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Application of MOS based electronic nose for the prediction of banana quality properties

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ABSTRACT

This study deals with the examination of the ability of a low-cost electronic nose (e-nose) for prediction of banana quality indices such as total soluble solids (TSS), titratable acidity (TA), pH and firmness at different shelf-life stages. The relationships between sensor array responses of e-nose and quality indices of banana were established by means of partial least squares (PLS), multiple linear regression (MLR) and support vector regression (SVR) techniques. All models for firmness and TSS showed a good prediction performance. However for the TA and pH, there were a poor correlation with the signal of the e-nose in MLR and PLS models. The results proved that performance of SVR models for prediction of the quality indices of banana were better than others, with high correlation coefficients of the cross validation (R^2 = 0.8852 for firmness, 0.9608 for TSS, 0.7607 for pH and 0.7033 for TA) and relatively low RMSE values of 1.1716 for firmness, 0.9308 for TSS, 0.1523 for pH and 0.0267 for TA. Finally, these results demonstrated that e-nose has the potential of becoming a reliable instrument to estimate chemical and physical properties of banana from signals of an e-nose system.

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1. Introduction

In recent years, monitoring and controlling of fruits ripeness are a challenging issue in fruit industry since the state of ripeness during harvest, storage and market distribution defines the quality of the final product which is approved by customer preferences [1,2]. So far, many methods of shelf-life monitoring have already been proposed such as chemical analysis and spectroscopy techniques [3]. The main drawbacks of these methods are that they are not practical for commercial applications because they have destructive and labor-intensive nature. For example the ripening treatment of banana fruits has been accelerated through an experimental procedure by the experience of trained panelists into a programmatic ethylene gas control manner [4]. On the other hand, application of sensors such as optical, chemical, and tactile ones is in high correlation with the human senses. Most of the fruit quality measurement methods are destructive such as pulp to peel ratio determination and fruit firmness, which are mainly based on rheological properties [5]. Also, these methods do not sufficiently monitor the quality of banana fruits during ripening period [6].

Currently, bananas are cut at a mature-green stage and afterwards exported to consumer countries, so on-line quality control of banana during ripening treatment is quite important to keep a firm pulp texture, good color and flavor and also to prevent from bruise [6]. Fresh banana changes rapidly after harvesting and the color,

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firmness and flavor of the fruit are usually damaged during storage [7].

Aroma is one of the most important sensory properties of fruits and is particularly sensitive to the changes in fruits compounds. Gases involved in aroma of fruits are produced from the metabolic activities during ripeness, harvest, post-harvest and storage stages. However, more than 250 volatile components have been identified for banana [8].

Ethylene is the most important volatile component which constitutes about 50–75% of volatile components [9]. The aromatic components in green, ripe and full-ripe banana are 2-hexenal, eugenol and isopentanol [8]. However, the technique used for measuring aroma (GC–MS analysis) is time consuming, expensive and need a lot of experience.

In recent years, consumers and food processing industries are interested in non-destructive methods to estimate fruit internal quality [10]. Hence, technologies that classify the fruits according to their color, texture, taste, flavor and nutritive value would assure more fruit quality and consistency which in turn increases the consumer acceptance and satisfaction. Processing industries also compete with more profitability [11].

The e-nose is an instrument that mimics the sense of smell [12,13]. Using an array of chemical sensors of this device, complex odors could be detected and discriminated. The device is designed to detect and discriminate among complex odors using an array of chemical sensors [14]. As the sensor array is influenced by an odor stimulus, it generates a smell print. The response of the sensor array presents an electronic fingerprint characteristic of each sample [15]. All of these fingerprints construct a recognition pattern, qualitatively analyzed using an appropriate multivariate tool [16]. Providing real-time information, such characteristics greatly facilitate the application of the e-nose for fast monitoring of the volatile components of fruits [17,18].

Several studies have been done on the use of e-nose for assessing fruit quality and ripening [2,19]. Some experiments have been performed for apples [20–22], peaches [23–25] and tomatoes [26,27]. Gomez et al. [28,29] investigated the volatile production change of ripeness stages (unripe, half- ripe, full-ripe, and over-ripe) of tomato and mandarin, using an e-nose with ten different MOS sensors. Their proposed e-nose could differentiate among the ripeness stages of tomato with 100% correct classification, and among the ripeness stages of mandarin with 92% success rate.

There are few researches regarding to the relation of volatile compounds and the chemical and physical properties of banana during the ripeness process. Several works have recently reported that the e-nose signals can be correlated with the fruit quality indices. To perform an objective assessment of the e-nose system, it is quite necessary to compare e-nose predictions with fruit quality indices.

Brezmes et al. [30] used an e-nose system, consisting of 21 MOS sensors array, in order to assess the ripeness state of apples during their shelf-life. From discriminant analysis of the results, an e-nose could effectively classify the apples into three maturity groups with 83% correct classification. In order to investigate the e-nose performance, fruit quality indices, such as firmness, starch index and acidity, were also obtained to compare the results obtained with signals of e-nose. The results clearly indicated that the e-nose signals are related to the ripening process of apples.

Zhang et al. [24] investigated the predictability of an e-nose system for "xueqing" pear quality indices (firmness, total soluble solids and pH). The multivariate techniques were applied to predict the quality indices of "xueqing" pear prepared from different picking dates based on the signal of e-nose. The prediction models for firmness and total soluble solids indicated a good prediction performance, but for acidity, there was a very poor correlation with the e-nose signal.

There exist few reports concerning the use of an e-nose for analyzing banana ripening. A MOS sensor array was used by Llobet et al. [31] to calculate the performance of a neural network- based e-nose in determining bananas ripeness. The system was simple and ripening standard conditions in warehouses were not considered.

The objectives of the present research were to evaluate the ability of an e-nose system to monitor total soluble solids (TSS), titratable acidity (TA), pH and firmness of banana through comparison with standard destructive techniques to assess the respective shelf-life characteristics and developed models to predict the quality indices through the sensor array responses of the e-nose. Some multivariate techniques are employed to reach these objectives.

2. Materials and methods

2.1. Experimental material

Banana fruits (Cavendish variety) imported from the Philippines were used in this research. The banana fruits had been stored at 14 °C during transportation. Then, the fruits were stored in an airtight warehouse. Bananas' ripening is completed during 4 days. In the first day, fruits are stored at 20 °C, and in the second day, ethylene is injected. In the third day, ethylene is removed and temperature is decreased to 18 °C and finally temperature is decreased so that it achieved to 11 °C in the fourth day. Controlling temperature, humidity and ethylene gas concentration in the ripening room are very important. Bananas were kept in the warehouse at the humidity level of 85–88% for 4 days, as this time period is needed for completing the ripening treatment of fruits. At this period, ripeness is assessed visually by comparing the peel color of banana with standardized color charts describing various stages of ripening.

Before entering the warehouse, bananas are in the first ripening stage and after leaving the warehouse, they are in the fifth ripening stage. For performing the experiments, 15 bananas of the same size, weight and ripening stage, were daily transferred from the warehouse to the Lab during December 2012. The bananas were picked from the same position of each branch. Then e-nose tests were done on the samples till the fifth ripening stage. Moreover, all the measurements were performed in the day of transfer-

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