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Freshness Study of Non-Destructive Papaya by Using an Electronic Nose

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***Abstract*: The present paper highlights the low cost and rapid performance system to determine the freshness of papaya using an electronic nose. Various gases produced by the non-destructive papaya are alcohol, methane (CH_4) and carbon monoxide (CO). The concentrations of these gases were detected and determined by an array of gas sensors. In actual, the freshness studies were carried out by measuring the concentration of the alcohol, methane and carbon monoxide gases as a function of the time pertaining to status of the papaya. The system displays results using LabVIEW software and developed GUI. The studies are useful as a basic foundation design and making an economical practical detector system testing for freshness of papaya.**

Keywords: Sensor array, LabVIEW, Gas chamber, DAQ card, electronic nose, GUI.

I. INTRODUCTION

E-noses have stimulated the development of several measurement methods and techniques for various gases monitoring systems. In particular, gas sensors are highly attractive for particular detection and measurement because they are compact, portable and versatile and provide quick data analysis with high resolution. Therefore, the development of electronic noses from an array of the non-specific gas sensors, controlled and analyzed electronically and mimicking the mammalian nose, has opened a new route for freshness detection of edible fruits [1, 2]. As a novel physical method for measuring smell, the electronic nose technology has gained popularity in recent days. It has its sound footing in the pioneer work of NATO [3] wherein measurements using an electronic nose were compared with other measurement methods based on the objectives repeatability, accuracy and economic standards. It has been pointed out that the electronic nose is a simple, quick and real-time monitoring system [4] and is a very good statistical tool for many numeric as well as nonnumeric calculations. Specifically, ANNs are known to be a powerful tool to simulate various non-linear systems and have been applied to numerous problems of considerable complexity in many fields, including engineering [6], psychology, medicinal chemistry [7, 8], diagnostics [9, 10],and pharmaceutical research [11].

In this paper, we report on the development of a portable E-Nose system prototype using a LabVIEW. The system has successfully detected and classified the odour of a non-destructive papaya. Gas concentration detected was measured as a function of the changing resistance of a sensor across the coil. Sensing resistance for various gas concentrations were calculated and compared for different stages of papaya (unriped, fresh riped and over riped). Present system shows the results that are taken from the gas array for a period of continuous five-six days.

II. ARTIFICIAL NEURAL NETWORK (ANN):

As biologically inspired computational model, ANN is capable of simulating neurological processing ability of the human brain. Average human brain contains about 100 billions of neurons, each being connected with 1000-10,000 connections to others. A single neuron consists of three major parts-dendrites (fine branched out threads) carrying signals into the cell, the cell body receiving and processing the information, and the axon (a single longer extension). The axon carries the signal away and relays it to the dendrites of the next neuron or receptor of a target cell. [12]. In machine learning, artificial neural networks (ANNs) are a family of statistical learning algorithms inspired by biological neural networks (the central nervous systems of animals, in particular the brain) and are used to estimate or approximate functions that depend on a large number of inputs and are generally unknown. Artificial neural networks are generally presented as systems of interconnected "neurons" which can compute values from inputs and are capable of machine learning as well as recognition thanks to their adaptive nature. Neural network can be a hardware- (neurons are represented by physical components) or a software component (computer models) and can use a variety of topologies and learning algorithms [13]. In this system, software based ANN is designed which contains three layers as follows;

A. Input layer (I/PL):

The activity of the input units represents the raw information that is fed into the network [14].

B. Hidden layer (HL):

Hidden neurons are the neurons that are neither in the input layer nor in the output layer. These neurons are essentially hidden from view and their number and organization can typically be treated as a black box to people who are interfacing with the system. Use of additional layers of hidden neurons enables greater processing power and system flexibility [15]. The activity of each hidden unit is determined by the activities of the input units and the weights on the connections between the input and the hidden units.

C. Output layer (O/PL):

The behaviour of the output units depends on the activity of the hidden units and the weights between the hidden and output units.[14]

These three layers of ANN are shown in fig.1.

Figure 1: Artificial Neural Network

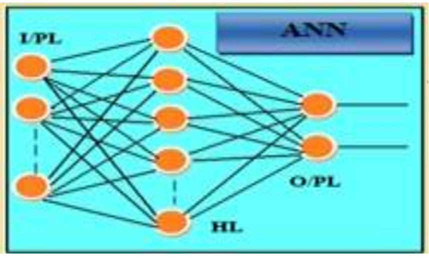
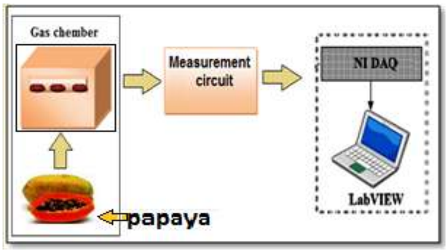


Figure 2: Electronic Nose System



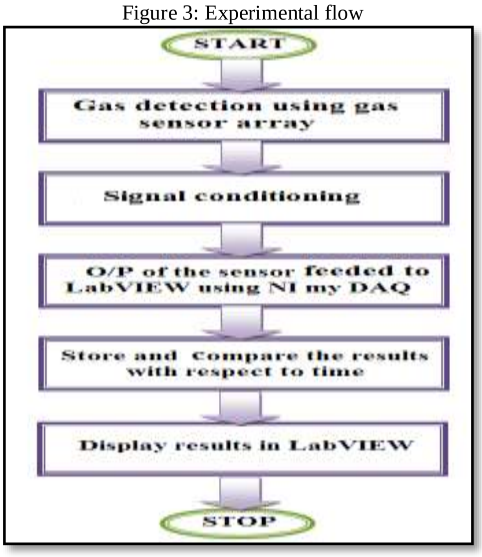
III. Experimental methods and tools:

The block sketch of a practical system used in these investigations is shown in fig.2. It consists of hardware and software developments. The hardware part includes a gas chamber consisting of the sensor array of different gas sensors. The MQ-3, MQ-5 and MQ-7 gas sensors detect alcohol, methane, and carbon monoxide which are emitted from a non-destructive papaya. The gas chamber is an air tight sealed box. Fig. 3 shows the measurement flowchart of a gas sensor.

The software component of the system utilizes, LabVIEW as a tool for designing the entire system, which provides optimal system scalability and increased performance at lower cost. This software also provides facility to build the graphical user interface (GUI), which displays the results on the front panel of a laptop or computer screen. The comparative data and daily variations in resistance across the coil of the sensors are stored in the MS-Excel export from LabVIEW.

The procedural chronology flow chart of this system is as shown in fig.3.

Figure 3: Experimental flow



The gas sensor array detects various gases which are present in the gas chamber, emitted by the papaya. The output of this gas sensor array is in volt that needs to be conditionized into physical usable form. Fig.4 shows the measurement circuit of the output gas sensor. The figure shows two terminals H of sensing element in which SnO_2 is sintered to form a thick film on the surface of an alumina ceramic tube which contains an internal heater. A and B mention the input and output terminals.

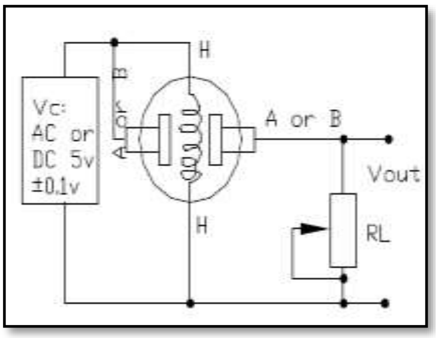


Fig.4 Measurement circuit of the gas sensor.

VI. EXPERIMENTAL RESULTS

The measurements performed on MQ-5, MQ-7 and MQ-3 sensors on the subsequent days are shown in table 1, table 2, and table 3 respectively. The resistance of the sensor was calculated using the relation,

$R_s = (V_C/V_{RL} - 1) \times R_L$

where, V_C is the loop voltage or circuit voltage, V_{RL} is detected voltage and R_L is the load resistance.

A. MQ-5 performance:

As per the observations of table 1, with increase in the time the resistance increased, which manifests the decreased methane gas concentration necessary for ripening.

Table 1. Sensing resistance across MQ-5 Sensor

Sensing resistance across MQ-5(Rs in KΩ)				
First Day	Second Day	Third Day	Fourth Day	Fifth Day
4	4.9	6.87	9.58	13.59
3.96	4.99	6.99	9.72	13.99
3.92	5.13	7.04	9.8	14.19
3.87	5.27	7.16	9.87	14.29
3.75	5.23	7.21	10.09	14.4
3.75	5.37	7.33	10.16	14.5
4.04	5.4	7.39	9.86	14.6
4.09	5.47	7.51	10.08	15.03
4.133	5.51	7.63	10.23	15.25
4.176	5.61	7.69	10.46	15.36
4.21	5.71	7.75	10.62	15.92
4.26	5.76	7.93	10.69	16.39
4.3	5.81	7.99	10.77	16.63
4.35	5.96	8.12	10.85	16.87
4.39	6.07	8.18	11.01	17.24
4.43	6.12	8.3	11.26	17.37
4.48	6.28	8.37	11.42	17.62
4.527	6.33	8.5	11.76	17.88
4.57	6.44	8.69	12.19	18.01
4.61	6.49	8.76	12.55	18.28
4.66	6.54	8.89	12.83	18.54
4.7	6.65	9.03	13.11	18.82
4.75	6.71	9.09	13.4	18.96
4.8	6.76	9.3	13.69	19.38

B. MQ-7 performance

As seen from table 2, the resistance decreased with increase in the time which indicates the increased CO gas concentration due to evolution of CO gas from papaya (for first and second day observations). The increase in the resistance in the ripened and over ripened states showed decrease in CO gas concentration (third to fifth day). The fluctuations in the resistance are due to the measurement errors.

Table 2.Sensing resistance across MQ-7 sensor

	Sensing resistance across MQ-7(Rs in KΩ)			
First Day	Second Da	Third Day	Fourth Da	Fifth Day
15.24	30.39	9.24	9.044	7.55
15.11	29.3	9.31	9.11	7.71
14.98	28.29	9.38	9.17	7.82
14.73	27.32	9.52	9.24	8.11
14.02	26.7	9.66	9.38	7.99
13.79	24.61	9.73	9.59	8.17
13.46	24.58	10.02	9.59	8.34
13.13	24.43	10.1	9.73	8.53
13.03	24.24	10.18	10.1	8.59
12.72	24.14	10.25	10.33	9.04
12.52	24.06	10.49	10.73	9.17
12.23	24.01	10.73	10.97	9.38
11.949	23.94	10.8	11.58	9.45
11.85	22.24	10.89	11.85	9.5
11.76	22.1	10.97	12.04	9.54
11.49	22.06	11.49	12.42	9.55
11.4	22.03	11.67	12.72	9.57
11.06	21.81	12.04	12.93	9.58
10.89	21.38	12.23	13.57	9.6
10.65	20.96	12.62	13.35	9.62
10.57	20.55	12.72	13.03	9.63
10.49	19.97	12.93	12.93	9.68
10.33	19.59	13.03	13	9.7
10.1	19.04	13.24	13	9.72
9.8	18.18	13.35	13.57	9.73
9.59	17.69	13.46	13.03	9.75
9.17	17.37	13.79	13.3	9.78
8.91	17.22	13.9	13.4	9.82
8.78	16.33	13.91	13.5	9.85
8.72	16.04	13.92	13.42	9.86
8.65	15.77	13.93	13.22	9.88
8.53	15.5	13.94	13.53	9.89
8.41	15.11	13.94	13.6	10.02
8.289	14.98	13.95	13.42	10.05
8.23	14.73	13.96	12.96	10.1
8.11	14.25	13.99	12.97	10.18
7.99	13.9	13.99	12.98	10.2
7.88	13.79	13.99	13.02	10.25
7.82	13.57	13.99	13.4	10.26
7.76	13.46	13.96	13.6	10.29
7.71	13.35	13.99	13.75	10.33
7.65	13.3	13.98	13.5	10.39
7.6	13.1	13.99	13.6	10.42
7.49	13	14	13.75	10.46
7.44	12.99	14	13	10.49

C. MQ-3 performance:

The observations of MQ-3 gas sensor shows that the high resistance of unripened and overripned papaya indicates the low concentration of alcohol gas. The fresh and ripened papaya shows the low resistance i.e. high concentration of the alcohol gas.

Table 3: Sensing resistance across MQ-3 sensor

Resistance of sensor MQ-3 (Rs in KΩ)					
First Day	Second Day	Third Day	Fourth Day	Fifth Day	Sixth day
4.52	2.49	1.65	1.93	1.93	12.69
4.53	2.21	2.21	2.49	2.49	12.37
3.91	1.39	3.34	2.77	3.05	12.05
3.34	3.91	3.914	3.34	3.34	11.42
3.05	4.2	5.36	3.91	5.06	11.11
2.77	4.48	5.65	3.05	5.36	10.48
2.75	4.77	4.48	2.77	5.37	10.17
2.78	5.06	4.77	2.74	5.38	9.55
2.71	5.653	4.65	2.78	5.39	8.94
2.64	5.94	4.94	2.77	4.99	8.63
2.63	6.24	4.9	2.98	4.98	8.65

V. Research and development part:

A novel physical method for determining freshness of non-destructive papaya by means of an e-nose is presented in this paper. Basically, the measurements involve sensing/detecting of a gas expelled out from the papaya and its measurement in terms of a physical parameter (in this case voltage) with an appropriate signal conditioning. The experiment was conducted for a period of five-six days starting from the under-riped stage of the papaya till them over-riped. The responses of the sensors were then analyzed using a LabVIEW tool. Figure 5, 6 and 7 shows the responses of an electronic nose at different stages of papaya ripeness and freshness.

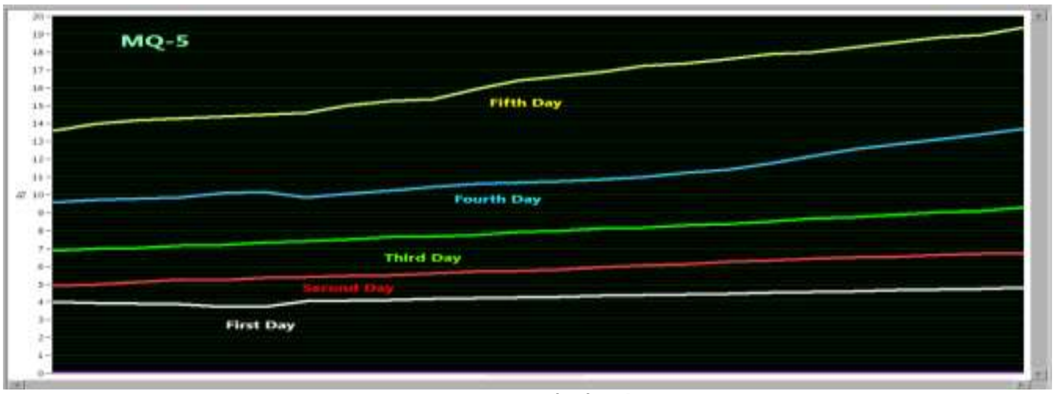


Figure 5: MQ-5 sensor response for five days (time vs. Rs)

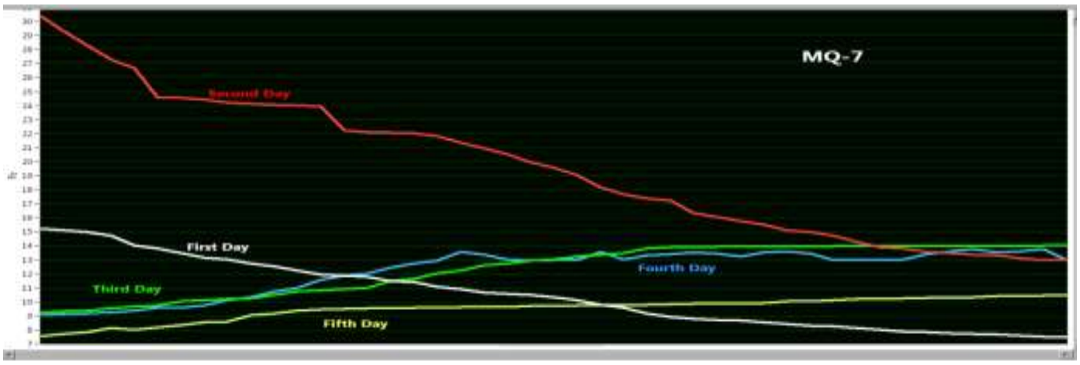


Figure 6: MQ-7 sensor response for six days (time Vs. Rs)

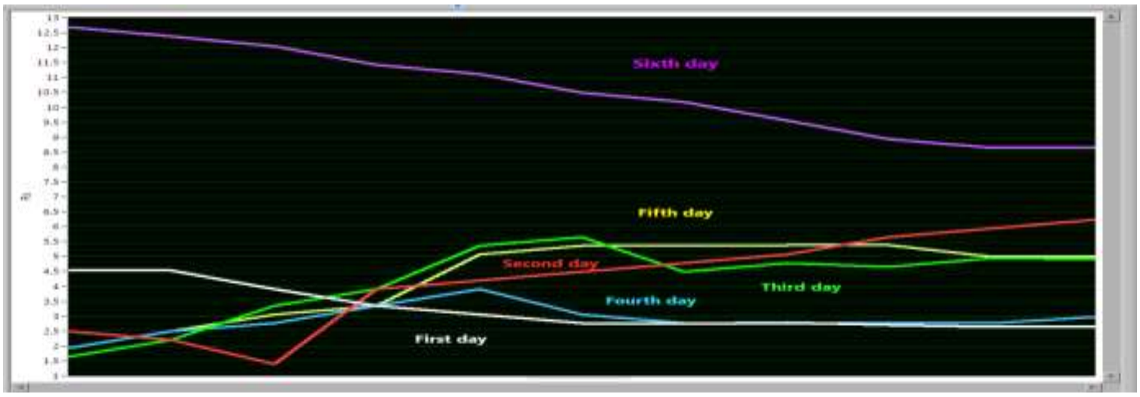


Figure 7: MQ-3 sensor response for five days (time vs. Rs)

In this measurement system, the non-destructive papaya is fluxed into the electronic nose sensor chamber. The variation of the sensors' resistivity is acquired and then digitized using a data acquisition board (NI myDAQ). A program in LabVIEW was developed to control the data acquisition process.

Data processing is decisive factor in order to obtain a versatile instrument able to reliably recognize a wide variety of odours. The front panel of the LabVIEW displays the state of the papaya ripeness and freshness. The brown LEDs indicate under-ripened stage of the papaya; the green LEDs indicate ripened stage of the papaya, whereas the over-ripened stage of papaya (non-eatable form) is indicated by the red LEDs.

Figure 8 shows the LabVIEW demonstration for freshness of papaya.

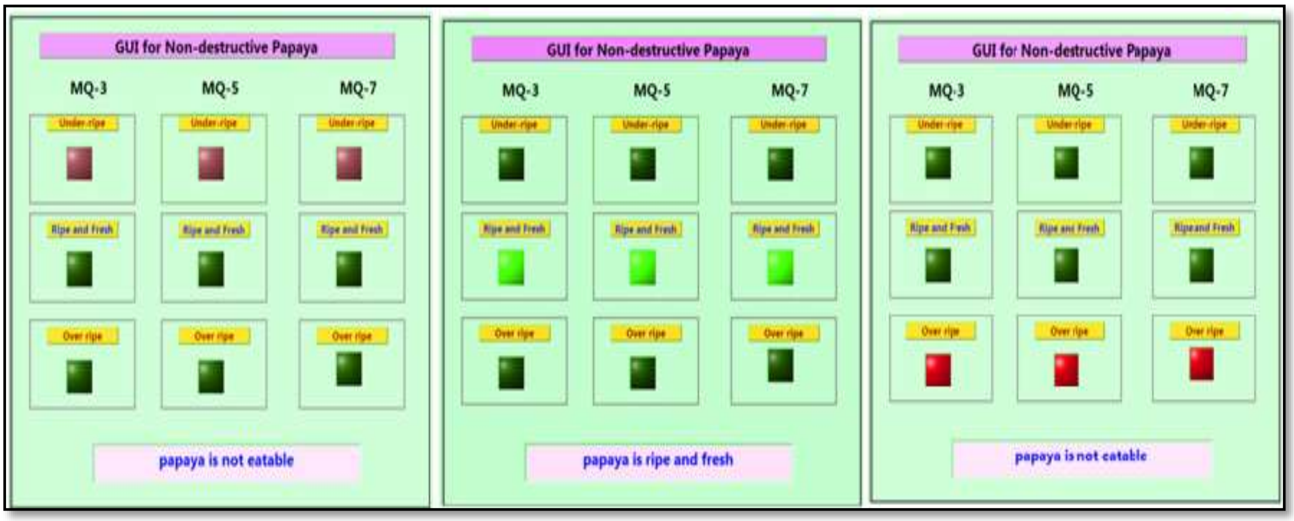


Figure 8: LabVIEW demonstration for freshness of papaya

VI. CONCLUSIONS

1. Developed system is a unique and novel sensing measurement system that points out the different stages of papaya; the under-ripened, ripened and fresh and over ripened. Even, properly time monitored and controlled system can aware the customer for edible state of the fruit papaya.

2. The system requires a simple and costless gas chamber like tight plastic box or a closed metallic chamber, etc.

3. A powerful and reliable user interface offered by a LabVIEW provides an interactive and flexible integrated development environment.

4. The system can be modified and made many fold to determine the state of the art for other fruits (work underway).

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