A NOVEL APPROACH FOR THE QUALITY MONITORING OF MINT USING AN E-NOSE SYSTEM

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ABSTRACT

This article presents a novel and cost effective e-nose system for quality monitoring of the mint. Application of e-nose system in quality monitoring of the fruits and vegetables is currently an issue of serious attention because of the instrument confirmed competence of recognizing and cultivation between a range of different gases and odours using a minute number of sensors. In actual, this paper spells out fresh/spoiled states of mint according to the data received from the different sensors. Attempts are made to display the results on the front panel of the LabVIEW software. The GUI created using the LabVIEW makes the system more interactive and user friendly. The results from the different sensors are compared and displayed using the radar patterns. The variation in the area of the radar pattern shows the variation in the gases coming out from the mint. The consistency and efficiency of the system are the key concerns and influence the design choices for the system hardware and software. We conclude with a discussion of the long-term challenges for E-nose technology in quality monitoring of the fruits and vegetables and outlined our future vision.

KEYWORDS: E-nose, GUI, LabVIEW, Mint, Radar Pattern.

Electronic nose is an instrument consisting of a gas sensor array with fractional specificity and an appropriate pattern recognition arrangement that is able to aware of the single and or multifaceted odours. In environmental systems, an electronic nose uses an array of sensors with partial overlapping sensitivities to classify and recognize the odours [1]. In general, it is composed of a variety of coordinating devices such as gas sensors array, data acquisition system and a pattern recognition algorithm with appropriate arrangements with respect to the application in hand and its implementation. The role of the sampling system is to collect and convey the volatile signal from the sample to the sensors and then to restore previous conditions by means of a cleaning procedure. The interaction between the sensors and odours is the first fundamental step of the data acquisition process, since its execution influences all the successive steps [2].

In the past decade, a lot of techniques evolved for classification, ripening stages of the fruits, the quality and the freshness of the fruits and vegetables. Human's life is becoming easy and defensive day by day, since the occurrence of high-speed and smart equipments and technologies. Several techniques are being used in daily routine. Food containing pathogenic microorganisms can be extremely harmful for customer's health; while most food-borne diseases are sporadic and often not reported food-borne disease outbreaks may take on massive proportions [3].

Now a days, many researchers are devoting to develop an electronic nose systems and off course some are in the developed states whereas others are under continuous improvement in the system performance [4].

Mentha is a type of green leafy vegetable basically included in perennial vegetables because it is available in all seasons. It contains perfume type and sweet smell, hence it can be used for smelling purpose in the various delicious meal dishes. It is also used in various health problems like cough, weakness, stomach problems, nausea and headache, etc. Also it can be very useful in the weight loss, good digestion and for asthma patients. Hence in the medical and ayurvedic fields, it is having a lot of demand. When mentha are fresh or in edible form, it emits strong and large amount of perfumed like smell however, this smell reduces with declining freshness.

Leafy Vegetables

Leaves are the edible part of the plants. Such types of vegetables are known as leafy vegetables or succulent vegetables. The time duration of freshness of leafy vegetables is minimum one day and maximum two or three days after harvesting; using some preservation methods it can be increased. In many cases, the freshness of green leafy vegetables depends on the type of a vegetable, climate, environment, storage process

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and harvesting process. These vegetables are called succulent because they are having juicy nature. All vegetables are not sweet or having full of flavours like fruits, but after making some recipe, they become delicious and tasty. Spinach, fenugreek, mint, dill, cilantro, cabbage and spring onions are easily available in Indian markets. All over the World, many types of leafy vegetables are used in daily meal for example brussels sprout, rapini, broccoli, arugula, ceylon spinach, chinese mallow, bitterleaf, amaranth, bok choy, cabbage, cauliflower, lagos bologi, samphire, land cress, chicory, cress, etc [5].

Maturation, ripening and senescence are the three stages in the life duration of fruits and vegetables. In the case of climacteric fruits, maturation or ripening is indicative of the fruit being ready for harvesting. At this point, the edible part of the fruit or vegetable is fully developed in size, although it may not be ready for immediate consumption. Ripening follows or overlaps maturation, rendering the product edible, as indicated by texture, taste, colour and flavour. Spoiled or over ripening is the final stage distinguished by ordinary degradation of the fruit or vegetable, with loss in texture, flavour, etc. At this point, ripening process is an important operation in many climacteric fruits before put in the market. On the other hand in case of non-climacteric fruits, improvement of edible quality (or freshness) and ripening state before harvesting are indicative of the fruit being ready for harvest. Hence, these types of fruits are supposed to be harvested after getting proper development of edible quality (ripening) while still attached to the mother plant. A leafy vegetable also follows this properties and harvesting of leafy vegetables are done after completion of appropriate development.

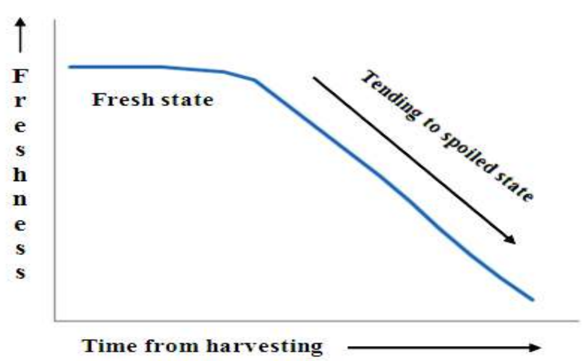


Figure 1: Graph of freshness vs. time from harvesting of the vegetable.

Non-Climacteric fruits and vegetables are harvested at full matured (or riped or fresh) stage. On the other hand, climacteric fruits and some fruity vegetables are harvested before riped state or at unriped state. Therefore, the freshness of climacteric fruits and leafy vegetables are increased after harvesting and decreased in case of leafy and non-climacteric fruits. Figure 1 show the variations in the freshness or quality of the fruits and vegetables respectively with respect to the time.

After harvesting or cutting the vegetables, changes in the properties of the vegetables are different than the changes in the fruits (after harvesting). The rate of change of freshness of some kinds of vegetables are very fast (e.g. leafy vegetables) whereas, for some vegetables, the freshness decays slowly. In the determination of freshness and monitoring of the vegetables, key difference is that, all the vegetables are not emitting the ethylene or alcohol type odour after harvesting and do not participate in the ripening process after harvesting. Hence for monitoring of the vegetables we have concentrated on all the aspects and parameters, i.e. changes in the other gases (VOC) and humidity of the chamber for a particular sample.

SYSTEM DEVELOPMENT

An electronic nose system development consists of a fruit/vegetable chamber, sensor array chamber (an air tight food grade box), gas sensor array, DAQ-card and ANN designed in LabVIEW software. The gas sensors detect various gases which are emitted from the fruits. All the gases are collected in a gas chamber. An air tight food grade box was used for collection of the gases which are emitted from the fruit. A gas sensor array is set in a gas chamber. A block diagram of experimental setup of electronic nose is shown in figure 2 [6]. LabVIEW receives the voltage form of the gases from hardware setup through NImyDAQ. Gas sensor array detects those gases which are emitted from the samples (mint). The various gas sensors in the array were TGS-2602, TGS-2620, TGS-6812, TGS-821, TGS-822 and TGS-813. These gas sensors detect VOCs and odorous gases, air contaminants, Alcohol and organic solvent vapours, Hydrogen, Methane and LP Gas, Organic solvent vapors such as ethanol, Combustible Gases, methane, propane and butane. Measurement, circuit of sensor array was connected to DAQ card. NImyDAQ is portable device basically used as an interfacing tool between hardware and software sections.

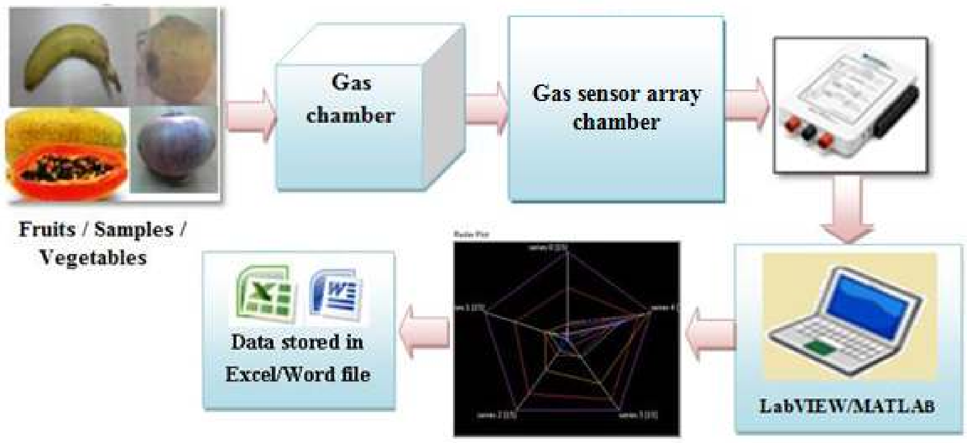


Figure 2: The experimental setting of an E-Nose (for fruits or vegetables).

FUNCTIONING OF AN ELECTRONIC NOSE

Arrangement of chambers is shown in figure 3 [7]. The schedule of an experiment starts with placing a sample of vegetable (or fruit) in the application. Flow of the gas was controlled by the exhaust fans; Fan1 and Fan2 and valves are valve-1, valve-2 and valve-3. The gases and VOCs emitted by the given sample were collected in the sample (fruit/vegetable) chamber-1. Those gases were passed to the sensor array chamber (Chamber-2) for recording and measurements. The sample can produce gases upto 10 minutes, where in all the valves and fans were in OFF condition. After10 minutes, all the gases from gas chamber were passed to sensor chamber (i.e. chamber-1 to 2) through a transparent PVC pipe using an exhaust fan (i.e. fan-1). Exhaust fan-1 now becomes OFF. Exhaust fan-2 (i.e. from sensor array chamber-II) then becomes ON after some time interval, when all the gases are inserted into chamber-II and detected by the sensors. In short Fan-1 was used for sucking and removing the gases from chamber-I and passing them into the chamber-II and Fan-II was used for removing all the gases from chamber-II and for refreshing the sensor array chamber for incoming gases from chamber-1. In this process, 3-valves were used having important function of removing the gas and sucking the gas from the chambers as shown in the figure 4. If fan-1 is in ON condition, fan-2 must be in OFF condition and vice versa.

WORKING OF 3-VALVES

Valve-1

In the process of passing the -collected gases from chamber-I to chamber-II, valve-1 should be in the ON state condition, wherein fan-1 is also in ON state condition. Otherwise it remains in OFF state always (when fan-2 is ON and gases are removed from chamber-II to outside).

Valve-2

When the gases are passed from the chamber-I to Chamber-II (fan-1 ON), valve-2 should be in the OFF state and when the gases are removed from the chamber-II (fan-2 ON), valve-2 must be in the ON condition.

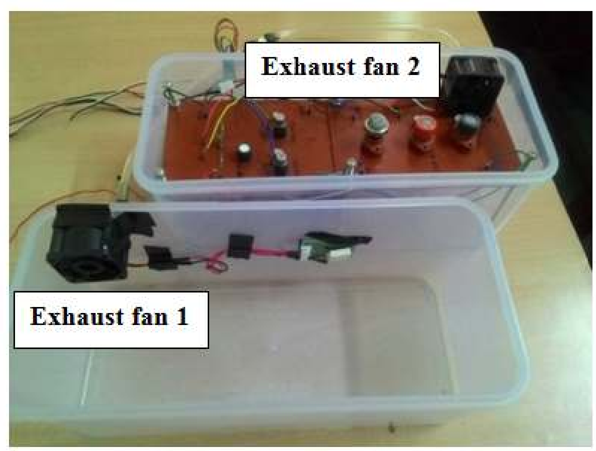


Figure 3: Arrangement of gas sensor chamber and fruit/ vegetable chamber

Valve-3

When fan-1 is ON and fan-2 is in OFF state, Valve-3 should be in ON state, because the flow of gases is towards the chamber-II from Chamber-I. After this, gas detection process initiated and observations have been taken. Here valve-3 should be in the OFF state. After some time interval, when the observations process is completed then Fan-2 becomes ON so also valve-3.

Flow of the emitted gases is shown in the figure 4., path 1 is the flow of gas, when gases and VOC are transferred from fruit chamber (chamber-1) to the sensor array chamber (chamber-2). During this process fan-1 is ON for 3-5 minutes. The path 2 is the flow of gases from chamber-2 to the outside for removing the gases and clean the sensor chamber (chamber-2). In this case fan-2 is in ON condition for 3-5 minutes and valve-3 and valve-2 must be in ON condition whereas valve-1 must be OFF. During this gas flow, the ON and OFF conditions of valves and fans are shown in the table 1. Controlling part of the system and storage of the sensors responses were done using a LabVIEW software, XBee module and an arduino microcontroller. The observations are recorded continuously.

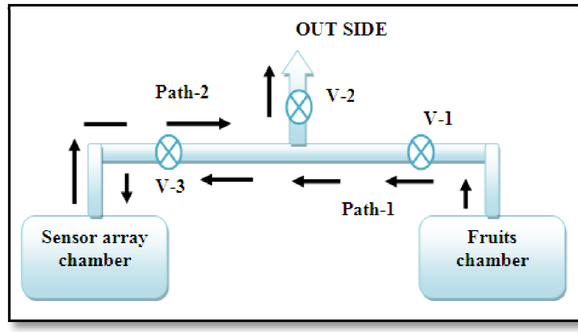


Figure 4: Demonstration of the flow of the gases.

Table 1: Working and valves setting for corresponding chamber.

Flow of gas	V1	V2	V3	Exhaust Fan-1	Exhaust Fan-2
Fruit Chamber to sensor chamber (chamber-1 to 2)	ON	OFF	ON	ON	OFF
Sensor Chamber (chamber-2) to outside	OFF	ON	ON	OFF	ON
For cleaning the chambers (chamber-1 and 2)	ON	ON	ON	ON	ON

Circuit designing considerations are as under:

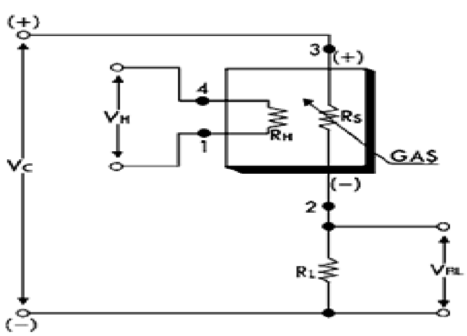


Figure 5: Measurement circuit of sensors.

Formulae for gas sensors:

Sensor Resistance is,

$$Rs = (VC / VRL-1) X RL$$

where, RS is the sensor resistance when gas is present in the environment, VC is the circuit voltage (Max. 24V only, $Ps \leq 15mW$ Load),

VRL is the output voltage across the load resistor, changing with respect to the gas,

RL is the load resistor.

Heating voltage, VH = 5.0±0.05V (AC or DC),

Power dissipation across sensor electrodes (Ps),

$$PS = (VC2 X RS) / (RS + RL)2$$

The relative response or the difference when gas is produced by the fruits is,

$$\Delta V = (Vgas - Vclearair)/ Vclearair$$

where, Δ V is the relative response of a sensor,

Vgas - output voltage of gas sensors when gas is present, Vclearair- response of gas sensor in clean air/ fresh air.

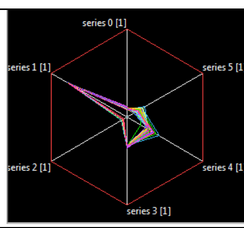
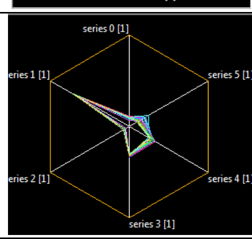
RADAR PLOTS

A chart or plot to represent graphical structure of the variable values or the sensors data is called radar plot or radar chart or radar pattern. The radar chart is also known as cobweb chart or polar chart or star plot or irregular polygon, or kiviat diagram [8] or web chart or star chart or spider chart. The multivariate values or data are displayed in 2D chart of 3 or may be more types of variables having same starting point of axes for all the sensors or quantitative variables. The positions of all the quantitative variables are presented with the same angle and on the same axes. These types of plots are very useful in the comparing process of numerous quantitative variables or values. The advantages of this plot are that: we can easily observe that which variables achieve high or low or similarity from a given data and provide perfection for displaying performance. A chart or plot region encloses a series of the 1D values which are expanding in 2D, then a plot region takes the form of polygon having n-sides with a circular X-axis on behalf of categories and a radial Y-axis representing the data or values. One of the examples of the radar plot representing the area, growth, inflation and population of kab lab. Radar area, radar line, radar stripe and radar point are the typically used types of radar chart out of its 35 types.

RESULTS AND DISCUSSION

Mint or mentha having sweet and fresh smell is used in most of the mouth fresh products. In the study and monitoring the freshness of mint or quality of mint, we have collected 150-250 gm mint leaves and carried out the same procedure using E-Nose system and recorded the data continuously from fresh mint for 7-10 hours. The freshness of mint decreased with respect to the time. Radar plots of fresh and unfresh mint are displayed in the table 2.

Table 2: Radar plots and area of the radar for mint.

State	Radar plot	Area of the response in cm2	Area of gas response with respect to total area in %	Humidity of the chamber
Fresh		1.42	8.28	95 %
Unfresh		1.1	6.41	96.96%

The area of radar plot is 1.42 cm2, with a corresponding area of gas response with respect to total area 8.28 % when the mint was in the fresh state. When the freshness is reduced, after 7-10 hours area of the pattern is 1.1cm2 with a corresponding total area of 6.41%. The area of plot decreased with respect to the time.

Thus odour must have reduced with respect to the freshness. Thus area of radar and the amount of odour in the case of fruits and fruit vegetables are increased when the ripening stages or the time is increased. Hence the gases or the odour pattern/ area of radar pattern increased when the freshness is increased. However, in the case of leafy vegetables freshness is decreased when the area of radar is increased. Humidity content of chamber is 95 %RH, when the mint was fresh. After 7 hours the humidity content increased to 96.96 %RH when the freshness is decreased.

Figure 6 shows the variation in responses of the gas sensors, radar plot and measurement window (i.e. GUI using LabVIEW) for the cauliflower.

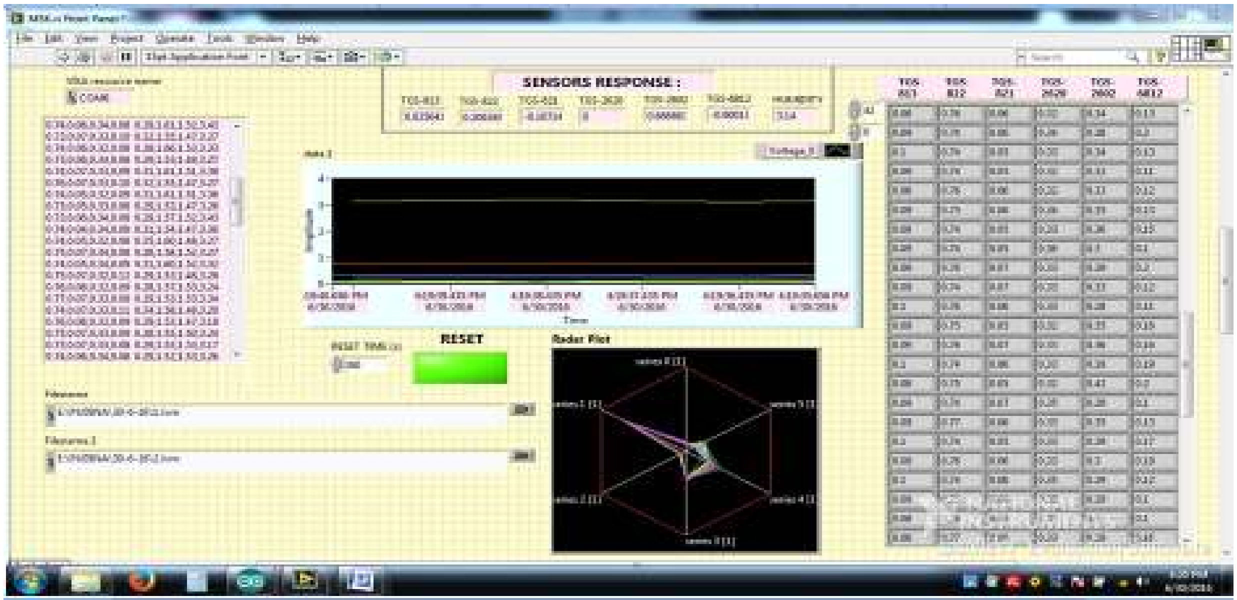


Figure 6: Observations, responses and radar plot of mint.

CONCLUSIONS

The radar pattern plots illustrate variation in the emitted gases from the mint. We can observe any rapid growth or reduction or any changes in the given responses by means of GUI. Freshness of the vegetable (mint) is decreased the area of radar is decreased. The area of radar shows the amount of odour and gases which are emitted by the particular vegetable (mint) or the given sample. Hence if the area is increased it means that the corresponding odour is also increased, and vice-versa. The developed system has successfully demonstrated all the tasks which are expected and are predicted. Hence the system is capable of classifying and identifying the given samples. The system can be implemented for all the types of samples (fruits and vegetables) with a little change and training.

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