Development of Robotic Sensing System for Food Analysis Application
การพัฒนาระบบการรับรู้กลิ่นในหุ่นยนต์สำหรับงานตรวจวัดคุณภาพอาหาร

Rotthaporn Palasuek (รถพร พละศึก)* Dr.Teerakiat Kerdcharoen (ดร.ธีรเกียรติ์ เกิดเจริญ)**

ABSTRACT

At present, robotic technology is in interest and handle in various applications especially in food application such as food processing. However, it is still lack in the field of food quality control. The electronic nose is a well-known device for food and beverage analysis and quality control. The electronic nose is a device mimicking mammal olfactory system with repeatable measurement and allowing detection and discrimination of complex odorants. In this work, we have been developed an electronic nose which is a device imitating biological human olfactory model, called simulator nose. The sensor array consists of 8 metal oxide semiconductor gas sensors performing as a human olfactory receptor. The discrimination of sour prawn soup by the simulator nose was observed and compared with a brief case electronic nose. The results indicated that the simulator nose can classify different types of sour prawn soup from different restaurants in various operation temperature.

บทคัดย่อ

ในปัจจุบันเทคโนโลยีหุ่นยนต์กำลังเป็นที่สนใจและนำมาประยุกต์ใช้ในหลากหลายงานโดยเฉพาะขบวนการผลิตอาหาร แต่อย่างไรก็ตามเทคโนโลยีนี้ยังไม่เข้าถึงการวิเคราะห์และควบคุมคุณภาพอาหาร จมูกอิเล็กทรอนิกส์เป็นเครื่องมือที่ใช้กันอย่างเผนแพร่ในงานวิเคราะห์แควบคุมคุณภาพอาหาร ซึ่งจมูกอิเล็กทรอนิกส์นี้เป็นเครื่องมือที่ประดิษฐ์ขึ้นโดยอาศัยการทำงานของจมูกของสัตว์เลี้ยงลูกด้วยนม ในงานวิจัยนี้ ผู้วิจัยได้พัฒนาจมูกอิเล็กทรอนิกส์ที่เลียนแบบโครงสร้างของจมูกคนทั้งด้านการรับกลิ่นและอากาศที่หมุนเวียนในระบบและเรียกเครื่องมือชนิดนี้ว่า “เครื่องจำลองจมูกคน” โดยเซ็นเซอร์ในการตรวจวัดกลิ่นทำมาจากเซ็นเซอร์โลหะกึ่งตัวนำไฟฟ้า (metal oxide semiconductor) ในการทดลองจะใช้เครื่องจำลองจมูกคนตรวจวัดต้มยำกุ้งเปรียบเทียบกับจมูกอิเล็กทรอนิกส์แบบกระเป๋าหิ้ว พบว่า เครื่องจำลองจมูกคนสามารถใช้ในการจำแนกชนิดของต้มยำกุ้งจากต่างร้านค้าในอุณหภูมิที่แตกต่างกันได้

Keywords: Electronic nose, Food analysis, Robotic technology

คำสำคัญ: จมูกอิเล็กทรอนิกส์ การวิเคราะห์คุณภาพอาหาร หุ่นยนต์

** Student, Master of Science Program in Materials Science and Engineering, Faculty of Science, Mahidol University*

*** Assistant Professor, Department of Physics, Faculty of Science, Mahidol University*

Introduction

In recent year, robotic technology is in attention. The robotic technology is applied in many fields in daily life such as military, life rescue and industries (Blitch, 1996; Khurshid, Bing-rong, 2004; Nourbakhsh et al., 2005). It can be indicated that robots will play an important role in various works together with using human source at the same time and in the future in some work field, robots will be used as a main worker source. In recent decades, many researchers are heavily studying the principle of human behavior and trying to develop robots to behave likely to human called humanoid. A humanoid robot is a robot that has body shape looks like human body but some humanoid robots have only some part of human organ such as head and hand for a specific purpose application (Miwa, 2001).

Cooking is an everyday task like walking, talking or other activities. However, we cannot cook in every meal or not everybody can do cooking well. Therefore, dining at restaurant is a convenient choice for time saving or getting delicious dish. From this reason, a large number of chefs is needed. It would be good if we have our individual chef to cook for us every day. That made scientists tried to develop a cooking robot. Recently, a robot arm has been studied and developed for cooking application. There is a robot arm was opened to the public. This robot operates by giving operation command to the system such as data of food or dish that it have to cook, food ingredients, amount of ingredient or time for cooking. Moreover, there is a robot, developed by researcher from University of Marryland, operates by learning object recognition from neural network which help the robot to memorize shape of object and human wrist movement to simulate cooking. The robot can learn how to cook by watching cooking lesson from youtube video (Yang et al., 2015).

Deliciousness is a scent defined from taste and odor of food that different in an individual person. To develop a machine that can detect odor and study the scent of smell, an electronic nose has been advanced. An electronic nose is in interest because of its versatile advantages in various applications especially in food industry. Many application areas related to food industry such as fish, meat, alcohol beverage, coffee and tea. Within each application, the detection has been focused on a number of aspects such as freshness, adulteration and bacteria detection (Falasconi et al., 2012; Guohua et al., 2012; Loutfi et al., 2015; Murakami et al., 2010; Papadopoulou et al., 2010; Roy et al., 2012; Tian et al., 2013).

In our research group, many electronic nose platforms were developed in recent 10 years. Each platform was designed with different transducing system to use with different applications. The most interesting application is food and beverage quality control. In 2010, we have developed a portable electronic nose based carbon nanotube (CNT)/SnO_2 gas sensors and applied it for alcohol detection in whiskeys. They found that CNT enhances the sensitivity of the hybrid SnO_2 material and directly affects the selectivity to methanol and ethanol. In the real application found that this instrument can demonstrate contaminating alcohol in whiskeys within 1% alcohol (Wongchusak et al., 2010). After that year, a portable electronic nose based SnO_2 gas sensor was utilized to observe the quality of wine products with bottling under vacuum and nitrogen gas. The results show that effect of bottling with nitrogen help the wine keep preserving. For conventional bottling method with vacuum, wine aroma continuously decrease after opening. For our lately application, an opto-electronic nose based thin films of porphyrin and phthalocyanine gas sensor were used characterize rice species. The results have shown that thin film gas sensors base metalloporphyrin and metallophthalocyanine can discriminate hexanal and octanal which are volatile compounds containing in fragrant rice which leading to the study of rice species by classification of Jasmine rice, White rice and mixtures of them (Palasuek et al., 2014).

In this work, a model of an artificial nose, called simulator nose, based function of an electronic nose has been developed for using in robot chef head. This device was designed and built up on the structure of human olfactory system. The sensing array acts as human olfactory nerves to detect odor molecules. Thus, the robot can detect smell like human which can process deliciousness of cooking food. Moreover, our sensing array is a plug-in object which easy to take in and take off with the robot system.

Objectives of the study

The aim of this study is to study and develop sensing system in the robot that use in food quality control.

Methodology

Electronic nose system

A home-made electronic nose consists of 3 main parts which are air flow system, sensing system and data acquisition system. In air flow system, 2 three-way solenoid valves were used to control switching of gas between sample and reference to go to sensor chamber. Typically, the sensing system consists of different sensor types with the different ability toward gas detection. Figure 1 is the diagram of e-nose setup with 8 commercial (Figaro) tin oxide gas sensors which have high responsibility to the volatile organic vapors. For the data acquisition system, the voltage divider method was used to measure the voltage across each sensor that connected to 10 kΩ resisters. The direct current (DC) 5 volt was applied to sensor heater to optimize the sensing temperature. Then, the output voltage was sent to multiplexer and the resistant of each sensor was calculated using Ohm's law.

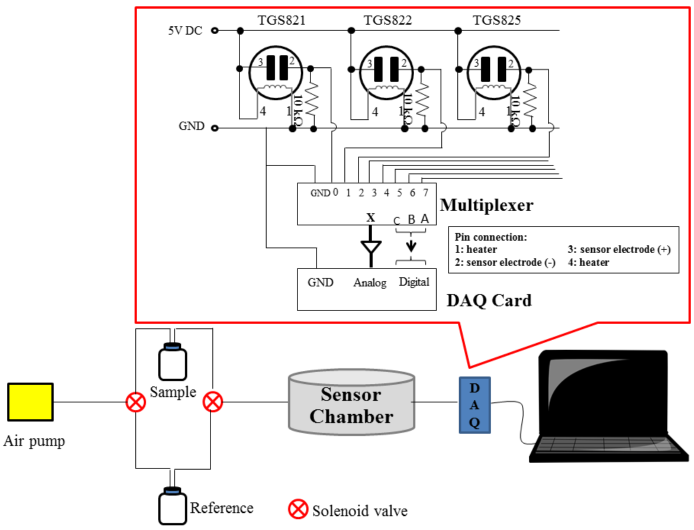

Figure 1 A brief case electronic nose system

Simulator nose system

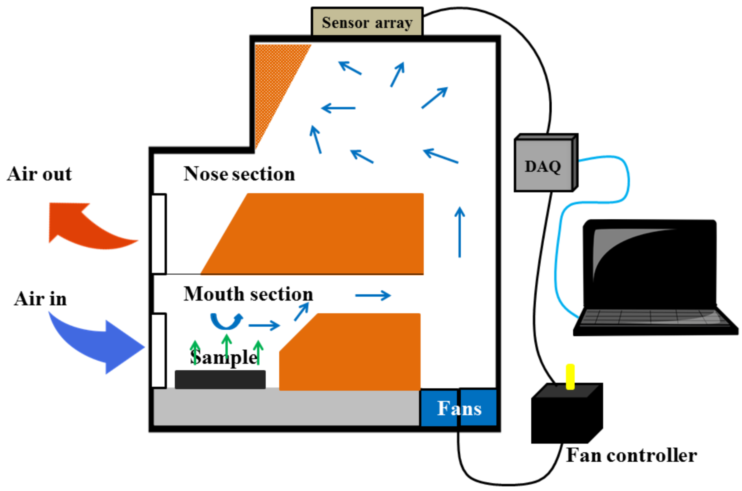

Figure 2 A simulator nose system

The simulator nose was developed to improve odor detection system of an electronic nose. This setup simulates human nose anatomy. The system is divided into 2 sections, a mouth section and nose section as shown in Figure 2. Casing of the simulator nose is made of polycarbonate. There are 8 different commercial tin oxide gas sensors (Figaro) function as human olfactory receiver with ability to detect various gas molecules. The change in sensor resistance and air flow system is controlled by LabView program through DAQ card. For the air flow system, there are 2 fans to control air inlet and air outlet to simulate human breathing with mouth and nose. When the air flow into mouth section, it carries odor molecule of samples go into nose section. Thus, the sensors can detect gas molecule which lead to change in sensor resistance. The data were sent to computer to differentiate sample types such as the sample is soft drink or alcohol beverage.

Experiment set up

Table 1 Specification of metal oxide gas sensors

Metal oxide sensor	Sensor	Target gas
TGS 821	S1	Hydrogen gas
TGS 822	S2	Organic solvent vapors
TGS 825	S3	Hydrogen sulphide
TGS 826	S4	Ammonia
TGS 2600	S5	Air contaminants (H_2, CO)
TGS 2602	S6	Air contaminants (H_2S, toluene)
TGS 2610	S7	LP gas
TGS 2620	S8	Organic vapors

First, the compounds containing in different types of sour prawn soup, which are sour prawn soup (mild soup; M) and sour prawn soup with coconut milk (creamy soup; C), were examined by gas chromatography technique. After that the recipes that use to cook sour prawn soup which are chili, shallot, galangal, kaffir lime leave, lemon grass and lemon were measured by the electronic nose and the simulator nose. Finally, the discrimination of different types of sour prawn soup from different restaurant at different operation temperature. The temperature was varying at 30°C, 35°C and 60°C. Table 1 shows list of metal oxide sensors that were used in this work.

Results

Figure 3 and Figure 4 present gas chromatography result of mild sour prawn soup and creamy sour prawn soup, respectively. It can be seen that mild sour prawn soup and creamy sour prawn soup not only the amount of the same compound that different but also the type of compound is different.

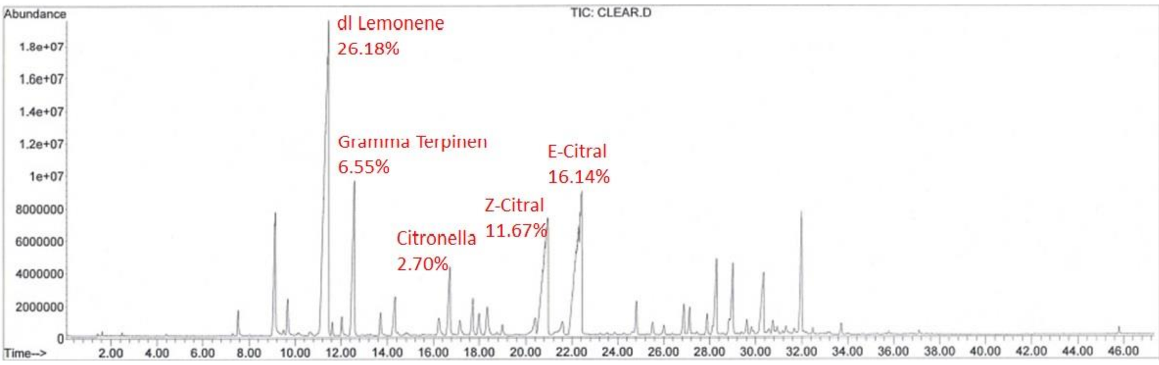

Figure 3 Chromatogram of mild sour prawn soup

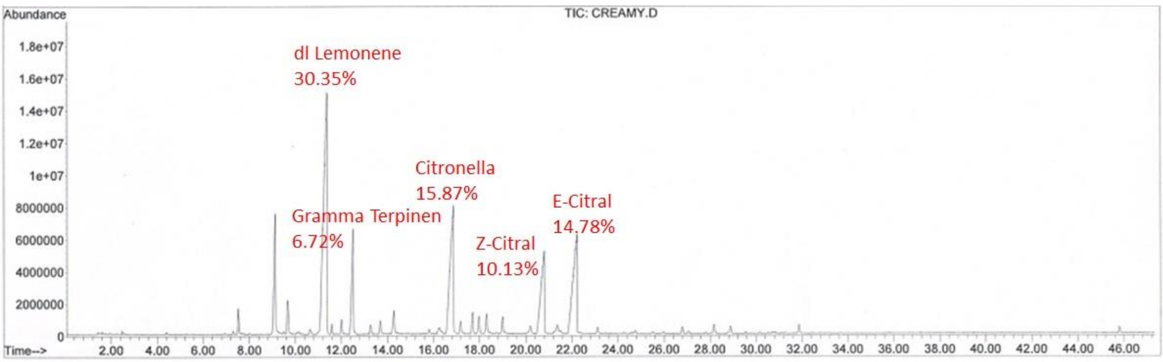

Figure 4 Chromatogram of creamy sour prawn soup

The sensing response (R) of both the brief case electronic nose and the simulator nose can be calculated by resistant of the sensor that change in the period of time as shown in (1).

$$R = \frac{\square_{\square}-\square_{\square}}{\square_{\square}} \times 100 \quad (1)$$

Where R_r refers to baseline resistance (obtained from reference gas) and R_s refers to the resistance obtained from sample vapor. The results from examination of recipes that contain in sour prawn soup exhibit that all sensors except sensor S6 show high response toward all recipes as shown Figure 5.

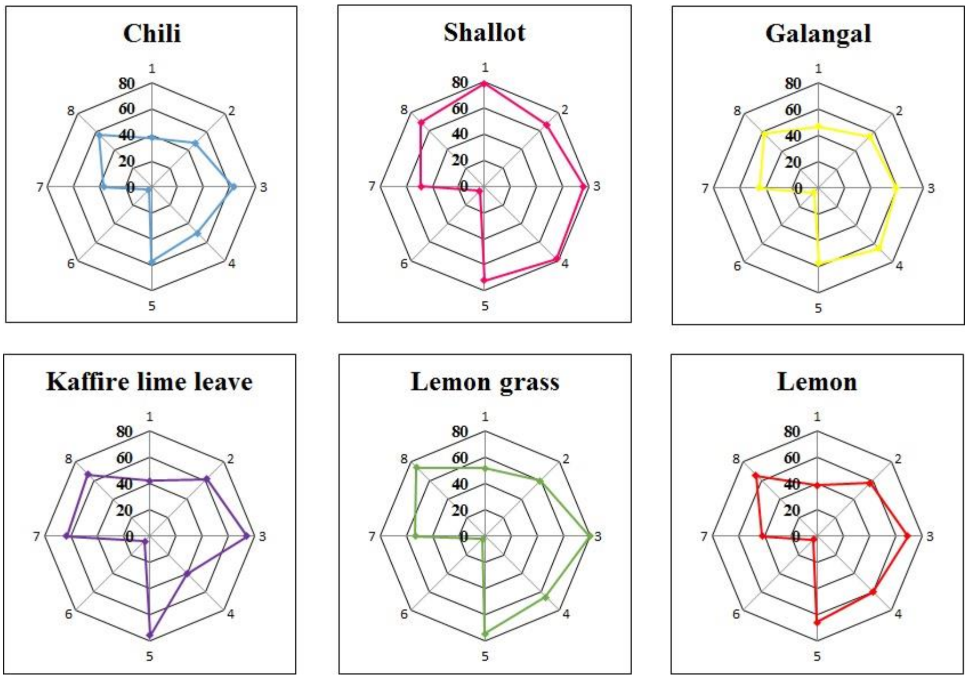

Figure 5 The sensing response of metal oxide gas sensors toward sour prawn soup recipes

When the samples of sour prawn soup from different restaurant were measured with the brief case electronic nose and the simulator nose with the increasing of operation temperature found that increasing of temperature operation increases the sensing response as shown in Figure 6 and Figure 7.

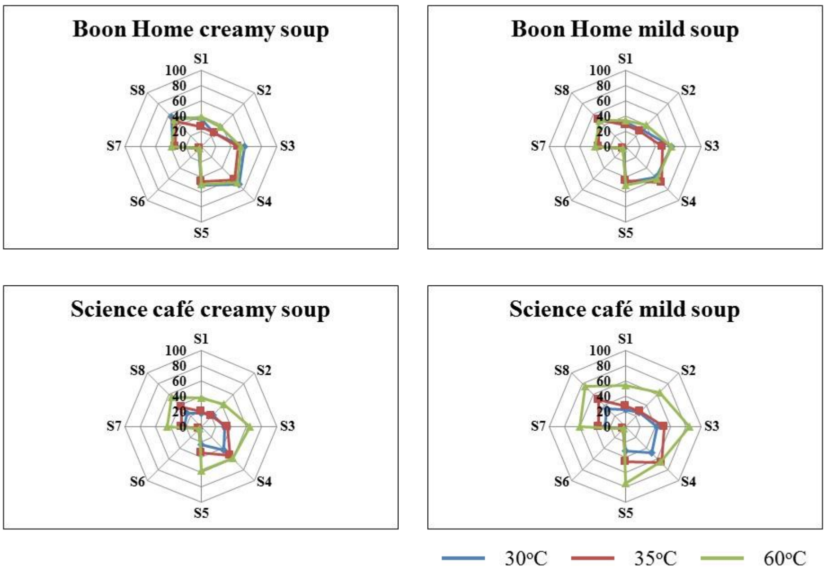

Figure 6 Sensing response of the electronic nose toward sour prawn soup at different operation temperature

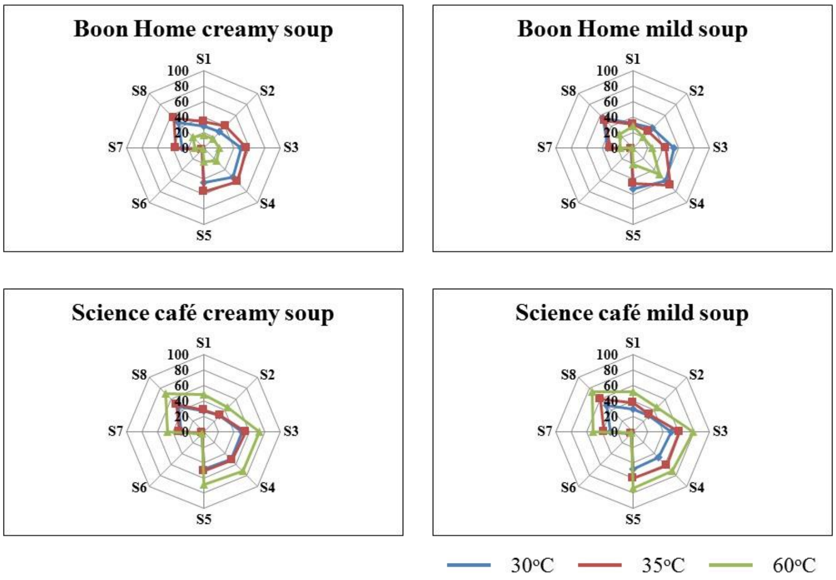

Figure 7 Sensing response of the simulator nose toward sour prawn soup at different operation temperature

Moreover, the PCA results (Figure 8 and Figure 9) show that the categorization of the samples is progressive with increasing of temperature. The group of samples distinctly separate from each other.

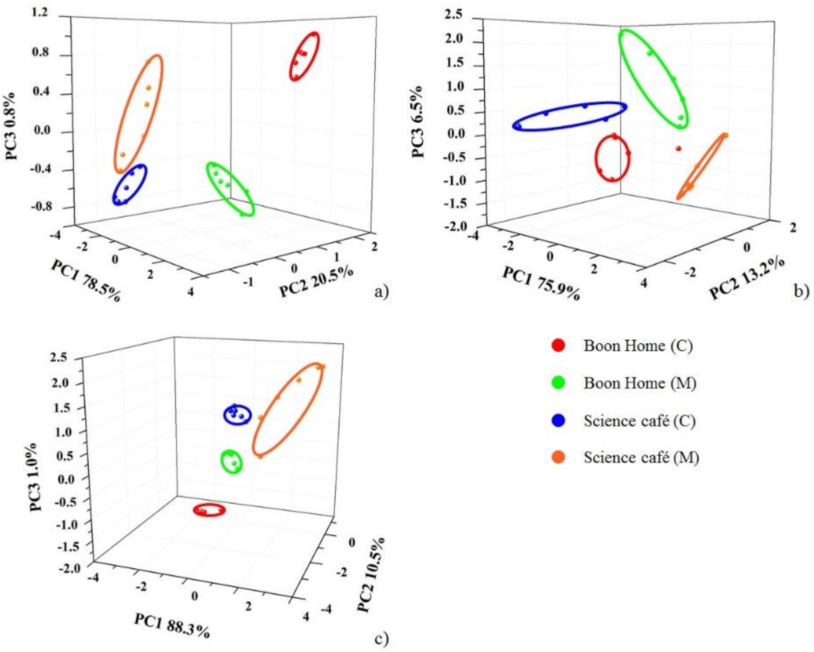

Figure 8 PCA score plot of sensing response from the electronic nose toward sour prawn soup samples at different operation temperature; a) 30^{o}C, b) 35^{o}C and c) 60^{o}C

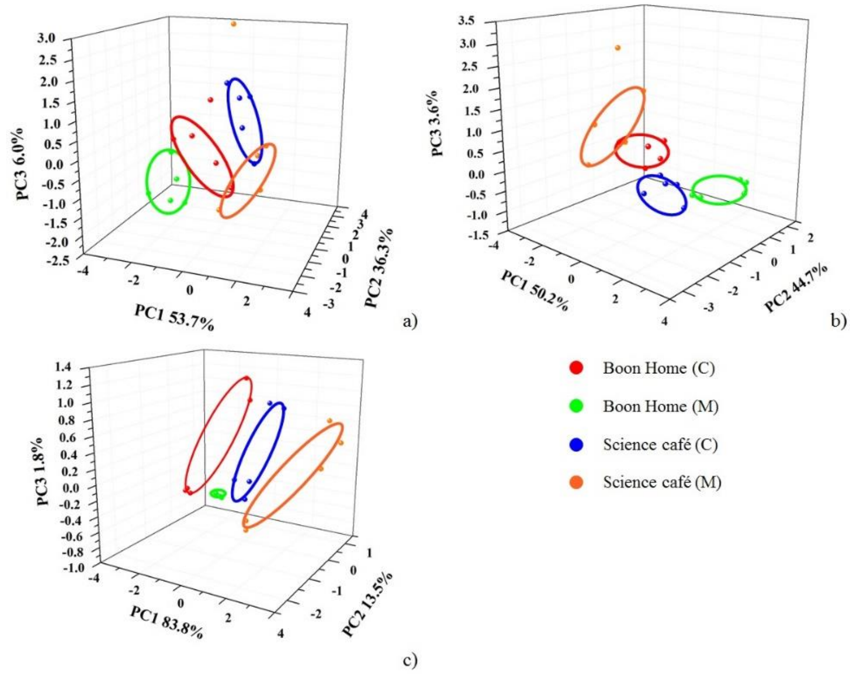

Figure 9 PCA score plot of sensing response from the simulator nose toward sour prawn soup samples with different temperature; a) 30°C, b) 35°C and c) 60°C

Discussion and Conclusions

The results can be concluded that simulator nose model based metal oxide gas sensors is successfully used to classify sour prawn soup with different types of soup and different cooked restaurants. Future more, the sensitivity of the sensor achieves the better response in increasing of temperature which suitable during cooking time without losing in sensing capability of the sensors because typical cooking temperature is nearly 100°C. However, the result found that the simulator nose system still shows lower ability to discriminate the samples as compared to electronic nose system which may due to air flow in the system. In the electronic nose, we flow nitrogen gas as reference while in the simulator nose we flow ambient air into the chamber which can cause the contamination in the sensing system. Thus, development of air flow system in the simulator nose is needed.

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