Processing E-nose Data for *Salmonella Enterica* Detection in Poultry Manure

Ünal Kızıl, Levent Genç, Tülay Turgut Genç, Shafiqur Rahman, and Margaret L. Khaitsa

***Abstract*—** An electronic nose, DiagNose II, was used to investigate the capabilities of such systems in the detection of *Salmonella enterica* pathogen in poultry manure. Poultry manure samples were collected and homogenized. Of the three portion of manure samples one was left as is, the others were artificially infected with *S. enterica*. Initial results showed that DiagNose II has capability to classify manure samples as infected or non-infected. Data acquisition and processing methods were also discussed along with future that needs to be done.

***Keywords*—**Electronic nose, Data processing, Manure, *Salmonella enterica*.

I. Introduction

THE use of electronic nose (e-nose) systems is becoming popular in a wide range of disciplines. These systems are often used to sense the quality parameters of biological materials [1]. In general, they can be used to identify, quantify, and classify different properties of biological materials [2] in a non-destructive, fast and reliable manner [1]. The performance of an e-nose system relies mainly on statistical methods employed to analyze sensor responses.

The analysis of e-nose systems' data employs processing techniques such as principal component analysis (PCA), linear discriminant analysis (LDA) and artificial neural networks (ANNs) [3]. There is a great deal of commercially available e-nose systems. However, their use is generally not as easy. Some systems collect, analyze, and classify data as an in-built function like in CyraNose (Smiths Detection, Maryland, USA) e-nose [4]. In some systems data handling and processing is a big challenge particularly identification or classification. Therefore, the aims of this study were to 1) explain data acquisition from a commercial e-nose system 2) summarize the data processing and 3) compare the e-nose responses to laboratory analysis results.

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II. Material and Methods

A. E-nose System

DiagNose II (The eNose Company, Zutphen, Netherlands) e-nose system is being tested in Agricultural Sensor and Remote Sensing Laboratory (ASRESEL) with different biological materials such as food and agricultural wastes. The system employs 12 gas sensors (Fig.1) and is connected to the computer via setting up a fixed IP address.

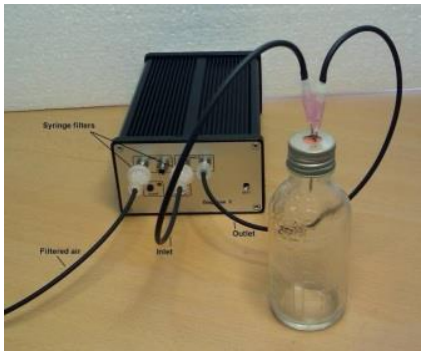

Fig. 1 DiagNose II e-nose system

In order to evaluate the performance of DiagNose II, poultry manure samples collected from various broiler facilities were used to test if the e-nose system could identify poultry manure that is infected with *Salmonella enterica* (*S. enterica*).

B. Sample Preparation

Manure samples were homogenized with Buffered Pepton Water (BPW). After that, *S. enterica* strain (ATCC 13311) was added to homogenized manure samples and incubated at 37 C^o for 24 hours.

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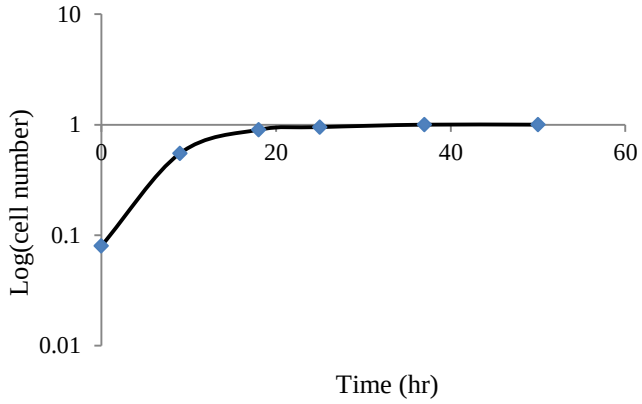

Fig. 2 Logarithmic growth of *S. enterica* cells

Once the manure samples were infected with different amounts of *S. enterica* they were then exposed to DiagNose II. Responses of the e-nose system to the head space of manure samples were recorded at 0, 12, 18, 24, and 48 hours. A logarithmic growth curve of *S. enterica* cells versus time was then computed as shown in Fig. 2.

C. E- Nose Data Acquisition

Once the system is connected to computer, the EPO software is activated to acquire and visualize e-nose data. As the system starts purging air samples, the response of an individual sensor within the system can be observed (Fig. 3). Response of any sensor can be visualized by clicking on the sensor name listed on the left side of the screen.

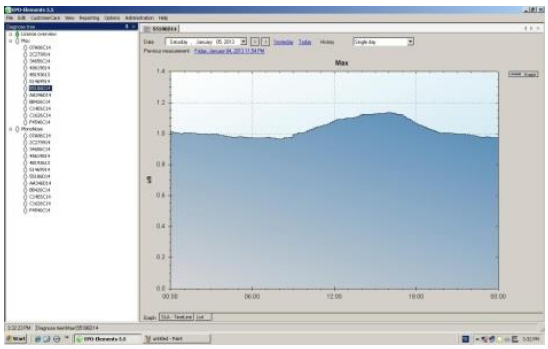

Fig. 3 Response of a sensor

The DiagNose II does not have a built in data processing capacity. The EPO software is only used to visualize and download sensor responses to the computer in CSV file format. The system can store the data until they are removed from the memory. Stored data within a time frame can be downloaded to the computer from e-nose via EPO software. A typical response curve of DiagNose II is given in Fig. 4. Considering that there are 12 sensors employed in the system it is highly laborious and time consuming to download the entire dataset.

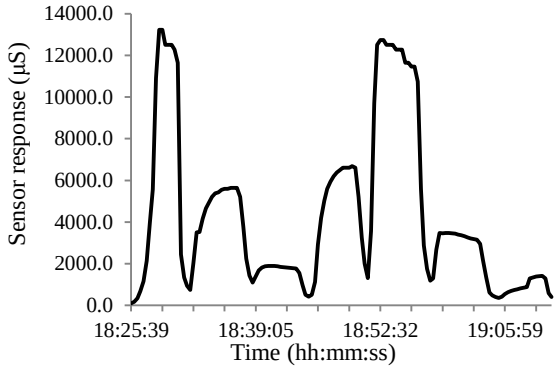

Fig. 4 A typical raw sensor data

In the Fig.4 each hill represents an individual sample reading. There are 7 readings conducted between 18:25 and 19:09.

D. Data Processing

Since the e-nose system does not provide a statistical method to process and analyze the data all these tasks must be done manually. Data collection and processing methods are represented in Fig. 5.

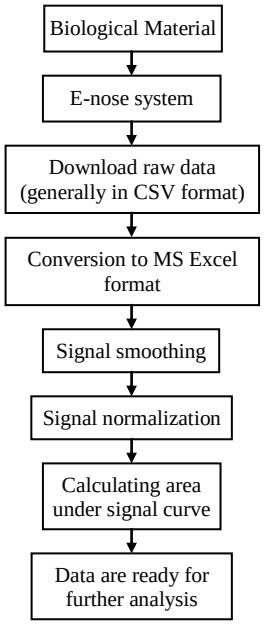

Fig. 5 Data collection and processing methods

In the data processing, moving average smoothing algorithm is applied to remove noises from the signals (1) [5].

$$y[i] = \frac{1}{M}\sum_{j=0}^{M=1} x[i+j] \quad (1)$$

where; $[x_i]$ is the input signal, M is the number points in the average. In the smoothing, 2 points are used. Smoothed signals then normalized using the following equation (2) [1].

$$V_n = \frac{V_i - V_{min}}{V_{min}} \quad (2)$$

where; V_n is normalized sensor response at a given time *i*; V_i

is smoothed sensor response at a given time *i*; V_{min} is minimum sensor response obtained during the recording time.

A sample of raw, smoothed, and normalized data are shown in Fig. 6.

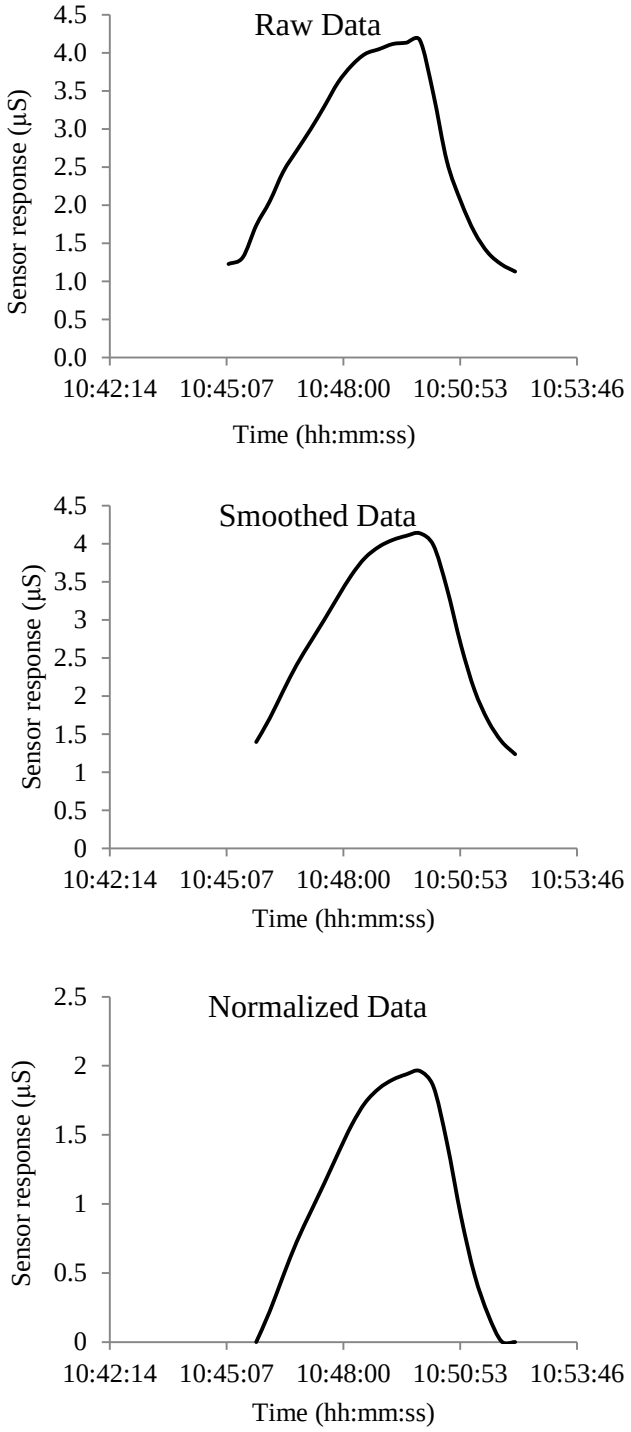

Fig. 6 Processed data

The processed data shows the response of a sensor over a time period. However, in its current form it can't be used in statistical analysis. One approach is to compute the areas under each smoothed and normalized sensor response curves. In calculation of the area under the curve (AUC) a trapezoidal approach is used; this approach assumes that the curve can be divided into trapezoidal areas (Fig. 7).

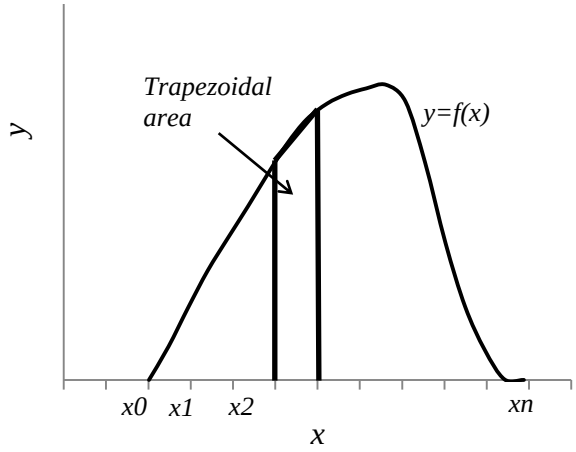

Fig.7 Calculating area under a curve using trapezoidal approach

The total AUC is the summation of all trapezoidal areas (3). Sensor dataset is completed upon the calculation of AUCs for each unit response.

$$\sum A = \frac{\Delta_x}{2}[f(x_{i-1}) + f(x_i)] \quad (3)$$

III. Results and Discussion

Sensor responses and *S. enterica* populations in each manure samples are required. The objective is to observe if there is a relationship between sensor responses and microbiological analysis results. To achieve this goal homogenized manure sample was divided into 3 portions. The first portion was exposed to e-nose as is. Into second and third portions 10^3 and 2×10^3 *S. enterica* cells added, respectively. The samples were sniffed with the e-nose system at different time intervals. Fig. 8 shows the sensor responses versus *S. enterica* populations after 48 hours. These results belong to sensor #1.

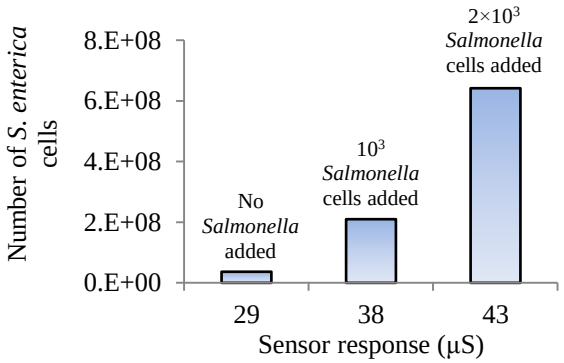

Fig. 8 Sensor responses vs S. enterica populations

The results clearly show that the e-nose system can sense the difference between natural (or non-infected) and infected

samples. Even though there is no pathogen added into the first portion of the manure sample, there is still a sensor response. The reason is that there are other odor causing bacteria, chemicals and other substances that exist in manure. Hence, the sensor reacts and shows some response. The e-nose systems are not designed to quantify exact numbers of cells or other biological characteristics of a sample. The system employs gas sensors each of which is specifically designed to respond to existence of different volatile gases.

Sensor response values are not enough to make classifications or quantifications. There should be a statistical method such as PCA, LDA, or ANNs to make sensor values meaningful. The performance of these methods mainly relies on the quality of database. As discussed earlier, one of the biggest challenges in using e-nose systems is data handling and processing if this capacity is not provided within the system.

The ultimate purpose of our study was to classify poultry manure samples as either infected or non-infected. Additionally, this paper investigated data processing techniques that can be used with DiagNose II e-nose system. Overall, this study showed that DiagNose II e-nose system is capable of discriminating infected manure samples from the non-infected ones. Work is ongoing to develop a cost effective and user friendly electronic nose system that has a built-in data handling and processing software. Also, we plan to use ANNs as a classification method on larger datasets. Future work will also include use of e-nose systems in different biological engineering areas.

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