BIOLOGICAL OLFACTION SYSTEM MODELING FOR MEAT ANALYSIS USING E-NOSE SENSORS

Arş. Gör. Özge Cihanbeğendi
Dokuz Eylül Üniversitesi

Doç. Dr. Özgün Boray Yurdakoş
Ege Üniversitesi

ABSTRACT

The need for high level of understanding of storage conditions for food products have become mandatory with enhanced population and demand for the freshness and quality of food. Even with advanced preservation methods, a very large amounts of foods are lost because of microbial spoilage. As the very first step of the preservation process, the microflora that grows during the storage time and in spoiling foods should be well-known to identify the critical levels. In this point of view, gas measurement systems used to detect the existence of such microflora with a specific methodology can be easily referred to as electronic nose or e-nose. Odour and taste sensations emerging from a range of compound identification can be used in many field of industries to determine the quality of such structures taking part in foods or drinks. Considering the comparison techniques with the others, electronic nose systems are quite simple to perform and can ensure sensitive and promising results since they can verify each other practically. The other measurements are conducted only verification of data obtained from the sensor outputs since these process are time-consuming, expensive and requires pre-operational work though they give important data would be needed for the other measurements techniques. Likewise, bacterial analysis is also essential process to determine what kind of living of bacteria groups lead to such gasses emerged in analysis during the degradation time. The main measurements are based on sensory. The aim of this thesis is to determine the degradation levels for some foods under different environmental conditions such as temperature and duration by keeping the others stable and to compare with other measurement techniques for evaluating the verification of data. In order to test sensory measurements during the period and microbial measurements are used.

Keywords: Food quality, microbial spoilage, electronic nose

1.INTRODUCTION(1 sayfa max., bitsin, toplam 3 paragraf olabilir)

Smart odour sensing is a complex research subject and involves a comprehensive analysis regarding many steps such as mainly signal processing, types of sensors, advanced pattern recognition methods. An electronic nose is composed of an array of chemical sensors whose internal resistance value rise or fall in the event of exposed to the specific gasses. The fields of the application of commercial electronic noses are widely expanding in ordinary to various areas such as environmental monitoring, medical instrumentation, and food industries (Hussein, Luo, Liu & Xu, 2007).

Electronic noses are used in a number of industries by smell recognition being capable of dangerous chemical gasses as well as analyzing wide range of food products beside evaluating the quality inspection. The process of recognition of an odour starts by obtaining the responses of each sensor, which creates electrical change as a signal through the chemical reactions odours caused. The choice of number of and type of these sensors taking part in the array highly determines the selectivity grade in the process. Electrical nasal techniques allow the identification of complex odors using various chemical gas sensors with appropriate statistical methods. In the evaluation of volatile compounds in food, cosmetics and other daily life, the availability of commercial facilities has led to a significant increase in research on the application of electronic noses. Recently, piezoelectric crystal, organic conductive polymers, metal oxide semiconductor field effect transistors, metal oxide semiconductors sensors are among the types of industrial gas sensors. Analysis that have many variables such as radial basic functions, artificial neural network and simple graphical evaluation can be named as statistical analysis techniques. Electronic nose application areas include freshness determination, process monitoring, quality control, originality analysis and shelf life calculation. In addition to this, there are many studies on meat, fish, cheese, mushrooms, sugar, apple, coffee and other beverages have already been performed. (Schaller, Bosset & Escher, 1998).

In the design of these systems, repeatability and stability should be ensured at a high level, based on long-term use. Therefore, the ability of analyzing on same sensor array for a sample along the duration that measurements are obtained and the ability of various sensor groups or tools to built the same sample pattern with the previous one should be adequately high. Since sensor analysis is a key factor to achieving the desired analytical results, the current

state of the sensor analysis method and statistical data analysis depending on those will be examined in the following section.

On the other hand, the term of an electronic nose for smell categorization by using smart sensor arrays including gas sensors did not appeared throughout approximately 20 years after these studies until the publication of Persaud and Dodd in 1982. Artificial nose system was adduced the same year. As a theory, the basically such systems is based on gas sensors progressed 30 years ago. At the first years of 90's, with the spread of the term artificial electronic nose, many devices started to be used commercially and as the researches in this subject increased. These devices were tested especially in the food industry. The olfactory system of mammals is very complex and difficult to understand. The ordinary mammalian nose structure includes the olfactory epithelium and olfactory receptor cells consequently. These cells are nerve cells are directly responsible to sense the smell, by interacting with the source of smell. In the design of olfactory technologies, mammalian olfactory systems are referred to. Thus, mammalian olfactory systems should be well analyzed to better understand the nature of these measurements using a sensor array.

The electronic nose aims to mimic the mammalian olfactory system by modeling the responses to odorants with a sensor array. Methods such as bubbles, pre-concentrators, diffusion methods or headspace sampling are applied until this odor is transmitted into the nose and sent to the next unit. The odour source is processed through the sensor array and a reversible chemical reaction occurs by altering the conductivity as one of the electrical properties. As in the olfactory systems, every single cell located in sensor array attitudes like a single receptor by responding to different odourants with the different levels. These differences can be converted to electrical signals by pre-processing and defined by the model recognition system. This response from the array is formed as an electronic nose to allow for a specific odor in each odor group (Arshak, Moore, Lyons, Harris & Clifford, 2004).

When the historical process of e-Nose is examined, it seems that the earliest study on the improvement of such tool specifically to sense smells probably dates back to very early in 60's belong to Moncrieff in 1961. This design was quite similar to a nose yet looking like more mechanical one, less electronic one. In this context. The first electronic noses in the real sense, as the formation of redox reactions of a substance of odorants were publicated by Wilkens and

Hatman in 1964, Buck et al. as modulation of the odorants' conductivity odourants and Dravieks and Trotter as the modulation of odorants' contact potential, both in 1965 were designed successfully. Since 1993, the amount of publications in the area of electronic olfaction is more than 12,000 articles. The main application areas related to the food industry have been: fish, meat, milk, wine, coffee and tea, and constitute approximately 5000 publications since 1993. The number of the food applications reveal that main investigation area of electronic olfaction is food analysis having approximately half of total publications (Loutfi et al., 2015).

2.DESIGN OF THE SYSTEM

2.1 Block Diagram of the Study

The study included a few steps seen on the block diagram in Figure 3.1 demonstrating the principle of the e-nose system designed according to sensor array outputs to appoint the sample freshness. In the beginning, samples were brought closer enough to sensor array by helps of a injector obtained from the chamber in order to detect what type of gas content exist. This mixture of gasses was separated according to sensor type for each sensing among all the gas content. Then this value was calculated over analog outputs whether the critical value was exceeded or not in terms of determined values for each ones before. According to this exceeded limit, the system gave deterioration warning number of 1 to 4. If such value is not observed over the sample then logic-0 is produced to carry on measurements.

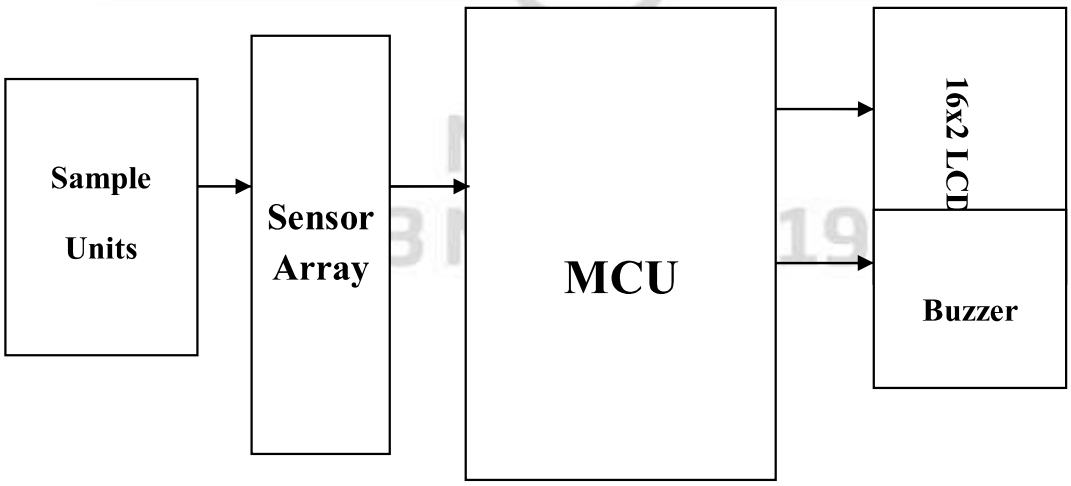

Figure 2.1 Block diagram examining how the selective software of the thesis works

Designing an e-Nose system requires many tools. In this study there are several modules such as the sampling unit, sensor array, microcontroller and LCD in addition to the buzzer. The sampling units where the samples located as the input of the sensor array module. In this transition of analog data from the source to the sensory inputs, the efficiency of related transfer is not %100 naturally. Considering the gas forms as the storing element, the highest level of the loss occur here. Nevertheless, the adequate effort is shown to transfer this data into the next module. The sensor array is another analog data part of the design which sense and send the data into MCU. In this module, analog data is converted into digital data to process or to work the outputs which is able to work only digital inputs. Finally the decision(logic 1 or 0) is shown in these outputs.

2.2 Metal Oxide Sensors

In operational mode, the main response of a metal oxide sensors is heavily depend on the alteration in value of conductance of the oxide as the interaction occurs with an external excitation such as a gas. This change is usually proportional to the concentration of the gas since the number of molecules bound to the compound increases. Basically, there are two types of metal oxide sensors; n-types and p-types. This discrimination is made depending on their response type. N-type respond to reducing gases while p-type respond to oxidizing gases.

Having low response time in addition to recovery time can be consider as the one of the advantages of metal oxide sensors, directly depends on relationship between gas and sensor and the temperature. Provided that thin film metal oxide sensors are preferable, being smaller compared to the others with the same mission. Beside this, easy to obtain low prices respectively. Therefore they could be directly interconnected into the circuit. This is a key factor to built larger systems including multi sensor array. On the other hand, one of the disadvantage of these type of sensors is their high level of consumption since they can work on high temperatures could be appointed. Another side effect of this sensors is that they are in danger in performing of sulfuric compounds to poisoning risk whose mean in sensor language, being blind to the other volatiles after that time for long periods (Arshak, Moore, Lyons, Harris & Clifford, 2004).

2.2.1 Gas Types Detected By Sensors

As the elements of MQ series of HANWEI company, MQ7 is used to detect Carbon monoxide (CO), MQ4 is for methane (CH_4), MQ3 is for ethanol (C_2H_5OH) and MQ137 is for ammonia (NH_3) are used for the samples during the period 7-days.

2.3 Sample Preparation

Samples were kept in close chamber under same condition for the duration time. Sensory measurements were recorded for every single day through an injector over the chamber with neglected gas leakage from one measurement to the another. The samples were purchased from a local butcher and they were stored at 4°C during 7 days. Sample size was determined for red meats as minced shaped so that there can be observed microbial contamination obviously.

2.4 Microbiological Population Enumeration

Counts of the microbial population is a accurate data in order to able to have an idea about the verification of the gas measurements. If the expectation can be made before the process for what type of bacterial growth would be observed, the other measurements would be more meaningful in terms of emerged gasses over the sample. As it is known this amount of gasses results in almost completely from the respiratory mechanism of such bacteria. The higher number of bacteria groups, the more verified the environmental gas detection. The measurements were conducted in Microbial Laboratory in Ege University, Izmir by the device with the model STOMACHER 400.

In the following section there will be experimental layout including various steps of the study. The goal of this study was determined to detect the degradation levels of a punch of minced beef meat between the intervals consequently 1 to 7 days under temperature 4 °C by using a sensor array. Additionally, microbial analysis were conducted at the very beginning and the last phase of the study to verify the sensory outputs during this period.

3. EXPERIMENTAL RESULTS

3.1 Bacterial Analysis

Bacterial analysis is an essential technique for the evaluation of the emerged gasses during the process. The counts are made in the beginning of the degradation as t_0 and t_1 in order to determine a reference level of bacterial growth for the minced beef meat.

Table 3.1 Displays total number of living or occurring bacteria over the samples at 4°C for t_0

Sample Type	Scaled Calculation	Multiplication	Exponential Factor	Total Counts of Bacteria
Red meat	31 x 2	62	(-4)	6.2 x 10^5 cfu/g

The total number of aerobic mesophilic bacteria was analyzed in the microbiology laboratory. The aim of this experiment is to determine the 7-day change (t_0 and t_1) in total number of microorganism in red meat. For this purpose, total aerobic mesophilic bacterial count test was performed on days on which samples were purchased (t_0) and after 7 days (t_1). Plate Count Agar (PCA, MERC) was used in the experiment. Incubation degree is 30°C and incubation period is 24-48 hours. Results and other information of total number of aerobic mesophilic bacteria analysis were given in between Table 3.1 and Table 3.2 for red meat. Total number of live in red meat were calculated 6.3 x 10^5 cfu/g at t_0 and 3.7 x 10^7 cfu/g.

Table 3.2 Displays total number of living or occurring bacteria over the samples at 4°C for t_1

Sample Type	Scaled Calculation	Multiplication	Exponential Factor	Total Counts of Bacteria
Red meat	185 x 2	370	(-5)	3.7 x 10^7 cfu/g

3.2 E-nose Analysis

The sensory results were obtained under vary temperatures and durations. Each result emerged on the output pins of the sensor array is shown in the following figures. In contrast to examining each sensor output response towards related to released gas of the samples, as given on the thesis detailed, the total approach is selected in terms of evaluating general perspective.

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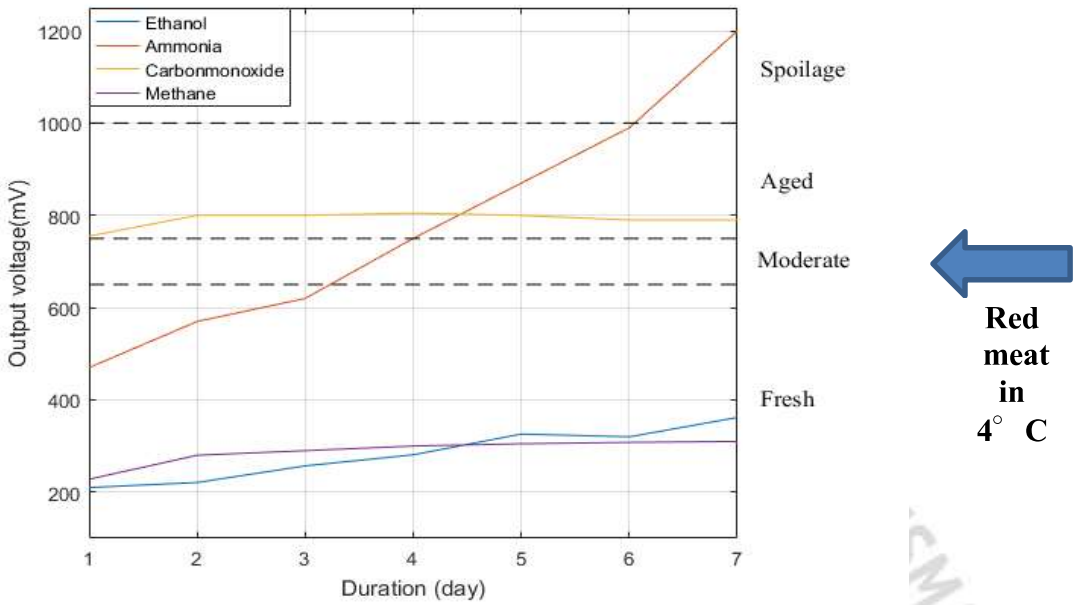

Figure 3.3 Concentration of such gasses under 4 °C temperature for red meat

Calibration is another enhancement issue to obtain better correlation between measurements. The main measurements were performed by sensors to create a reliable data processing system. Hence the sensor values are expected to be decisive to evaluate the samples are whether available to consume or not. In this context, since it is one of the key point to calibrate the related sensors especially on gas sensors, they should be calibrated depending on what type of conversion is made in software command. In this study ppm measurements was not performed. Hence calibrations were carried out in consideration output voltages.

4. CONCLUSION

Traditional techniques will always be necessary in near future to specify quantitatively or qualitatively the difference among the other food product samples from one to another. The other measurements are conducted only verification of data obtained from the sensor outputs since these process are time-consuming, expensive and requires pre-operational work though they give important data would be needed for the other measurements techniques. Likewise, bacterial analysis is also essential process to determine what kind of living of bacteria groups lead to such gasses emerged in analysis during the degradation time. In this point of view, this can be strongly put forward that including the number of higher sensor makes the area of applicable the larger. Although it is thought to have much more space adding numerous different sensors, the total circuit area would not increase linearly in the same way since several

output pins are able to connect mutually. This system can easily be made portable taking up such little space. The main measurements are based on sensory.

There could be several improvements to maximize the impact area of the system. As the number of studies in this field increases, the most portable, easy-to-apply and fastest-performing systems will be developed in a similar way. Focusing and performing the developed methods frequently with minor differences will also increase the reliability of such systems and pave the way for their widespread use. Thus, even individually widespread use of similar methods will lower the price and in the near future these measurements could be compulsory for the suppliers. The general trend in this area is to built up a system for many specialized application to measure the freshness quality. This approach puts forward that a portable and compact instrument or a experimental product would be desirable. Nevertheless the thesis in this form is adequately sufficient to be a guide for the new researchers in their road maps having good repeatability and stability.

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