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RGB color imaging technique for grading of dates

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ABSTRACT

Hardness is one of the major factors in determining the quality of dried fruits. It increases the chewiness and toughness of the fruits. A robust quality assurance system is required for on-line grading of dried fruits as the present manual methods are inconsistent, inaccurate and laborious. The objective of this study was to determine the efficiency of a RGB color imaging technique to classify dates into three classes based on hardness: hard, semi-hard and soft dates. Dates from three common varieties in Oman (Fard, Khalas and Naghal) were used in this study (total 3300 samples). The RGB image of individual date sample was taken by a CCD camera and analyzed using Matlab software. Thirty nine features (13 features in each R, G and B channel) were extracted from each image and analyzed. Three classes (hard, semi-hard and soft) and two classes (hard and soft ("semi-hard and soft" together as "soft")) classification models were developed using linear discriminant analysis (LDA) with all features and stepwise discriminant analysis (SDA) with selected features (based on level of contribution to classification). In three classes approach, the overall classification accuracy was 69%, 87% and 82% for Fard, Khalas and Naghal varieties, respectively, using LDA. It was 68%, 86% and 81% for Fard, Khalas and Naghal varieties, respectively, using SDA. The classification accuracy was improved in two classes approach. It was 84% (LDA) and 83% (SDA) for Fard, 90% (LDA) and 91% (SDA) for Khalas, and 96% (both in LDA and SDA) for Naghal varieties. Imaging techniques have great potential to develop on-line quality monitoring systems for dates based on hardness. However, further studies are required using other image acquisition systems such as NIR cameras to improve the classification.

1. Introduction

Date palm (*Phoenix dactylifera*, L.) is considered to be one of the oldest trees in the world. Over thousands of years, dates have been consumed as a stable food by the people in the Middle East and North Africa (Ait-Oubahou and Yahia, 1999). Dates are popular in these regions because of their nutritional values and readily available energy (Al-Marshudi, 2002; Al-Shahib and Marshall, 2003; Kader and Hussein, 2009; Al-Rawahi et al., 2005). In general, dates are mostly consumed as a whole fruit without any processing. However, recently the government in many dates growing countries are promoting the processing and export of dates. In spite of massive efforts, the amount of export continued to be a challenge in Oman and many other countries. This may be due to the inconsistencies in the supply of quality dates in the international markets (Al-Marshudi, 2002). There are four major attributes in the grade standards of dates: color, size, absence of defects and physical properties (such as hardness) (Kader and Hussein, 2009).

Hardness is one of the major degrading factors of date's quality. According to USA standards for grade of dates, hardness receives the highest points (Kader and Hussein, 2009). Hard dates are tough and difficult to chew (Rahman and Al-Farsi, 2005). Admixture of hard dates with soft dates will reduce the consumer preferences. During processing, the hard dates can damage the machine components that are used in making the date paste or syrup. Therefore, a robust quality assurance system is required to identify hard dates in handling and processing facilities.

At present, in most of the dates growing countries, the hard dates are identified by visual inspection method. But this is a time consuming, inaccurate, inconsistent and subjective method (Brosnan and Sun, 2002; Jarimopas and Jaisin, 2008; Al-Janobi, 1998). Al-Ohali (2011) mentioned that visual inspection is the main source of delay in the grading and sorting of dates. The common instrumental method used to measure the hardness of agricultural and food product is texture profile analyzer (TPA). However this method follows sample-destructive approach, and therefore it cannot be implemented in date factories for online quality monitoring.

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Computer vision technology has been widely used for quality assessment of various food products. The principle of this technology relies on the extraction of information from the acquired image about the quality of object (Gunasekaran, 1996). It is considered to be an accurate, non-destructive, consistent, fast, cost effective and efficient emerging technology (Chen et al., 2002; Lu et al., 2000; Tao et al., 1995; Brosnan and Sun, 2002; Du and Sun, 2006; Venora et al., 2009; Miranda et al., 2007; Ercisli et al., 2012). In computer vision method, several types of camera such as NIR, X-ray, infrared, thermal, RGB color and so on are broadly used to acquire images based on application.

However, the RGB color camera has been commonly used in many food industries mainly due to the easiness in image analysis and lower price. Some of the successful application using color imaging are: sorting of apple (Shahin et al., 2002), sorting of sweet tamarind (Jarimopas and Jaisin, 2008), grading of apple (Leemans et al., 2002), grading of strawberry (Liming and Yanchao, 2010), defects in apple (Puchalski et al., 2008; Leemans et al., 1998) and defects in citrus (Blasco et al., 2007; Lopez-Garcia et al., 2010).

Computer vision techniques have been used for measuring various internal and surface qualities of dates. The linear dimensions such as length, width and thickness of Mazafati cultivar was measured using RGB camera by Jahromi et al. (2008). From the basic measured units, projected area and sphericity were calculated. Shomer et al. (1998) studied the cellular damage in Madjhoul date variety after frozen storage for 10 months using an electron microscope. In another study, a computer vision based prototype mechatronic system was developed for grading of Saudi Arabian date varieties (Sukkari and Maneefi) (Al-Janobi, 2010). The average grading accuracy (three grades) for Sukkari variety was 88% and Maneefi variety was 93% while using feed forward multilayer perceptron neural network trained with back propagation algorithm. Lee et al. (2008b) developed an automatic date grading system using reflective near-infrared imaging to obtain reflectance images of the top surface of dates. The percentage of delamination was calculated and used in grade determination. The overall accuracy of the system was in the range of 79 to 95% for various grades. Al-Rahbi et al. (2013) detected surface cracks on dated using RGB camera with 58% to 78% classification accuracy in three classes model (no-crack, low-crack and high-crack) and 75% to 88% in two classes model (with-crack and without-crack) using statistical classifiers. The same color features were also used to determine the classification accuracy using back propagation neural network (BPNN) (Al-Rahbi et al., 2015). The classification accuracy was 77% for three classes model and 90% for two classes model. Thomas et al. (2012) classified three date varieties (Khalas, Fard and Madina) using a color camera and investigated the effect of motion blurring on classification. It was determined that motion blurring did not affect the classification results. Abdellahhalimi et al. (2013) developed a camera sensor system to sort date fruit bunches based on their maturity. Algorithm was developed to detect external defect and level of maturity based on HSV space color. Al-Ohali (2011) used color images to grade dates based on flabbiness, size, shape, intensity and defects (bruise and bird flicks) into three grades (grades 1, 2 and 3). Despite various studies on date quality using computer vision method, there is no published work on the evaluation of hardness using RGB color images.

Generally in handling facilities, the hardness of dates is identified by the graders based on visual surface appearance such as color, texture and waviness. While capturing the color image of the dates, and analyzing the surface qualities, it may be possible to identify the hardness of dates more accurately. Therefore, the objective of this study was to determine the potential of RGB color imaging technique to classify dates based on hardness.

2. Materials and methods

2.1. Samples collection

Three popular varieties of dates, Fard, Khalas and Nagal, were used in this study. Khalas and Naghal varieties were obtained from the Seeb Market, one of the biggest markets for dates in Oman. Different grades of these two varieties were purchased from different suppliers. In each variety, the samples were graded into three classes (hard, semi-hard and soft) from the conglomerate bulk, and class standard was confirmed by a date quality expert in Sultan Qaboos University. A representation of 750 dates (250 dates/class) in each variety were selected and used.

Fard variety is a commercial and one of the most processed varieties in Oman. Samples for this variety were collected from three main date producing regions (Al-Batinah, Al-Dakhliah and Al-Sharkiah). The dates were graded into three classes according to hardness (soft, semi-hard and hard) by an experienced grader and confirmed by the quality manager in Sun Bright Factory, Barka, Oman. A total of 1800 representative date samples were selected and used in this study (200 samples/class/region). Therefore, in total, 3300 dates (1800 Fardh + 750 Khalas + 750 Naghal) were imaged individually and analyzed.

2.2. Image acquisition

The image acquisition system used in this study consisted of three components: RGB color camera (model: EOS 550D, Canon Inc., Japan) at resolution of 5184 × 3456 pixel, two fluorescent lights for illumination (model: Dulux L, OSRAM, Italy), and a personal computer. The camera was calibrated by customizing the white balance using a gray card (model: Digital Gray Kard XL, DGK Color Tools, USA) with 18% reflectance (Valous et al., 2009; Pedreschi et al., 2006) before taking each batch of imaging.

A dark box was used to create an imaging chamber in order to avoid backscattering effects from other light sources. During imaging, each date sample was placed manually on a white background at 15 cm distance from the camera. The image was captured using an automatic remote shooting software in the computer linked with the camera. All the acquired images were stored in the computer and used for further analysis.

2.3. Feature extraction

The RGB components of all images were analyzed using an algorithm developed in Matlab software (Version 7.6.0, The Mathworks Inc., Natick, MA, USA). In each image, the date sample was segmented from the background using simple thresholding method combined with morphological operations (Fig. 1). The morphological operations such as dilation and filling of holes were performed on images to improve the segmentation process. After segmenting the date sample from the background, 13 features in each R, G and B channels (total 39 features) were extracted from the region pertaining to date in each image. The description for all features is explained in Table 1.

2.4. Statistical analysis

All extracted features were used in the development of classification models using SPSS software (Version 20, IBM Corporation, New York, USA). The classification accuracies were determined in three classes model (hard, semi-hard and soft) using linear discriminant analysis (LDA). Similarly, in two classes model, the images of semi-hard dates and soft dates were mixed together and treated as soft dates (soft vs. hard). In both approaches, the classification accuracy of stepwise discriminant analysis (SDA) with selected features