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Research Paper

# Evaluation of bacterial population on chicken meats using a briefcase electronic nose

*Kriengkri Timsorn* [a], *Theeraphop Thoopboochagorn* [b], *Noppon Lertwattanasakul* [b], *Chatchawal Wongchoosuk* [a,*]

[a] *Department of Physics, Faculty of Science, Kasetsart University, Chatuchak, Bangkok 10900, Thailand*

[b] *Department of Microbiology, Faculty of Science, Kasetsart University, Chatuchak, Bangkok 10900, Thailand*

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A novel portable electronic nose (E-nose) based on eight metal oxide sensors was used for evaluation of chicken meat freshness and bacterial population on chicken meat stored at 4.0 °C and 30.0 °C for up to 5 days. Aerobic plate counts were employed for the total count of bacterial population in term of typical biological analysis. Gas chromatography/mass spectrometry (GC/MS) analysis of fresh and spoilage chicken meats was presented. Principal component analysis (PCA) was used for pattern recognition and classification. A model for bacterial population evaluation was built by using a back propagation neural network (BPNN) based on sensor responses from the E-nose. The PCA results clearly showed the classification of chicken meat freshness corresponding to different storage days and temperatures. The E-nose with a constructed BPNN prediction model exhibited good evaluation of bacterial population on chicken with high correlation coefficient ($R^2 = 0.94$) and mean square error of 0.016. The results suggested that the developed E-nose system can be used as a rapid and alternative way for evaluation of bacterial population on meats and offers several advantages including fast, portable, low cost, and non-destructive measurement with high relative accuracy.



## 1. Introduction

Chicken meat is one of the most popular meat products being consumed worldwide due to being rich in protein, its low price, and availability in all countries and cultures. However, chicken meat usually has comparatively short shelf life depending on meat processing conditions (Salinas et al., 2012). To quickly monitor chicken meat ageing, the two main indicators used to evaluate meat quality are colour and odour change. During storage days, the freshness of meat degrades due to microbial activity and biochemical reactions. The results of these reactions cause the release of unpleasant odours from meat and change in colour. To evaluate colour change, computer vision technique and several typical instruments such as colourimeters and spectrophotometers are available (Mancini & Hunt, 2005). In case of odour detection, the traditional instruments such as gas chromatography (GC), gas chromatography/chemiluminescence (GC/SCD) and gas chromatography/mass spectrometry (GC/MS) (Ayseli, Filik, & Selli, 2014; Byrne, Bredie, Mottram, & Martens, 2002; Capone

* *Corresponding author*. Fax: +66 2 942 8029.
E-mail address: chatchawal.w@ku.ac.th (C. Wongchoosuk).

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et al., 2013; Duan et al., 2015; Peris & Escuder-Gilabert, 2009; Senter, Arnold, & Chew, 2000; Wettasinghe, Vasanthan, Temelli, & Swallow, 2001) are mostly employed. Unfortunately, they are destructive and time consuming for sample measurement. Furthermore, these instruments are very expensive and bulky.

In recent decades, electronic noses (E-noses) with sensor technology have been developed for odour detection. Sensor array used in E-nose systems is mostly metal oxide semiconductor (MOS) sensors because of low cost, high sensitivity and simple circuit operation. The MOS sensors absorb chemical molecules in gas phase and convert them into electrical signals (Comini et al., 2013; Mendoza et al., 2014). The changes of sensor resistances, either increase or decrease, are measurement data generated from an E-nose system. The sensor responses to odours are normally nonlinear. Many classification and prediction techniques such as principal component analysis (PCA), support vector machines (SVM), artificial neural networks (ANN) and back propagation neural network (BPNN) are employed to process nonlinear measurement data from E-nose systems. The obtained results from these techniques can be used to evaluate meat freshness. An E-nose process in odour detection is quite rapid and easy, while delivering high accuracy, and safety for samples. This feature of E-nose makes them very useful for various applications (Barbri et al., 2007, 2009; Delgado-Rodríguez et al., 2012; Guohua, Lvye, Yanhong, & Lingxia, 2012; Haddi et al., 2011; Hong, Wang, & Hai, 2012; Ponzoni et al., 2008; Liu & Tu, 2012; Sankaran, Khot, & Panigrahi, 2012; Song et al., 2013; Wongchoosuk, Lutz, & Kerdcharoen, 2009; Wongchoosuk, Choopun, Tuantranont, & Kerdcharoen, 2009; Wongchoosuk, Wisitsoraat, Tuantranont, & Kerdcharoen, 2010; Wongchoosuk et al., 2014).

Although, the E-nose systems have been successfully employed for evaluation of meat freshness, development of an E-nose that is portable, fast, low cost, able to be used under real conditions (outside laboratory) and no humidity effects (no need nitrogen or air zero as a carrier gas) is still necessary. Moreover, E-nose that can be directly used to identify bacterial population on meat is very important for general customers, industries, or governments in quickly monitoring meat quality and freshness. In this work, we have designed and constructed a portable E-nose based on eight MOS gas sensors to assess the freshness and evaluate the bacterial population in chicken meat stored at different storage temperatures and days. The PCA and BPNN methods were used to analyse measurement data collected from sensor signals. Classification of chicken breast samples related to their storage days and temperatures was analysed by using the PCA method. Bacterial population prediction was performed by a BPNN model based on direct sensor responses from E-nose measurements.

## 2. Materials and methods

### 2.1. *Sample preparation*

Sliced chicken breast meat samples were obtained from a local market in Bangkok. The samples were immediately packed in commercial food grade polymer wraps without cleaning. The samples were then cut into pieces of the same weight (10 g ± 1 g) and stored under different temperatures (4.0 °C and 30.0 °C) for 5 days in temperature controller incubators (Low Temp. Incubator, IL-11, Jeio Tech). These storage temperatures were selected to mimic the sample storage in a refrigeration system (4.0 °C) and room temperature (30.0 °C). Chicken breast freshness evaluation was performed everyday by using E-nose measurement in parallel with microbiological analysis in terms of aerobic plate counts.

### 2.2. *Electronic nose system*

The constructed portable E-nose system, called briefcase E-nose as shown in Fig. 1, consists of four parts; (I) valves and air pump with mass flow controller, (II) sampling system, (III) sensor array and (IV) data acquisition (DAQ) with a computer, as shown in Fig. 2. Sensor array used in the E-nose system is listed in Table 1. The eight gas sensors were selected in order to cover the volatile organic compounds in chicken (Ayseli et al., 2014; Du, Ahn, Nam, & Sell, 2000).

In this work, the material type of sensors is metal oxide semiconductor (MOS), i.e. $SnO_2$ or WO, used as the sensing layer of sensors. It should be noted that the sensing layer is an active region of gas sensor that reacts with oxidizing/reducing gases. The resistance of its active sensing layer changes due to increase/decrease charge carrier concentration with the gas to be detected. The sensor array was placed in a chamber made of a Teflon material. The chamber consists of three Teflon pieces: a bottom plate, a top plate and a body (inset of Fig. 2). At the bottom and top plates have inlet and outlet holes of odours, respectively. The bottom plate was pierced as odour path intersection to divide odours into each sensor. When odours are carried through the inlet hole at the bottom plate, they are reflected along the pierced paths (red arrows) by a circle barrier. The inside of the body, eight sides of inner wall, was pierced to contain eight metal oxide sensors matching the pierced paths at the bottom plate for flowing odours equally into each sensor. The body containing the sensors was covered by the top plate, which has a hole for odour outlet. The volume of the sensor chamber is 392 ml with air inlet hole diameter of 5 mm. The sample and reference bottles were

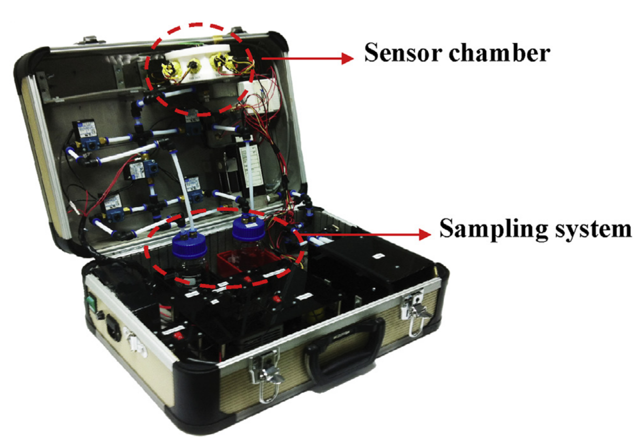


**Fig. 1 – Our constructed briefcase E-nose.**