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Ripeness and rot evaluation of 'Tommy Atkins' mango fruit through volatiles detection

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ABSTRACT

An ultra fast GC (zNose™), based on an uncoated surface acoustic wave sensor, was employed to detect the volatiles of 'Tommy Atkins' mango fruits. The detected volatile signals were used to identify rot occurrence and evaluate mango ripeness during shelf life. Respiration rate, color, and total soluble solids (TSS) were measured accordingly to indicate mango quality status. Two peaks detected with the zNose™ predicted rot occurrence with 90% and 87% accuracy, respectively, while another peak was 80% accurate in predicting ripeness with respect to a reference color index. Partial least squares (PLS) regression combined with variable importance for projection (VIP) was used to select the peaks important in prediction. The rot prediction methods could have potential applications in the mango industry for the diagnosis of the occurrence of mango rots.

1. Introduction

Mango [*Mangifera indica* L.] is one of the most important tropical fruits marketed throughout the world. The fruits are normally harvested at the green mature stage and then transported and stored at low temperatures (10–15 °C) to extend their shelf life (Snowdon, 1990). However, severe post-harvest diseases still occur, resulting in rot contributing to substantial post-harvest losses (Beyers et al., 1979; Pantastico et al., 1984; Pesis et al., 2000). Hence, there is a need to monitor the disease severity and rot occurrence during the shelf life of mangoes in order to prevent the spread of diseases. Evaluating maturity and ripeness is another important issue for mango industry. Presently the pre-harvest maturing of mango fruits is estimated by size, sphericity, firmness, total soluble solids (Jha et al., 2006) and post-harvest ripening is often evaluated by respiration rate, skin color (Lalel et al., 2003), texture softening (Yashoda et al., 2006), etc.

An attractive flavor is one of the characteristics that make mango a highly prized fruit. The varying flavor at different stages of harvest and after certain storage time is not only distinguishable by human senses, but also reflects physiological and biochemical changes. Some studies of different mango cultivars' volatiles have been undertaken (Macleod and de Troconis, 1982; Macleod and Pieris, 1984; Idstein and Schreier, 1985), and flavors at different developmental stages have also been compared (Ibanez et al., 1998; Lalel et al., 2003). Unfortunately, all the methods used in these studies, including GC, GC/MS and SPME, are labour and time intensive, making their application outside the laboratory almost impossible.

In recent years, electronic noses have been employed to evaluate fruit flavor, and a number of applications for different fruits have been reported: apple (Saevels et al., 2004), mandarin (Gomez et al., 2006), orange (Natale et al., 2001), and peach (Natale et al., 2002). In terms of mango, Lebrun et al. (2008) recently achieved partial success in using an e-nose FOX 4000 to discriminate mango maturity. However, no fast and practical method has been reported for ripeness and rot prediction.

In this study, an ultra fast portable GC (zNose™) was employed to detect mango volatiles. The specific objectives were:

(1) To predict rot occurrence of mango fruits by detecting volatile signals;
(2) To evaluate mango ripeness over the period of their shelf life.

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Nomenclature

B	predictor coefficient in PLS regression model
Cts	counts
GC	gas chromatography
GC/MS	gas chromatography/mass spectrometry
PLS	partial least square
RR	respiration rate
RT	retention time
SAW	surface acoustic wave
SPME	solid phase microextraction
TSS	total soluble solids
VIP	variable importance for projection

2. Materials and methods

2.1. Experimental materials and procedure

One hundred and twenty mango fruits of cv. 'Tommy Atkins' (*Cocanmex S.A. de C.V.*), selected to be as green as possible, were obtained from a local fruit distribution company (Aliments IMAX Foods Inc., Montreal, Quebec) and stored at room temperature (20–22 °C) without any treatment. Twelve mangoes were used as control samples and the remaining 108 as regular samples. The control samples were measured every day for 31 days until all were rotten. In contrast, the 108 regular samples were randomly chosen, measured, and then discarded.

Airtight glass jars (2.3 l) were used for both respiration rate (RR) and volatile measurements. An aperture was made in the metal cover, fitted with a rubber septum for gas sampling and sealed with Teflon sealant. The containers were tested to be free of zNose™-detectable volatiles when empty. A single mango was put in a container for 2 h at room temperature (20–22 °C), prior to measurement. This equilibrium time was obtained from preliminary experiments where, in 10 h, the volatiles signal reached 80% of its highest value within 2 h (results not shown). Fruit weight was measured with an electronic scale.

2.2. Respiration rate (RR)

Gas samples (5 mL each) were taken from the glass jar, CO_2 and O_2 were measured with a SRI 8610A Gas Chromatograph (SRI Instruments Inc., Las Vegas, USA). The sensor temperature of the Gas Chromatograph was set to 55 °C and the flow pressure was 70 psi (482 kPa). The measured RR was compared with the volatile profiles acquired from the zNose™ in an attempt to assess ripeness of mango fruits. All measurements were repeated twice and mean values are reported.

2.3. Volatile detection system

A zNose™ (7100 Fast GC Analyzer, Electronic Sensor Technology, New Bury Park, CA, USA) was used for volatile compound detection. It is actually a miniature, high-speed gas chromatograph (GC) containing a detector, a short separation column, and support electronics.

The detector of the zNose™ is an uncoated, high quality surface acoustic wave (SAW) crystal. The crystal operates by maintaining high frequency acoustic waves on its surface. The targeted compound lands and sticks on the detector and changes its frequency. The frequency change is measured by a microcontroller and processed by software, allowing the compound to be identified and quantified.

Before the volatile compounds reach the detector, they are separated by a short column (DB-5). The time a given component remains in the column is recorded as its retention time (RT), which is supposed to be unique for each specific chemical, while the derivative of frequency signal is used as a quantitative measurement of the quantity of the chemical (area under a peak, expressed in Counts).

The zNose™ employs headspace and bubbler techniques as its sampling modes. A side Luer needle was used as a sample odour injection tool, and a spark needle as the bubbler generator. A rotating valve was used to switch the machine from sampling configuration to an inject configuration. A trap was used as a preconcentrator to collect and hold volatile samples, and high grade helium was used as the sample carrier gas.

All samples in this experiment were tested using the following mode of operation: sampling through side Luer needle for 10 s, separating different compounds in the column for 14 s, acquiring a frequency signal every 0.02 s for 20 s, and baking the sensor for 30 s. The sensor detection temperature was set to 60 °C. Column temperature was ramped from 40 °C to 180 °C at the rate of 10 °C s^{-1}, while the sensor baking temperature was 150 °C. The carrier gas flowed at a rate of 3.0 cm^3 s^{-1}. Between each measurement, at least one air blank was run, such that baseline peaks were all under 200 Counts before resuming sample runs. All measurements were repeated twice and mean values are reported.

2.4. Subjective assessments of ripeness and rot

Disease severity was assessed by evaluating the percentage of fruit surface covered by black lesions (Kobiler et al., 2001). The arc length of a lesion was measured with a soft ruler and the surface area of the spherical calotte was calculated, and thus the corresponding percentage obtained. However, as the lesions did not present a perfectly spherical calotte and the mango fruits were not perfect spheres, the calculated percentage value was assigned to the nearest 5% step percent (i.e., 0%, 5%, 10%, etc.) by combining visual observations. The degree of rot was continuously monitored until 50–70% of the surface area was damaged.

Ripeness development was assessed by viewing the mango fruit's skin. A color index was recorded according to the following rating scale (Shorter and Joyce, 1998): (1) 100% green; (2) 75% green; (3) 50% green and 50% yellow; (4) 75% yellow; (5) 100% yellow. The color index was proportionally converted from a percentage to a numerical value to facilitate comparison with respiration rate and volatile signals.

2.5. Objective color and total soluble solids (TSS) measurements

The skin color of mango samples was also measured with a tristimulus colorimeter (Chroma Meter CR-300, Minolta Co. Ltd., Japan) in the L^*, a^*, b^* color space. Four evenly distributed places along the equator were selected and a mean value was used. Three values were obtained: "L" measures lightness and varies from 100 for perfectly reflective white to zero for perfectly absorptive black; "a" measures redness when positive, gray when zero, and greenness when negative; and "b" measures yellowness when positive, gray when zero, and blueness when negative.

Total soluble solids (TSS) of 108 regular samples were measured with a handheld refractometer (ERMA, Japan) after RR, volatiles, and color measurements. Four pieces of flesh were drawn from