

# Classification of ripening stages of bananas based on support vector machine

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**Abstract:** Non-destructive quality detection and automatic grading are important in fruit industry. The traditional way divides bananas into 7-level ripening stages based on color. This study investigated the changes of peel color at three positions of banana fingers, i.e. stalk, middle and tip. A support vector machine method was used to classify the ripening stages by color value  $L^*$ ,  $a^*$  and  $b^*$  as input data. The ripening stages were classified by 10-fold cross validation method of support vector machines with radial basis function kernel and linear function kernel. The results showed that the color change of middle position of banana finger adequately reflected the changes in banana ripening stages.  $a^*$  value continuously increased from ripening stage 1 to ripening stage 7,  $L^*$  and  $b^*$  values increased from ripening stage 1 to ripening stage 5, and then decreased from ripening stage 5 to ripening stage 7. It was difficult to recognize the ripening stages using  $L^*$ ,  $a^*$  and  $b^*$  values individually. The accuracy of classification using support vector machine based on radial basis function kernel reached 96.5%, which was higher than that for linear function kernel. This research can provide a reference for automatic classification of banana ripening stages.

**Keywords:** banana, ripening stage, color change, support vector machine, classification, image recognition

**DOI:** 10.3965/j.ijabe.20150806.1275

**Citation:** Hou J C, Hu Y H, Hou L X, Guo K Q, Satake T. Classification of ripening stages of bananas based on support vector machine. Int J Agric & Biol Eng, 2015; 8(6): 99–103.

## 1 Introduction

Banana is one of well known and widely consuming fruits in the world for its flavor, texture, and high nutritional value<sup>[1,2]</sup>. According to FAO data (2013), the

aggregate production of bananas was 101.99 million t all over the world in 2012<sup>[3]</sup>. In order to improve market acceptance, it is important to keep peel color uniform of same batch bananas on the shelf. Generally, banana is green when harvested, transported over long-distance, and then ripened at destination before being marketed. The parameter ‘time’ is used to evaluate the ripening stage (RS), however it is not suitable to act as an indicator because some correlative factors such as environmental conditions and chemical agents can retard or accelerate bananas ripening<sup>[4,5]</sup>. During ripening process, banana undergoes significant color and textural transformations. The peel color changes from green to yellow due to the synthesis of a few pigments<sup>[6]</sup>. Consumers usually judge the quality of banana upon the first visual assessment. Color acted as an important indicator of RS of banana to influences consumers’ acceptability. Usually, peel color is used as a predictor of shelf-life for retail distribution,

**Received date:** 2015-05-21 **Accepted date:** 2015-09-25

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and texture is an important part of eating quality<sup>[4-11]</sup>. In the fruit market, according to peel color, the RS of bananas is divided into seven levels based on Von Loesecke ripening scale<sup>[5-9]</sup>. Banana with appropriate RS on shelves is beneficial to prolong shelf-life and consumer acceptability.

Since RS is directly related to banana quality, to detect and control RS of banana is very important in fruit industry, and rapid detection of RS of banana is required in quality control<sup>[12]</sup>. Most of the traditional techniques used to detect fruit RS are destructive and cannot be so readily applied<sup>[13]</sup>. Some of these techniques rely on assessing pulp starch conversion, which is correlated to RS by starch iodine staining chart<sup>[14]</sup>, or detection of firmness<sup>[15]</sup>, impact force<sup>[16]</sup>, pH value and titratable acidity<sup>[17]</sup>. The above methods require destructing the fruit and need complex analytical techniques.

Recently, color detection of fruit ripening as a promising non-destructive method has been studied. The RS was evaluated traditionally by experienced workers based on bananas peel color according to Von Loesecke ripening scale, which is subjective, time consuming, tedious and expensive. With the detection technology exploring, automatic non-destruction detection methods for RS are developing. Nowadays, the computer vision system used to identify the RS of fruits based on color, such as recognizing the ripen tomato under natural lighting conditions of greenhouse, using segmentation algorithm based on combination of RGB, HSI, and YIQ spaces to recognize the ripen tomato<sup>[18]</sup>, however the system needs image processing and complex algorithm, and the cost is high. Usually, BP artificial neural network was a main identification algorithm for ripening stage of fruits<sup>[19]</sup>, but this method needs big data for training and predicting, and slow training speed and possibility of leading to a local minimum of optimized function can be produced. Support vector machine algorithm has the advantage in response to the small sample data using support vector to complete linear or non-linear classification problems, and the problem of local minimum can be avoided<sup>[20]</sup>.

The purpose of this research was to recognize RS of bananas based on peel color in  $L^*a^*b^*$  color space using

support vector machine (SVM), and to investigate the firmness change of banana fresh as RS increasing from RS1 to RS7.

## 2 Materials and methods

### 2.1 Banana samples and storage conditions

Green banana (*Musa* AAA group, Cavendish subgroup) was obtained from the fruits market of Tsutiura city, Ibaraki, Japan, treated with ethylene at the market by the wholesaler according to the regulation, and then packaged in a carton, with a net weight of about 13 kg. After purchasing, the bananas were transported to laboratory and ripened in temperature of  $(20\pm 2)^\circ\text{C}$  and relative humidity of  $(80\pm 8)\%$  until experiment end. According to Von Loesecke ripening scale, the bananas were sampled at RS 1-7 during ripening.

### 2.2 Banana color determination

Color measurements of banana skin were made using a portable tri-stimulus colorimeter (Minolta Chroma Meter CR-200, Minolta, Osaka, Japan) with an 8 mm diameter testing area, which was calibrated on the Hunterlab color space system using a standard white plate (Minolta calibration plate,  $Y=92.6$ ,  $x=0.3136$ ,  $y=0.3196$ ). Color was described as coordinates of the CIELab scale (CIE 1978): lightness, greenness (-a) or redness (+a), and blueness (-b) or yellowness (+b), respectively.

The position selected for color measurement was stalk, middle and tip of each banana fruit as shown in Figure 1. At every position, three points were measured around the peel. Thirty bananas were used to measure from RS1 to RS7. The color values in the same position of all samples and ripening stage were averaged for analyzing.

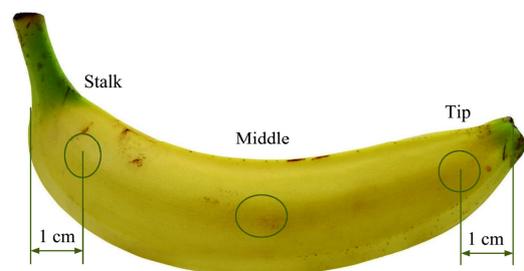


Figure 1 Positions for bananas color measurement

## 3 Results and discussion

### 3.1 Analysis of bananas peel color

For banana peel color at 3 positions, the values of  $L^*$ ,

$a^*$ ,  $b^*$  of each RS were shown in Figures 2a-2c, respectively. It was observed for the  $L^*$ ,  $a^*$  and  $b^*$  values of the tip, middle and stalk of banana fruits that the change trends were approximately similar, and the value curve of middle position was nearly situated between the curves of tip and stalk values, so it was enough to use the  $L^*$ ,  $a^*$  and  $b^*$  values of middle position to reveal the RS change of bananas.

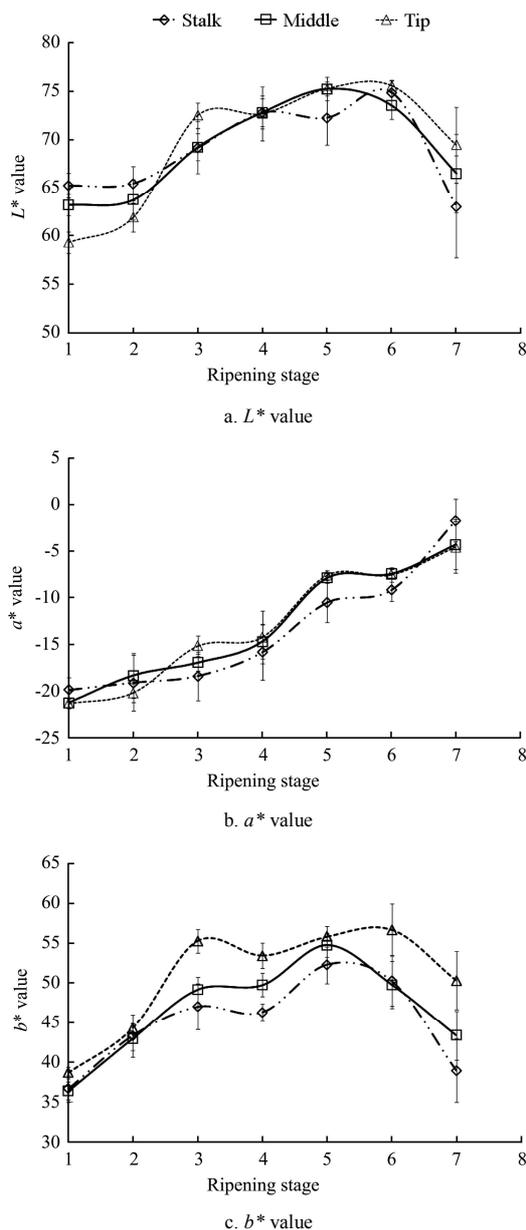


Figure 2 Color values change of the tip, middle and stalk of banana fruit during ripening

From Figure 2a and Figure 2c, with the development of ripening stage, it can be observed that  $L^*$  and  $b^*$  had the same trends, the values increased from RS1 to RS5 and decreased from RS5 to RS7, the decrease was probably caused by the brown spot appearance. The

values of  $L^*$  for RS4, RS5 and RS6 were very close. Figure 2b showed that the  $a^*$  values continuously increased from RS1 to RS7 due to the chlorophyll degradation.

The similar results, the values of  $L^*$ ,  $a^*$ , and  $b^*$  increased parts with ripeness developing, were observed by Chen and Ramaswamy<sup>[21]</sup>, the over ripening stages (RS6 and RS7) were not appeared in their results. With the chlorophyll destroying, the values of  $L^*$ ,  $a^*$ , and  $b^*$  increased until brown spots appeared which led to dark peel, and can result in values of  $L^*$  and  $b^*$  decreasing. Our results were in accordance with those obtained by Gomes et al<sup>[5]</sup>. It was difficult to judge the ripening stage of bananas individually using the values of  $L^*$ ,  $a^*$ , and  $b^*$ . The values of  $L^*$  and  $b^*$  increased from RS1 to RS5, then it decreased at the RS6 and RS7. Although the values of  $a^*$  increased from RS1 to RS7, it could not be accepted as a dependable indicator of the ripening stages because the values at the RS5 and RS6 were too close to classify.

### 3.2 Classification of banana ripening stage based on RCI

With the aim of classifying the bananas ripening stage with color values, the RCI (Ripening Color Index) was used into this paper. RCI was a practical parameter to classify banana RS which was proposed by Gomes, RCI was defined as: “ $RCI = c/(1-a/b)$ ”, and it was valid for the Brazilian ‘Prata’ bananas. In that research,  $c$  was defined as a constant which was related to bananas cultivars, and  $a/b = a^*/b^*$ <sup>[5]</sup>.

In this research,  $c$  was empirically adopted as 100, so the RCI to the *Musa* AAA bananas was expressed as “ $RCI=100/(1-a/b)$ ”. Figure 3 showed the RCI change with the RS increasing. The trend curve was very similar with  $a^*$  value, it was difficult to recognize RS5 and RS6, so the indicator RCI was not suitable to classify the RS of *Musa* AAA bananas. The invalid of RCI was caused by color values due to bananas cultivars and treatment. In this research, the *Musa* AAA bananas were ripened by ethylene in 7 d from RS1 to RS7. And in Gomes’ research<sup>[5]</sup>, the Brazilian ‘Prata’ bananas were ripened for 20 d without any chemical agents. The different treatments resulted in different color values in

different RS.

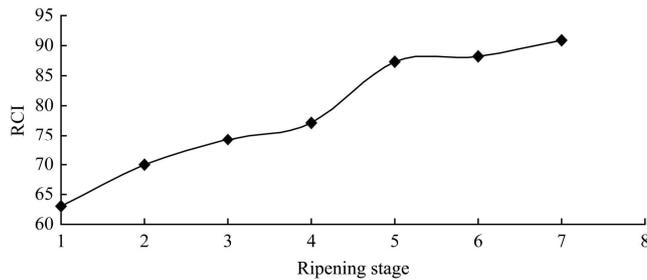


Figure 3 Changes of RCI during ripening stages of *Musa* AAA bananas

### 3.3 Classification of banana ripening stage based on SVM

In order to recognize the ripening stage of banana based on the values of  $L^*$ ,  $a^*$  and  $b^*$ , support vector machine (SVM) acted as classification method. SVM was a set of supervised learning method that analyzes data and recognizes patterns. SVM was an especially useful method for data classification<sup>[22,23]</sup>. An SVM model was a representation of the examples as points in space, mapped so that the examples of the separate categories are divided by a clear gap that was as wide as possible. The standard SVM took a set of input data, and predicted, for each given input, which of two possible classes comprises the input, making the SVM a non-probabilistic linear classifier.

SVM was one of the most robust and accurate methods. For a two-class linearly separable learning task, SVM can found a hyperplane that could separate two classes of given samples with a maximal margin<sup>[20,24]</sup>.

In this study, ripening stages of banana were 7 levels, there was a problem of one-to-many in SVM, thus  $C_7^2=7 \times (7-1)/2!=21$  classifiers were constructed to recognize the RS. The classification was conducted in Matlab 10 (MathWorks, US), and the SVM tool box was used to aid the classification. The average data of  $a^*$ ,  $b^*$  and  $c^*$  measured in one measurement acted as a set of sample, all total sets used for SVM were 210. Ten-fold cross validation method was used to predict the RS. Total sets were randomly divided into 10 equal size subsamples, 21 sets included in a subsample. A single subsample was retained as the validation data for testing the model, and the remaining 9 subsamples were used as training data. The cross-validation process was then

repeated 10 times, with each of the 10 subsamples used only once as the validation data. The 10 results were averaged to obtain a single evaluation. In this analysis, two kinds of kernel function were attempted to predict the recognition accuracy, one was linear kernel, and another was radial basis kernel. The analysis results showed that the recognition accuracy of the radial basis function as the kernel function was 96.5%, which was better than the value of linear function of 95.0%.

## 4 Conclusions

During banana ripening, the color change in  $L^*$ ,  $a^*$ ,  $b^*$  values of stalk, middle and tip parts had similar trend, it was enough to present the ripening procedure using color values of middle parts. Along of  $L^*$ ,  $a^*$ ,  $b^*$  values from ripening stage 1 to ripening stage 7, only the  $a^*$  values were monotone increasing.

$a^*$  value increased clearly from ripening stage 1 to ripening stage 7, but from ripening stage 5 to ripening stage 6 the  $a^*$  value increase was not clear, so it was difficult to judge ripening stages of bananas relying on  $a^*$  value individually.

The firmness decreased quickly from ripening stage 1 to ripening stage 5. At ripening stage 5, the starch and cell wall may be degraded and transformed completely, after ripening stage 5 the firmness decreased slowly.

The classification of banana ripening stages based on SVM with 10-fold cross validation was used to classify, and the accuracy was 96.5% of radial basis function kernel, which was better than linear function kernel.

## Acknowledgement

This research was supported by the Fundamental Research Funds for the Central Universities (2452015057). The authors would like to thank Professor Shaojin Wang for correcting the English text.

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