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Grading of ripening stages of red banana using dielectric properties changes and image processing approach

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ABSTRACT

In this research work, the dielectric properties of red banana fruit are studied at different ripening temperatures for developing a rapid and non-destructive assessment method to measure the ripening stages of red banana. A 5 volt sine wave AC power supply and a rectangular parallel plate capacitor circuit are used to measure the difference in dielectric properties caused by the introduction of a red banana in between the plates. The values of properties like capacitance and relative permittivity are increased continuously whereas impedance and admittance are decreased gradually with increase in ripening stages of red banana. In image processing approach, Noise Reductant Local Binary Pattern (NRLBP), Local Binary Pattern (LBP), Completed Local Binary Pattern (CLBP) based techniques are used for red banana's ripening grade determination. The processing stages involved are enhancement, Binary Pattern generation and classification. The variant Binary patterns are tested on noisy as well as noiseless condition and the results are compared. A novel enhancement technique for banana ripening grade determination is proposed based on segmentation using Tsallis entropy. Also novel idea on the automation of q parameter involved in Tsallis Entropy is implemented. The threshold parameter of the Noise Reductant Local Binary Pattern (NRLBP) varied and its effect on classification rate is studied. A new modification is proposed and implemented on NRLBP to accommodate uniform background and areas with the image. Classification is done using Chi-Square distance/nearest neighbor and Fuzzy C means (FCM) clustering. The results are compared and superiority of FCM method for banana ripening grade determination is noted.

1. Introduction

Banana is one of the important fruits in India having total annual world production of 86 million tons in which India leads the major production of banana with an annual output of 14.2 million tons (NHB, 2014). Red bananas, also called as red Dacca bananas are a variety of banana having reddish-purple skin and it is smaller, plumper and sweeter than the common Cavendish banana. At fully ripening stage, the flesh of red bananas is cream to light pink in color having a slight mango flavor with higher nutritional and calorific value, containing large amounts of potassium, Vitamin C and β-carotene (NRCB, 2005). In banana, the ripening can be assessed by using standard color charts available commercially in which 7 stages of peel color are reproduced and translated to a numerical scale. But for red banana, still there is no standard color chart available which significantly decreases the value, export potential and commercial uses of red banana. Normally for local market distribution, banana is harvested at over mature stage, so difficult to maintain the quality for export purpose. Hence, it's important to harvest fruit at the right maturity stage to suit the purpose. Therefore, a non-destructive method of approach for the assessment of ripeness of banana is mostly required. Many researches have already done for quality and maturity determination of fruits like apple, avocado, mango and tomato (Halm, 2004; Kim et al., 2009; Lee, 1981; Lien et al., 2009) which require expensive laboratory equipment facilities. Therefore, for the estimation of ripening level of banana, a non-destructive method of ripening assessment with easy operative application is needed to institute among which dielectric spectroscopy is found to be a promising technique for quality evaluation of food now a day. The electrical measurement technique has already shown its best potential for quality evaluation of banana and some agricultural products like common bean and eggplant (Berbert et al., 2002; Wu et al., 2008). Determination of moisture content of grains is done using dielectric properties (Ragni et al., 2006). Many studies are already being carried out regarding dielectric characterization since last 40 years (Nelson, 1973; Venkatesh and Raghavan, 2004). These studies are investigated for fruits, vegetables (Nelson, 1983), grain (Nelson, 1965) and other

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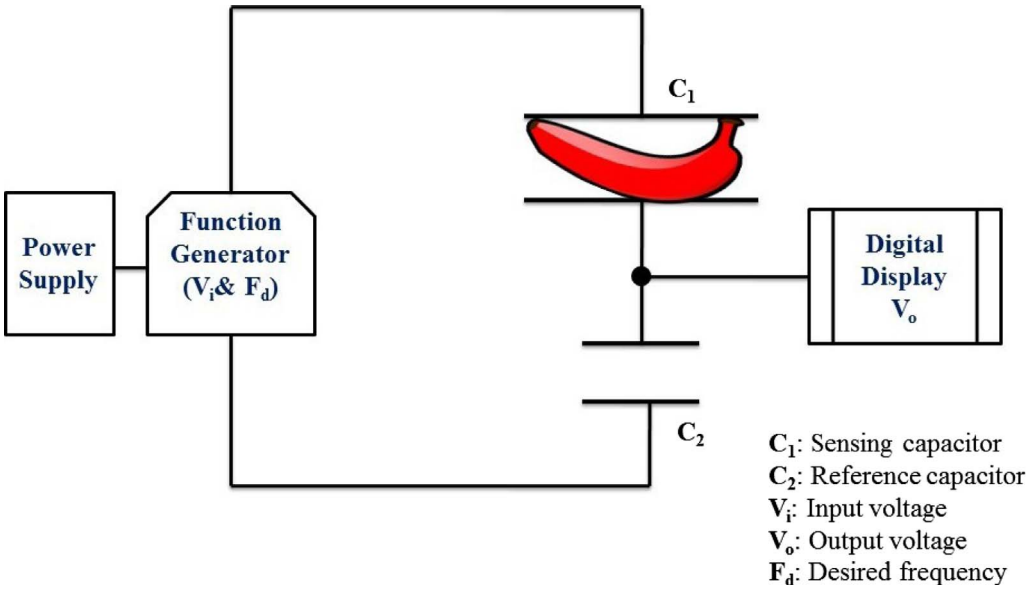

Fig. 1. Schematic circuit diagram of dielectric properties measurement system of red banana.

products. Also dielectric properties of grains, fruits and vegetables are investigated by checking the dependence of these parameters on temperature, moisture content and frequency (Nelson, 1965, 1973, 1983; Nelson and Bartley, 2002). Dielectric properties of watermelon are measured and correlation is done using quality parameters like soluble solids content (Nelson et al., 2007, 2008). Mathematical modeling of banana fruit is done for estimation of the volume, surface area and projected area (Soltani et al., 2010).

The image processing approach is another non-destructive technique which involves the enhancement, segmentation, feature extraction and classification. Image enhancement is used to make the image better for easy further image processing operations. Machine vision system or computerized image analysis method is a successful technique for quality evaluation of various fruits (Bato et al., 2000; Riyadi et al., 2007; Roseleena et al., 2011; Rodriguez-Pulido et al., 2012).

The image analysis is performed by the Local Binary Pattern (LBP) and the variants of the LBP. The LBP is sensitive to noise. The Local Ternary Pattern (LTP) partially solves the problem (Ren et al., 2013). The Noise Reductant Local Binary Pattern (NRLBP) shows greater noise resistance compared with other approaches, Gaussian noise and uniform noise of different noise level is added for testing in this process. A completed modeling of LBP (CLBP) operator is proposed (Guo et al., 2013) and is developed as a scheme in image analysis. Three code maps are combined to form the final CLBP histogram. In noiseless case, this CLBP method will be significantly useful since the magnitude factor is also taken into account. Due to inherent noise present in red banana images the NRLBP will prove to be significantly useful in banana ripening index classification. In this research work the histogram is used as feature vector where the histogram bins represent the various pattern obtained. Image descriptor is very much suitable as it has good tolerance to changes in illumination, perspective distortions, blurring of image, image zoom, robustness on flat image areas, computational efficiency, long histograms (256 bins in case of LBP) sensitive to image rotation, small spatial area of support and loss of local textural information. It has a number of variants such as Completed Local Binary Pattern (CLBP) and Noise Redundant Local Binary Pattern (NRLBP). The NRLBP coding scheme encode the input pattern as an uncertain state first and then its matching uniform patterns are found out. The Chi-square test is used for finding similarity of histogram (Oakes et al., 2001). Banana ripening index matching is the process used to determine whether two sets of banana have the same ripening index. The banana ripening grade determination and banana ripening index matching requires less computational timing complexity when use with enhancement.

This paper aims to study the changes in dielectric properties during the ripening process and image processing of red banana for the estimation of the ripening level and also aims to apply the dielectric properties measurement technique and image processing technique for the ripening assessment of red banana.

2. Materials and methods

2.1. Fruit materials

The red banana is procured from the local farmer of Thanjavur district, Tamil Nadu, India. The banana fruits have been stored at 25 °C temperature when transferred and stored in the ripening chamber of IICPT. The experiment is carried out in ripening chamber with fruits kept at humidity level of 85–88% and different ripening temperatures like 15.5 °C, 22 °C, 28 °C and control (30 ± 2 °C) for 14 days, 9 days 8 days and 7 days respectively, the time needed for completing the ripening treatment of fruits from a stage of fully unripen to fully ripened. Ethylene gas with 100 ppm concentration is treated about 24 h on first day and subsequently the experiments are conducted.

2.2. Measurement of dielectric properties

The dielectric properties like capacitance, relative permittivity, impedance and admittance changing during the ripening process of red banana are measured by constructing a dielectric properties measurement system as a standard hardware instrument basing on the parallel plate capacitance technique as shown in Fig. 1. The system consists of two copper plates having dimensions 250 mm × 75 mm × 2 mm which act as conductive plates because of its consistency which would not be easily ionized as a factor that will ruin the results of experiments. The capacitance of capacitive sensor is measured by a voltage divider circuit shown in Fig. 1 using the formula given in Eq. (1):

$$\frac{V_o}{V_i} = \frac{C_1}{C_1 + C_2} \quad (1)$$

Where, V_O = Output voltage of the circuit, in Volts
V_i = Input voltage of the circuit = 5 V
C_1 = Sensing capacitance, in Pico Farad
C_2 = Reference capacitance = 10 pF
C_2 is chosen as 10 pF to maximize the circuit sensitivity.