]Degree of freedom [3]Mean squares [4]The test statistics

From the two way ANOVA, it shows that the F value is greater than the F critical value (F > Fcritical) for the different types of rice and also between the morphological factor with the P value being less than 0.05. for both conditions. Therefore we can say that the morphological factors are significantly different between these types of rice grain harvested in different years. As a result, we conclude that the morphological information can distinguish between the different types of rice, but cannot differentiate freshness levels of the rice.

Conclusions

From this research, it can be concluded that the double lighting machine vision system provides the most promising results for multiple quality evaluation of sake rice grains. The results show frontlighting based on UV LEDs provides fluorescence information useful for detection of freshness. These promising results provides an alternative way to grade rice using two features of quality evaluation: freshness and chalkiness.

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