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Non-destructive quality monitoring of stored tomatoes using VIS-NIR spectroscopy

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ABSTRACT

The postharvest quality and storage life of vegetables are controlled by maturity due to their cells still alive after harvest and continue their physiological activity. The objective of this study was to monitoring physico–chemical quality parameters of intact tomato (*Lycopersicum esculentum*) during storage (18 °C, 85% RH) for 12 days, based upon visible/near-infrared (VIS/NIR) absorbance spectroscopy from 350 nm to 1050 nm. Partial least squares regression (PLSR) was applied to estimate soluble solids content (SSC), Titratable acidity (TA), and lycopene content of the tomatoes. The PLSR calibration model with SSC at 12 days storage, gave the highest coefficient of determination (R^2) = 0.91, root mean squared error of prediction (RMSEP) = 0.285 and bias = −0.003. While the lowest R^2 with lycopene (0.73) and bias of −0.002 at harvesting day. Changes of sweetness index (SI), SSC, TA and lycopene content varied from 7.16 to 11.39, 4.25 to 5.51 °Brix, 0.5936 to 0.4837% and 8.65–42.69 mg/kg fresh tomato, respectively. While, Hunter colour values L*, a*, and b* were changed from 60.5 to 38.86, −2.85 to 36.59 and 37.07 to 30.92, respectively. The results showed that physico–chemical quality parameters changes significantly during storage of turning maturity tomatoes and have potential application in the field of post-harvesting.

1. Introduction

Tomato is one of the most important vegetable food crops of the world which widely consumed either fresh or processed form. Tomatoes can make people healthier and decrease the risk of conditions such as malignant neoplastic disease, osteoporosis and cardiovascular disease, due to the antioxidant content of their main compounds (Bhowmik et al., 2012). Carotenes are one of the most important antioxidants in tomatoes (Jacob et al., 2010), and lycopene is the prevailing carotenoid in tomatoes and significantly depending on maturity stage, variety and environment of tomatoes (Brandt et al., 2006; Ali and Ismail, 2014).

Most of conventional methods lead to a measurement of tomato physico–chemical parameters are time and effort consuming as well their being destructive (Saad et al., 2014). Moreover, there would be need for instruments and preparation of samples for each property determination (Nikbakht et al., 2011). For economic reasons, near infrared (NIR) spectroscopy was using as cheap, fast, user friendly and accurate for quality assessment and sorting of vegetables. NIR spectroscopy has been widely used to measure tomato quality (Lee et al., 2014). There are some quality criteria of tomato such as soluble solids content (SSC), lycopene content and colour affecting on consumer appreciation for selection (Shao et al., 2007). The mostly change in the interactance spectra in green tomatoes is useful for predicting changing maturity levels occurred in the 600–750 nm portion of the 400–1000 nm region (Tiwari et al., 2013). Thus the application of the Vis/NIRS technique at spectral range 400–2350 nm could be successful for estimate the quality properties of tomatoes (He et al., 2005). Many parameters are

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related to tomato maturity stage (TMS) as colour, lycopene content, firmness, TA, pH, and SSC. Clement et al. (Clement et al., 2008) developed a regression model to predict TMS with RMSEP of 0.259 and R^2 of 0.93 by VIS/NIR spectroscopy. The TA and SSC are important components of flavour. Tomato fruits high in both acids and sugars have good flavour, while bland tomatoes have low acidity and tart tomatoes have low sugar content (Yahia and Brecht., 2012). The PLSR model used for building up a calibration model to predict acid-Brix ratio in tomato juice at wavelengths ranging from 1059.5 to 1124.8 nm (Jha and Matsuoka, 2004). VIS-NIR spectroscopy coupled with PLS regression models can be adopted successfully for determining the optimal harvest time of tomatoes (Yang, 2011). So the PLS is not only to estimate the component concentrations, but as well to distinguish the chemical and physical properties from VIS/NIR spectra (Gomez et al., 2006). Harvesting immature tomato leads to reduces sugar import, and starch degradation during the postharvest, which is both inadequate and undesirable (Balibrea et al., 2006). While picking the fruit at a later stage, that would allow more sugar accumulation ripest fruit is easily damaged and also has a short shelf-life (Reid, 2002; Toivonen, 2007; Watkins, 2006). Consumer preference to any fruit is driven by external aspect and some of physiological parameters (Jaiswal et al., 2012). Colour measurements have been used as quality parameters and indicator of some inner constituents of the material (Jha, 2010). The complexity of tomato colour is due to the presence of a diverse carotenoid pigment system, their appearance being conditioned by pigment types and concentrations, and subject to both genetic and environmental regulation. During tomato ripening, red colour is the result of chlorophyll degradation as well as synthesis of lycopene and other carotenoids, as chloroplasts are converted into chromoplasts (Lopez Camelo and Gomez, 2004; Radzevicius et al., 2008, 2009).

Therefore objective of this study was to study the feasibility of monitoring the changes in physico–chemical parameters of tomato during storage based upon VIS/NIR spectroscopy, and establish calibration models to predict non-destructively the quality of tomato.

2. Materials and methods

A 180 of fresh tomatoes (Naveen hybrid variety) samples were picked in their turning maturity stage from Central Institute of Post-Harvest Engineering and Technology (CIPHET) farm and brought to the laboratory. Fruits with uniform size, colour and free from damage and fungal infection were washed twice with water. They were then drained and surface dried in air. The turning maturity stage was determined in the laboratory according to a*/b* colour index (Lopez Camelo and Gomez, 2004).

Fruits were stored in the refrigerator for 12 days at 18 °C and RH 85 ± 1%. All measurements, including spectral data collection, weight loss and physico–chemical quality parameters (colour, SSC, sweetness index (SSC/TA), and lycopene content) determination were carried out in four times at day of harvesting and after 4, 8, and 12 days during storage, starting with the non-destructive measurements.

Spectra data were directly measured in absorbance mode, along the whole tomato using VIS/NIR spectroscopy (Avantes BV, Netherlands) in a spectral region of 299–1100 nm. A USB cable was employed for the data transmission between the spectrophotometer and a portable computer. A blank scan was carried out before each set of analysing samples. For each fruit, spectroscopy scanning was made in four measurements (two at the distal area and two under equatorial zone in different fruit directions) and the average of it was used in the analysis.

Weight loss was defined according to the following equation:

$$\text{Weight loss}, \% = \frac{\text{Initial fruit weight} - \text{Final fruit weight}}{\text{Initial fruit weight}} \times 100 \quad (1)$$

The colour of tomatoes in terms of L*, a*, b* values were determined using HunterLab mini Scan XE Plus colorimeter (HAL, USA, Model 45/0-L), L* denotes the lightness or darkness, a* green or red and b* blue or yellow colour of the samples. The each colour record was an average of four measurements of every tomato fruit (two at the distal area and two under equatorial zone in different fruit directions). Before measuring, the colorimeter was standardized with black and white calibration tiles provided with the instrument. Colour index (a*/b) was calculated according to Lopez Camelo and Gomez (Lopez Camelo and Gomez, 2004).

After colour and spectral measurements, each tomato fruit was cut into four equal pieces and extracted juice from every piece by using manual stainless steel squeezer, and the resultant tomato slurry was filtered through two layers of muslin fabric. The filtered tomato juice was applied for chemical reference analysis.

Soluble solids content (SSC) value was measured using portable digital refractometer (ERMA, Japan) with a scale of 0–32 °Brix (least count 0.2°Brix) at room temperature (~30 °C).

Sweetness Index (SI) was determined by following procedures outlined by Agbemavor et al. (Agbemavor et al., 2014) and expressed according to the following relation.

$$\text{Sweetness Index (SI)} = \frac{\text{Soluble solids content (SSC)}}{\text{Total Titratable Acidity(TA)}} \quad (2)$$

Total titratable acidity (TA) was determined according to the AOAC official method 942.15. Five grams of tomato juice diluted in 25 ml of distilled water and titrated by 0.1 N sodium hydroxide (NaOH) to pH 8.1. Titratable acidity as percentage of citric acid was estimated by the following equation.

$$\%\ \text{citric acid} = \frac{\text{Titre value (ml)} \times 0.1\ \times 0.064 \times 100}{5\ \text{g of juice}} \quad (3)$$

Where: 0.064 = Milliequivalent weight of citric acid and 0.1 = The normality of NaOH.

Lycopene content was estimated by using (4 ± 0.01 g) of tomato juice deposited into a 200 mL flask wrapped with aluminium foil to keep out light. A 100 mL mixture of hexane-acetone-ethanol, 2:1:1 (vol/vol%), was added to the flask and agitated continuously for 10 min on a orbital shaking incubator, after that, 15 ml of water was added followed by another 5 min of agitation. The solution was then left to separate into distinct polar and non-polar layers and filtered using filter paper (Whatman grade 42). Lycopene concentration was calculated by measuring the absorbance of the extract containing lycopene at 503 nm by UV/VIS Spectrophotometer (SHIMADZU, Japan, Model UV-1800) using hexane as a blank (Ranveer et al., 2013). Each sample of fresh tomato was extracted twice in triplicate analysis, yielding six results for each fresh tomato. The lycopene concentration was calculated using its specific extinction coefficient (E1%, 1 cm) of 3120 in hexane at 503 nm. The lycopene concentration was expressed as mg/kg fresh tomato, and calculated by the following equation.

$$\text{Lycopene(mg/kg fresh wt.)} = (A_{503} \times 537 \times 100 \times 0.55)/(4 \times 172) \quad (4)$$

$$= A503 \times 42.9 \quad (5)$$

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