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Electronic nose based on partition column integrated with gas sensor for fruit identification and classification

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ABSTRACT

An alternative model of electronic nose systems by applying a combination of partition column with gas sensor was investigated for fruit classification and identification. The principle of physical and chemical separation in chromatography analysis known as an interaction between stationary phase material and compounds is able to profile the flavor sample; thus it is potentially implemented to substitute function of the sensor array on the conventional electronic nose. The electronic nose consists of a sample handling with combination of solenoid valves, a packed partition column coupled with a gas sensor as detector operated under a controlled temperature and data analysis software by using a neural network. The system was tested to classify three different flavors of fruit, i.e. durian, jackfruit, and mango. The result showed that it can generate reliable and repeatable chromatograms, from which, a unique pattern among samples can be extracted. Therefore, the patterns are able to be clearly classified with the neural network. The experiment showed that it can recognize the three different flavors with the level of accuracy of 82%.

1. Introduction

Quality monitoring system plays an important role on the food preparation and processing especially in industry. It is necessary to guarantee and maintain quality of the food product. Since food quality is not only responsible for nutrition but it also corresponds to the consumer perception, monitoring for both quality aspects, nutrition and perception, is usually conducted simultaneously. As responsible for the perception, the quality parameter cannot be separated from the human sense, by which, the food quality is measured. The assessment does not measure the amount or type of the nutrition substance but it more emphasis to the sensory acceptance of food including sense of visual appearance, taste, smell, or touch. Regarding on smell or taste, the flavor strongly influences the quality of food. In short, the acceptability of foods is still determined by their flavor. The role of flavor for quality characterization is becoming more important for such fresh food particularly for fruits.

Although flavor is associated to the compounds or substances found in food, because it is closely related to the human sense, it is often associated with overall sensations sensed when human smell or taste the food. Since the common food flavor contains of compounds either those are responsible for taste or those are responsible for odor which are often nominated as the aroma substance (Belitz et al., 2009), the two groups have different character. Compounds corresponding for taste are usually non volatile, while the other group of aroma substance is usually volatile at room temperature, for analysis reason, both of quality parameters are measured simultaneously through two ways, either by consuming or smelling them. The assessment is also known as sensory test. Because the assessment method directly relates to the human perception, up to now, food industries still give trust to the method for measuring their product qualities.

In general, the sensory test is conducted by a group of panelist, ten or more person in a group, for scoring or recognizing well-defined flavor parameters. Although each sample being analyzed has been prepared with a standard procedure, the test often yields an inadequate final result. Beside the assessment accuracy is strongly influenced by the panelist ability, psychological factor which often determines the perception can influence the final test result. Furthermore, quality assessment by human sense is difficult to be quantified, error prone, inconsistent, and therefore, it is becoming an expensive and labor intensive measurement for routine quality application (Xiaobo and Jiewen, 2008). Therefore, development of measuring devices is necessary for helping or substituting the role of human in the assessment. An electronic nose is one of the demanding instruments.

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Electronic nose is a model of an artificial olfaction inspired by the biological olfactory system which is able to detect, identify and classify an aroma (odor) of a sample (Pearce, 2003). This electronic nose usually adopts the process of odor sensing technique in the biological olfactory system. Basically, a biological olfactory system, either in human or animal, classify or recognize an odor sample when for such volatile compounds entering into the nasal cavity, inside which sensitive smell receptors are located. Each receptor releases a chemical signal which will be transmitted into the olfactory bulb organ. In the organ, signal combination from some receptors is then transformed in physicochemical pattern, by which, odor sample can be identified by the brain as nerve center of the olfactory system. This principle underlies experts for developing an electronic nose by applying several dissimilar sensors in one array. Some applications of the electronic nose model have been reported, i.e. for detection of bread baking aroma (Ponzoni et al., 2008), description of mango fruit maturity (Lebrun et al., 2008), discrimination of coffee aroma (Radi et al., 2012), evaluation of the optimal harvest date of apple (Saevels et al., 2003).

Although combination of several sensors may able to generate distinctive fingerprint pattern, by which, a sample can be identified; its application for food products still has disadvantages. Beside because of limited number of available sensors responsible for food flavors, the complexity of compounds found in food becomes main obstacles on the conventional electronic nose in the real application. Food flavor usually contains of a large number of compounds, for example, more of 800 compounds are presented in foods produced by thermal process or by combination between thermal and fermentation process (Belitz et al., 2009). Moreover, the compounds are only available at low concentration as well as flavor obtained at fresh foods like vegetables and fruits. Therefore, finding alternative models of electronic nose becomes objective in some researches. One model recently studied is developing electronic nose by applying a chromatography column for generating a fingerprint pattern.

Previous study by using gas chromatography method coupled with gas sensor array for rapid test in food industry processes has been conducted by Bauersfeld et al. (2008). This system was characterized by flavor candidates like methyl pyrole, hexanal, pinene, ethyl butyrate and limonene. The result showed that the model was able to respond them till to few ppb of each sample's concentration. A similar model of an electronic nose by applying gas chromatography with QCM sensor detector has been investigated by Rivai et al. (2011). The study resulted that the system could discriminate the common organic solvents, not only for compounds of a particular class but also for compounds responsible from different classes. Another research was also conducted by Sklorz et al. (2013) who applied a miniaturized packed gas chromatography column and a SnO_2 gas detector for detecting ethylene substance. Moreover, Oh et al. (2008) studied the fast gas chromatography combined with a surface acoustic wave sensor for determination of floral aroma with the target of lilac blossom. From the reported papers, no one reported the application of combination such chromatography column with gas sensor particularly for fruit classification and identification. Suppose each flavor of fruit distinguished by the human senses contains a number of different chemical composition, each compound has different concentration among fruits, the application of the combination of chromatographic column with gas sensor in the electronic nose system may able to provide better results. Some successes of food analysis by using such gas chromatography apparatus in recent decade can represent the future advantages of the new model of the electronic nose.

2. Material and methods

2.1. Sample

Three kinds of fruit with strong scent were prepared as material of study, namely durian (*Durio zibethinus Murr*), jackfruit (*Artocarpus heterophylus*) and 'pakel' mango (*Mangifera foetida*). The samples were prepared on full ripening condition indicated from their strong aroma, soft flesh, and color.

2.2. Device setup

This study used an electronic nose based on combination of a chromatography column (partition column) and a gas sensor. The device has four main parts, i.e. odor handling and delivery system, column and detector, signal conditioning, and data analysis software. The odor and delivery system was constructed by a sample chamber (vial) combined with two 3-way solenoid valves and a mini air pump for shipping out the carrier gases. Since the combination of column and detector became the main part of the apparatus due to its contribution on the formation of aroma pattern, selecting an appropriate type of column and sensor should be concerned. The column was 1.25% bentone 34.5% sp-1200 in 100/120 supelcoport (24539) with size of 10′ in length and 1/8″ of diameter, while the gas sensor as detector was Taguchi gas sensor (TGS 2620). The packed column was nominated due to its common application for such analysis of volatile compounds in the gas chromatography apparatus, while the gas sensor provides a good response for such organic compounds. Therefore, this combination was hopefully matched for profiling the fruit flavor containing volatile organic compounds. Besides, the sensor which is designed from a sensing element consisting of an integration of a metal oxide semiconductor layer and a heater element in one chip makes it possible to be acquired in simple wiring. The integrated column and sensor was then installed inside a chamber operated under controlled temperature. Schematically, the experimental setup can be presented on Fig. 1.

2.3. Experimental procedure

The system was operated automatically in order to stabilize the amount of sample being analyzed. Each measurement consists of three steps, i.e. referencing, sampling, and profiling. The referencing step was used to obtain a baseline signal of the sensor without sample (sensor drift) which was fixed at 60 s at initial measurement. The next step was sampling which was set for 90 s, and 39 min for profiling. Besides, sample preparation prior measurement was adjusted for 120 s. Once measurement was finished, the system needed to be cleaned for 30 min. During measurement, the system was set at temperature of 60 °C. In order to optimize the flavor, the sample of fruits needed to be sliced into small size before measurement.

The procedure for each measurement could be detailed as follow. Amount of sample (fruit slices) was put into the sample chamber (vial). The vial's lid was then closed and leaved for 2 min (120 s). During the time, flavor containing volatile compounds was naturally emitted from the sample and concentrated on the chamber headspace. After that, the measurement was started. The pump pushed carrier gases, the gases directly passes through from the solenoid valve into the packed column for one minute. At this step, only clean air could flow inside the system. While the interval time reached the second minute, the flavor sample from the headspace were inserted into the column by activating the solenoid valve. In this step, the carrier gases were mixing with the volatile compounds, pushed them into the partition column. The sampling time was limited at 90 s. Once the sampling interval