Colour measurements of pigmented rice grain using flatbed scanning and image analysis

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Abstract.

Recently, the National Bureau of Agricultural Commodity and Food Standards (ACFS) have drafted a manual of Thai colour rice standard. However, there are no quantitatively descriptions of rice colour and its measurement method. These drawbacks might lead to misunderstanding for people who use the manual. In this work, we proposed an inexpensive method, using flatbed scanning together with image analysis, to quantitatively measure rice colour and colour uniformity. To demonstrate its general applicability for colour differentiation of rice, we applied it to different kinds of pigmented rice, including Riceberry rice with and without uniform colour and Chinese black rice.

1. Introduction

Rice is one of the most important product of Thailand. In the past, Thailand was the world largest rice exporter. However, due to an increasing of production cost and the effect of climate change, there is the fluctuation of rice price in the past few years. To solve this problem, many farmer have changed to plant the high nutrient organic rices, especially the colour rices, due to a much higher price compare to the conventional white rice. This is also following the trend of having clean and healthy food. Since the market of high nutrient colour rices is growing, standardisation is then needed for a fair trade. Recently, the National Bureau of Agricultural Commodity and Food Standards (ACFS) have drafted a manual of Thai colour rice standard [1]. The standard of dimensions and some chemical properties of colour rices are described in quantitative details. However, there is no word quantitatively describing the "colour" of colour rice. This may be partly due to the lack of understanding that colour can be measured quantitatively. In this work, we try to apply the colour science to the standardisation of Thai colour rice. In the next section we will briefly describe the standard of Thai colour rice. We then describe the idea how to quantitatively measure colour and colour uniformity of rice grains. We then propose how to use some simple tool to implement this idea.

2. Thai Colour Rice Standard

Thailand has vast varity of rice, especially colour rice. So far the main product of Thai rice is white rice. Probably the most famous one is the jasmine rice. To have rice product with high quality, there are standards for white rice. The main features are size of rice kernels and the softness of cooked rice. The size of rice grains can be sorted by standard sieves, and the softness can be determined form the amount of amylose in the rice kernel. They are both measure *quantitatively* following the standards. Now, due to the increasing of the demand of colour rice, additional standard for the grain colour is needed. Studies show that the darker the grain is, the higher nutrient the grain have [2]. So a high quality grain is the one with the highest saturation of it colour classification, and also with uniform colour over the grain. Unfortunately, there is no quantitative description of the colour standard in the ACFS drafted standard manual. In a recent discussion on the colour rice standard, farmers demand quantitative criteria for rice colour that they can use to decide how good their products are. However, ACFS worried that such criteria may be too complicate and too expensive. It is the propose of our work here to show that is not the case. We can apply the computational colour science to standardise the grain colour, and due to the development of modern digital camera or scanner and image processing software, grain colour measurement can be simple and not that expensive.

3. Colour Measurement and Colour Uniformity

In this section we propose how to measure rice grain colour and colour uniformity. To measure a colour quantitatively, we can follow the *Commission internationale de l'clairage*, or CIE tristimulus values [3],

$$X = k \int_{\lambda} E(\lambda) P(\lambda) \bar{x}(\lambda) d\lambda, \tag{1}$$

$$Y = k \int_{\lambda} E(\lambda) P(\lambda) \bar{y}(\lambda) d\lambda, \tag{2}$$

$$Z = k \int_{\lambda} E(\lambda) P(\lambda) \bar{z}(\lambda) d\lambda, \tag{3}$$

where $E(\lambda)$ is the relative spectral power distribution of an illuminant, $\bar{x}$, $\bar{y}$, and $\bar{z}$ are the CIE 1931 (or 1964) colour-matching functions, $P(\lambda)$ is the spectral reflectance of an object surface, and k is a normalizing factor,

$$k = \frac{1}{\int_{\lambda} E(\lambda) \bar{z}(\lambda) d\lambda}. \tag{4}$$

In practice the more uniform colour spaces CIE $L^*a^*b^*$ is used. The three parameters L^*, a^* and b^* represent lightness, redness-greenness and yellowness-blueness of a colour, respectively. The transformation from XYZ to $L^*a^*b^*$ space is quite tedious. However, in actual measure we hardly obtain the XYZ values of the image since RGB data are common output from digital camera or scanner. An image processing software can then transform RGB data to $L^*a^*b^*$ space, under some assumption of the light source and reflectance spectra of the surface. We may imagine that $L^*a^*b^*$ is a representation of colour value in rectangular coordinates. A more natural representation is CIE $L^*C^*h^*$ colour value in cylindrical coordinate,

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \tag{5}$$

$$h = \arctan(b^*/a^*) \tag{6}$$

Chromaticity C^* gives vividness and hue h gives shade of surface colour. Both parameters can be used to identify the colour of the rice grains.

Uniformity is another important factor. The first condition for premium colour rice grain is colour uniformity. We can apply the concept of colour difference to quantitatively determine colour uniformity. Colour difference is defined as a Euclidean distance between two points in colour space. In CIE *Lab* space [3],

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \tag{7}$$

In fact, there are weighted factors multiply to each term in the square root above [4]. Again, the calculations of weighted factors are tedious and we give the tasks to image processing software. A rice grain with uniform colour can be defined as the grain that majority of surface area has colour difference from the average colour value less than the Just-Noticeable Difference or JND criteria. The word "majority" is user defined. Typically we may take 80% or higher as majority. The JND criteria is, on average, ranging from 1.0% 3.0% of the possible maximum value of ΔE.

4. Implementation

To implement the ideas in previous section, we can capture the image of rice grains using digital camera or scanner, extract the RGB data and then convert to $L^*a^*b^*$ (or L^*C^*h) colour space. The average values of L^*, a^* and b^* are determined. Colour differences of each pixels from the average value are calculated. A grain is said to be uniform if majority of pixels, say 80%, have colour differences less than the JND.

We use here a flatbed scanner as the capture device. Figure 1 shows the hardwares used in this work. The advantage of flatbed scanner is that we can easily block light from environment. Distance from grain to CCD sensor is fixed so we can also easily perform grain dimensions measurements. We use Mathematica software to do image colour processing. The software has powerful image processing routines which make our analysis much easier. Especially, Mathematica has internal routine to calculate the colour difference base on the most recent CIE2000 formular. In this routine the maximum colour difference is 1.16839, so we set JND to $\Delta E \approx 0.12$.

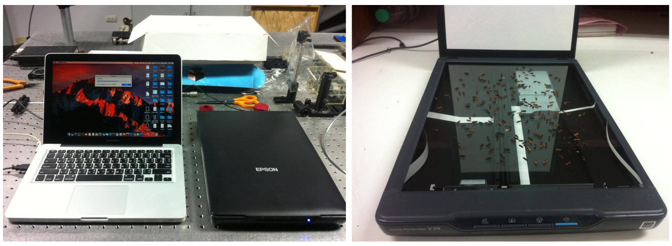

Figure 1. The hardwares used in this work. Images of rice grains are captured by a flatbed scanner. The images are send to a laptop and analyzed via `Mathematica` software.

5. Results

Here, we measured the colour and colour difference of three types of rice: (i) Riceberry rice with uniform colour (a high quality organic Riceberry grain); (ii) Riceberry rice without uniform colour (non-organic Riceberry grain); (iii) Chinese black rice.

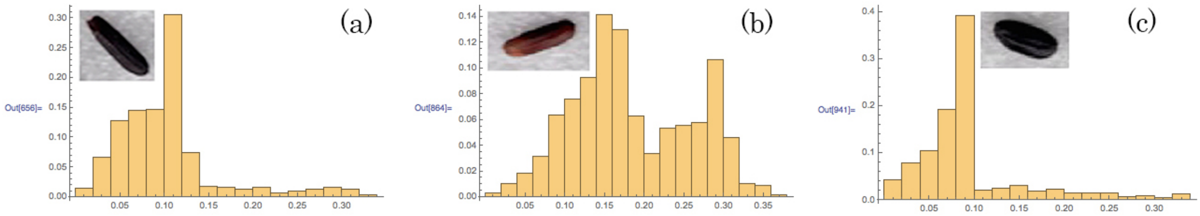

Figure 2. Grain examples and distribution of colour difference from average $L^*a^*b^*$ of (a) high quality organic Riceberry rice, (b) non-organic Riceberry rice, and (c) a Chinese black rice.

Table 1. The attribution table of colour measurment results

Types of rice	L	a	b	hue	saturation	brightness	ΔE_{av}	$\Delta E_{80\%}$
$\mathrm{RR_{UC}}$	0.1198	0.0401	-0.0099	0.8979	0.2907	0.1419	0.1035	0.1194
$\mathrm{RR_{NUC}}$	0.2194	0.1991	0.1081	0.9957	0.6156	0.3249	0.1855	0.2717
Chinese black rice	0.0938	0.0120	-0.0119	0.8234	0.1972	0.1037	0.0927	0.0955

$\mathrm{RR_{UC}}$, Uniform colour Riceberry rice; $\mathrm{RR_{NUC}}$, Non-uniform colour Riceberry rice.

For Riceberry rice with uniform colour, the value of hue ≈ 0.9 in table 1 corresponding to the reddish-purple colour of the grain. The distribution of colour difference from average $L^*a^*b^*$ (ΔE_{av}) in figure 2(a) confirms that the grain colour is quite uniform. The value of 80% quantile of the distribution ($\Delta E_{80\%}$) ≈ 0.12 means that most of the pixels have colour difference less than JND.

Hue ≈ 0.8 of non-organic Riceberry grain corresponding to the dark-purple grain. The high saturation and brightness represent bright colour. Figure 2(b) shows that non-organic Riceberry grain colour is not uniform. Here, it has much higher value of $\Delta E_{80\%} \approx 0.27$ than the JND. We can say that the grain of this kind has low quality.

For Chinese black rice, hue ≈ 1.0 corresponding to the red grain. The low saturation and brightness represent dark colour. The grain colour is highly uniform as shown in figure 2(c). The value of $\Delta E_{80\%}$ (≈ 0.095) is much smaller than the JND.

6. Conclusion

We show in this work the proof-of-concept that, by the help of powerful `Mathematica` software, we can use simple and inexpensive devices to quantitatively measure colour and colour uniformity of rice grains. Here, the system overall price is less than 20,000 Thai Baht, which should be affordable for farmers or cooperatives.

`Mathematica` is a great mathematical software with high efficiency image processing routines. However, it may not suitable to use the program to create and app, especially for general user as farmer. We plan to develop our system using more appropriate programming languages, such as`python` and `openCV`.

Colour calibration is other importance process that needed to develop. In this work, we follow the software assumption on light source spectrum, which might not match with the actual light source. We are not developing a simple, but reliable, calibration system. This will help users to calibrate their systems to get better device-independent colour measurement.

We are planing to port our code to a mobile app in the future. Since every smart phone nowadays equipped with high quality digital cameras, we can use them to capture the rice grain images and measure their colour. This should be a convenient tool for farmers to determine grains quality with especially an appropriate price for trading their products.

Acknowledgments

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