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 standards. However, there are no quantitative 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 products of Thailand. In the past, Thailand was the world’s largest rice exporter. However, due to an increase in production cost and the effect of climate change, there has been fluctuations in rice price in the past few years. To solve this problem, many farmers have switched to high nutrient organic rices, especially the colour rices, due to the much higher price compared to the conventional white rice. This is also following the trend of having clean and healthy food. Since the market for 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 standards [1]. The standard of dimensions and some chemical properties of colour rices are described in quantitative details. However, there is no quantitative description of 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 apply 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 how to quantitatively measure colour and colour uniformity of rice grains. We then propose how to use some simple tools to implement this idea.

2. Thai Colour Rice Standards
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 from the amount of amylose in the rice kernel. They are both measured quantitatively following the standards. Now, due to the increasing demand for colour rice, additional standard for the grain colour is needed. Studies show that the darker the grain is, the higher the nutritional value the grain has [2]. So a high quality grain is the one with the highest saturation of its colour classification, and also with uniform colour over the grain. Unfortunately, there is no quantitative description of the colour standards 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 is worried that such criteria may be too complicated and too expensive. The goal of our work here to show that is not the case. We can apply computational colour science to standardise the grain colour, and due to the development of modern digital cameras or scanners and image processing software, grain colour measurement can be simple and not that expensive.

3. Colour Measurement and Colour Uniformity

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

\[ X = k \int \lambda E(\lambda)P(\lambda)\bar{x}(\lambda)d\lambda, \]
\[ Y = k \int \lambda E(\lambda)P(\lambda)\bar{y}(\lambda)d\lambda, \]
\[ Z = k \int \lambda E(\lambda)P(\lambda)\bar{z}(\lambda)d\lambda, \]

where \( E(\lambda) \) is the relative spectral power distribution of an illuminant, \( \bar{x}, \bar{y}, \text{and } \bar{z} \) 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,

\[ k = \frac{1}{\int \lambda E(\lambda)\bar{z}(\lambda)d\lambda}. \]

In practice more uniform colour space 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 cameras or scanners. 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 coordinates is,

\[ C^* = \sqrt{(a^*)^2 + (b^*)^2} \]
\[ h = \arctan(b^*/a^*) \]

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

(7)

In fact, there are weighted factors in front of each term in the square root above [4]. Again, the calculations of weighted factors are tedious and we give the tasks to an 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, on average, ranges from 1.0% to 3.0% of the possible maximum value of $\Delta E$.

4. Implementation

To implement the ideas presented in the previous section, we capture the images of rice grains using a digital camera or a 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 the majority of pixels, say 80%, have colour differences less than the JND.

We use 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 the environment. The distance from the grain to the CCD sensor is fixed so we can also easily perform grain dimensions measurements. We use Mathematica software to perform image colour processing. The software has powerful image processing routines which make our analysis much easier. Especially, Mathematica has an internal routine to calculate the colour difference based on the most recent CIE2000 formula. In this routine the maximum colour difference is 1.16839, so we set JND to $\Delta E \approx 0.12$.

![Figure 1. The hardware used in this work. Images of rice grains are captured by a flatbed scanner. The images are sent to a laptop and analyzed via Mathematica software.](image)

5. Results

Here, we measured the colour and the 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 the 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.](image)
Table 1. The attribution table of colour measurement results

| Types of rice          | L   | a     | b     | hue  | saturation | brightness | \(\Delta E_{av}\) | \(\Delta E_{80\%}\) |
|------------------------|-----|-------|-------|------|------------|------------|---------------------|---------------------|
| RR\(_{UC}\)            | 0.1198 | 0.0401 | -0.0099 | 0.8979 | 0.2907     | 0.1419     | 0.1035 | 0.1194 |
| 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 |

RR\(_{UC}\), Uniform colour Riceberry rice; RR\(_{NUC}\), Non-uniform colour Riceberry rice.

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

Hue \(\approx 0.8\) of non-organic Riceberry grain corresponds 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 \(\approx 1.0\) corresponds 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 \(\Delta E_{80\%}\) (\(\approx 0.095\)) is much smaller than the JND.

6. Conclusion
In this work, we show 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 overall cost of the equipment is less than 20,000 Thai Baht, which should be affordable for farmers or cooperatives.

Mathematica is a powerful mathematical software with high efficiency image processing routines. However, it may not be suitable for developing an app, especially for general users such as farmers. We plan to develop our system using more appropriate programming languages, such as python and openCV.

Colour calibration is another important process that needs to be developed. In this work, we follow the software assumption for the light source spectrum, which might not match with the actual light source. Our goal is to develop a simple yet reliable calibration system. This will help users to calibrate their systems to get better device-independent colour measurements.

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

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