A Survey of Floral Aroma Sensors

Rekha P[1], Prabhavathi P[2], Veena S. Murthy[3], Padmaja Jain[4]

1,2,3,4Associate Professor, Dept. of ECE, BNM Institute of technology, Banashankari 2nd stage, Bangalore – 560070, India

---***--

Abstract - *Floral aromas are used in medicinal, cosmetics, food, beverages and perfume industry. They can quickly change moods of people. Quality assessment of these aromas is important from commercial value point. In general this assessment is done by human testers where results may be subjective and inaccurate. This problem is overcome by using electronic noses which can sense and assess the quality of aroma objectively for economic valuation in a faster, accurate and noninvasive way. Evaluation of quality of aroma is useful to predict flowering period and right time for extraction of aroma. Presently, there is no survey article available on floral aroma sensing, using electronic noses. This paper focuses on survey of sensing materials, sensing principles, aroma analysis methods, limitations of existing methods, future scope for research in floral aromas.*

***Key Words*: Aroma, E-nose, quality, evaluation, MOS, sensor, flower.**

1. INTRODUCTION

Aroma is a distinctive, usually pleasant smell perceived by the olfactory sense which can quickly trigger memories and emotions [1]. Plants are an important source of aromatic compounds. Plants synthesize aroma in different parts such as flowers, leaves, fruits, seeds, barks and roots. Of these different parts, aroma emissions from flowers sweet and pleasant are mainly used by perfume industry and in aroma therapy. Since unique aromas have high economic values, extracting, processing and assessing the quality of these aromas has created lot of interest in researchers. Present methods of evaluation of quality of aroma are human or Gas Chromatograph and Mass Spectrometry (GC-MS) based. Human based evaluation depends on olfactory system of the individual and results may vary from one evaluator to another because of varied perceptions, from the same evaluator when tested at different times due to mood swings; varied sensitivity or recovery of the olfactory system itself for multiple exposures. This method is expensive, laborious, highly subjective, may result in inaccurate and imprecise assessment. GC-MS method is expensive, time consuming and cannot be used on fresh flowers. These problems are overcome with the development of electronic noses (E-noses), devices designed to mimic mammalian olfactory system, operate faster and produce quantitative, reliable, repetitive and accurate results.

E-nose has two important components: sensing system and data analyzing system. Sensing system will be usually an array of sensors but occasionally a single sensor. Metal oxide semiconductor based sensors and quartz crystal resonators coated with sensing films are reported in literature [2-12]. Upon exposure to aroma, sensors' property/properties such as resistance, frequency, capacitance, work function, mass, quality factor, electrical phase, mechanical amplitude, optical characteristics etc. can change. These changes are captured and processed further using data analyzing system. Data can be analyzed using three methods; graphical method, multivariate analysis and using artificial neural network. Graphical analysis expresses result using bar charts, radar charts or images. Multivariate analysis is applied on large data size and used when measurand is a function of many attributes. Some of the multivariate techniques are: Principal Component Analysis (PCA), Singular Value Decomposition (SVD), and Cluster Analysis (CLA). Artificial Neural Networks (ANNs) consist of a set of interconnected trained networks with parallel processing algorithms functioning to learn and change based on input and output.

This survey highlights on chemical constituents that cause of aroma in flowers, sensing materials used, sensing principles, and methods of aroma analysis, summary of observations from literature survey, conclusions and further scope for research in the field of floral aroma.

2.   FLORAL AROMA

Floral aroma, pleasant smell of flowers is a complex mixture of low (30 to 300 g mol^{-1}) molecular weight compounds [13]. Flowers give out volatile aromatic compounds as a result of a process called anabolic synthesis. Anabolism is the process of putting together smaller molecules to make big ones or create a new compound during metabolism, a chemical process that occurs in living organisms. Isoprene, for example, is a small hydrocarbon molecule (68.12 g/mol) found in plants two of which join to produce monoterpene, a 10-carbon molecule that smells like lemons, lavender or other things, depending on their structure [14]. One monoterpene with an alcohol compound in its structure smells like Earl Grey tea where as another monoterpene without the alcohol smells like newly manufactured carpet.

Figure 1 shows the chemical components and their structure present in some of the aromatic flowers. Structure, color and aroma of flowers are critical factors in attracting pollinators. Flowers can be identical in shape and color but not in aroma. Large diversity of volatile compounds and their relative

abundances and interactions generate unique aroma. This uniqueness directs pollinators to a particular flower.
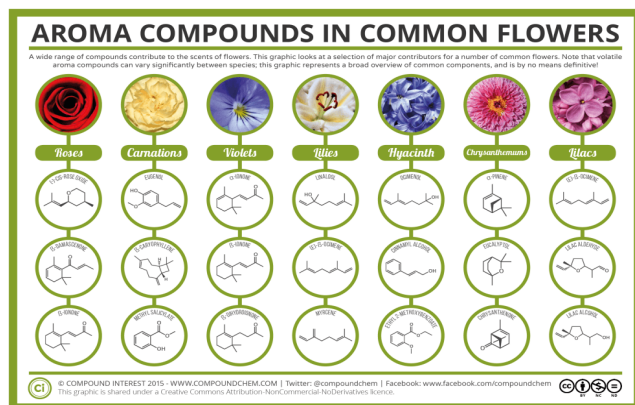

Figure 1: Aroma compounds in some common flowers[15]

Aroma of flowers such as Rose, Lily, Jasmine, Saffron, Cymbidium, Titanium, Chrysanthemums, hops of Chinook, Cascade, Saaz, Mazar, MendoPurps, and MB Kush have been sensed and analyzed [2-12]. Most of the flowers are either randomly selected (rose, hops) or is of regional interest (Titanium, Chrysanthemums) or is for breeding application (Lily, Cymbidium). However, aroma of flower such as Jasmine has high demand in perfume industry and is of high economic value. There is only one attempt made to evaluate quality of aroma of Jasmine flowers. Many more aromatic flowers such as Lavender, Plumeria, Evening primrose, Parijata, Gardenia, Nishagandhi, White Butterfly Gingers, Tube Roses, Honeysuckle, Ylang-ylang, Blue bells, Magnolia, Moonflower etc… are yet to be explored using E-noses.

3. SENSING MATERIALS

Metal oxide semiconductors (MOSs), insulating polymers, conductive polymers and organic compounds have been used as sensing materials [2-12].

Many metal oxides such as ZnO, SnO$_2$, NiO, CuO, WO$_3$, TiO$_2$ [16] are used as gas sensors. Though many MOS materials are explored, SnO$_2$ with dopants is extensively used due to its low cost, higher response and improved performance. SnO$_2$ based sensors is used in sensing of aroma of flowers such as Lily, Titanum, Chrysanthemum, Jasmine, Cymbidium. MOS sensors have the disadvantage of operating at higher temperature requiring heaters, cross sensitivity and complex design.

A class of vapor sensitive Polymers, which operate at room temperature, are used to sense alcohols, aromatic compounds and halogenated compounds. Insulating polymers such as Polyvinylalcohol (PVA) and Polyethyleneimine (PEI) have been used as sensing materials [4]. These films were coated on tuning fork prongs to sense hop's aroma. Flexible molecular chains, good adhesion to surface, ductile nature of PVA and PEI makes them to be good aroma sensing materials. Though authors in [4] say choice of PVA and PEI as sensing material was random, PVA and PEI have been used to sense

gases such as ammonia, hydrogen sulphide, ethanol, triethylamine, nitrogen dioxide, carbon monoxide, carbon dioxide, methane, hydrogen and oxygen [17, 18, 19]. Figure 2 shows dip coating of PEI on the resonator and curing in air at room temperature. Care is taken not to bridge the gap between the tuning fork prongs while making the film which otherwise would damp out resonance. An array of eight sensors is used of which three are coated with Poly-vinyl alcohol (PVA), three with PEI, one uncoated and another vacuum cased for reference.
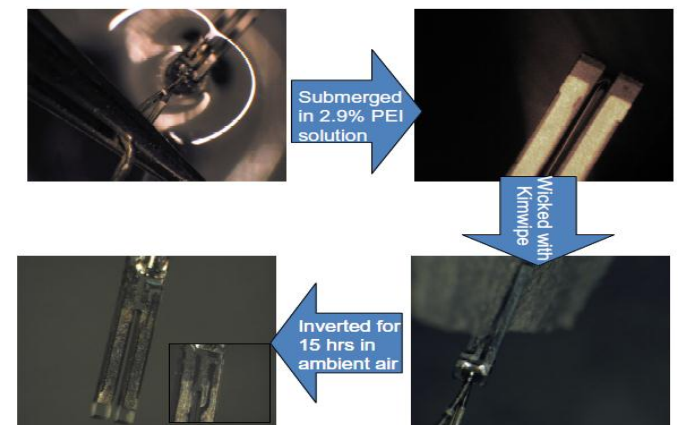

Figure 2: The dip coating of PEI on tuning fork prongs [4]

Conductive polymers (CPs) such as poly-pyrrole, poly-aniline and poly-thiophenes have been used as sensing material in the E-nose, "Aroma Scan" [20] to sense aroma of oilseed rape flowers [12]. Conducting polymers are used as gas sensors since 1980s [21].They are easy to synthesize, molecular chain structure can be easily modified, consume low power, operate at room temperature.

Organic compounds such as D-Phenylalanine, D-Tyrosine, DL-Histidine, D-Glucose, Adenine, Polyethylene, Polychloro-trifluoroethylene and D-Phenylalanine have been used as sensing material to sense Rose's aroma [3]. Sensing material is coated on Quartz crystal resonators (QCRs) using plasma polymerization. These organic compounds have also been used as sensing material to sense tea aroma, for breath analysis, to sense water vapor and to classify 22 odorants [22-25].

4. SENSING PRINCIPLES

E-nose sensors reported in the literature work on the principle of change in electrical resistance and/or change in resonant frequency. Below is a brief discussion on sensing principles involved in aroma sensing.

4.1 Change in Resistance

When aroma adsorbs over sensor, electrical conductivity of the sensor changes in accordance with the gas concentration. Electrical conductivity is determined by the potential barrier at the grain boundaries of the sensing surface. Figure 3 shows

modification of potential barrier at the grain boundaries when reducing or oxidizing gas adsorbs. Aromas such as Lily, Mustard, Jasmine, Titanum, Chrysanthemum, Cymbidium etc. are sensed using this principle. MOS sensors and Conductive polymers work on principle of change in resistance.
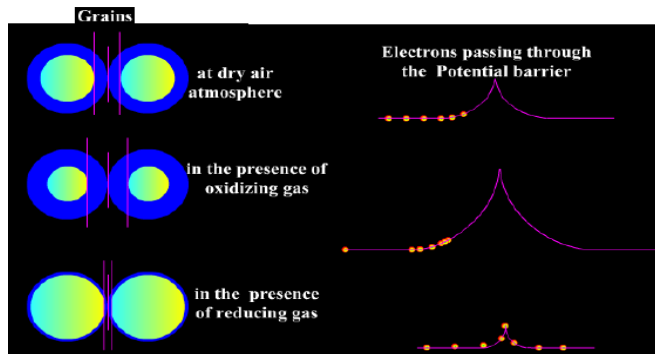
**Figure 3:** Change in potential barrier based on the nature of gas

When a piezoelectric crystal, coated with sensing film, is exposed to target aroma which adsorbs on its surface, the mass of the resonating structure increases with a corresponding change in natural frequency of the crystal. This is detected using a tuned oscillator. Aroma of rose, hop flower is sensed using this principle. Figure 4 illustrates shift in resonant frequency of a resonator when it is exposed to aroma.
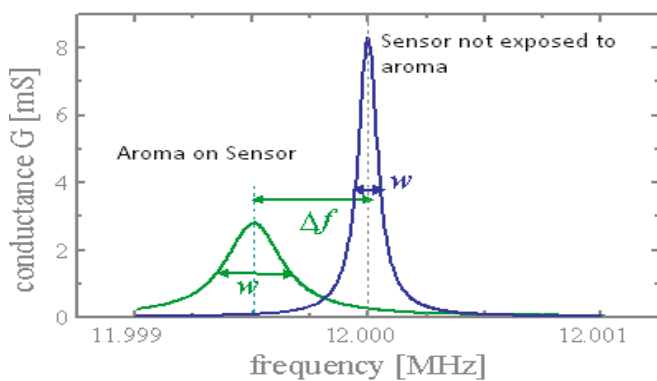
Figure 4: Shift in resonant frequency of QCR when exposed to aroma.

R Paul Wali et. al.[4], have used single sensor but integrated two sensing techniques, electrical impedance and mechanical resonance to differentiate aroma of varieties of hop family flowers (Cascade, Chinook, and Saaz) grown together under identical conditions. The E-nose uses Lab view-VI based computer-designed broadband voltage pulse train that spans a user-defined bandwidth around a user-selected center frequency. The range of frequencies spanned by the voltage pulse includes at least one mechanical resonating frequency of the sensor. A voltage pulse sent to a polymer coated resonator exposed to desiccated aroma excites mechanical resonance through piezoelectric effect.

The current response signal from the device is recorded and processed using Fast Fourier Transform. Components of the response to electrical impedance and mechanical resonance are separated and tracked with time upon exposure to floral aromas. Figure 5 shows shift in resonant frequency when exposed to three varieties of hop flowers. Both PVA and PEI have distinguished the aromas but the difference in the magnitude of shifts is owing to difference in coating thickness and stiffness of the materials. This e-nose has also distinguished three more varieties of hop family flowers Mazar, Mendopurps, MB Kush. This E-nose uses low cost sensors and a sensing technique that has potential for deployment in cell phones where pre-programmed, automated routines can be used to send pulse and receive response as claimed by the authors.
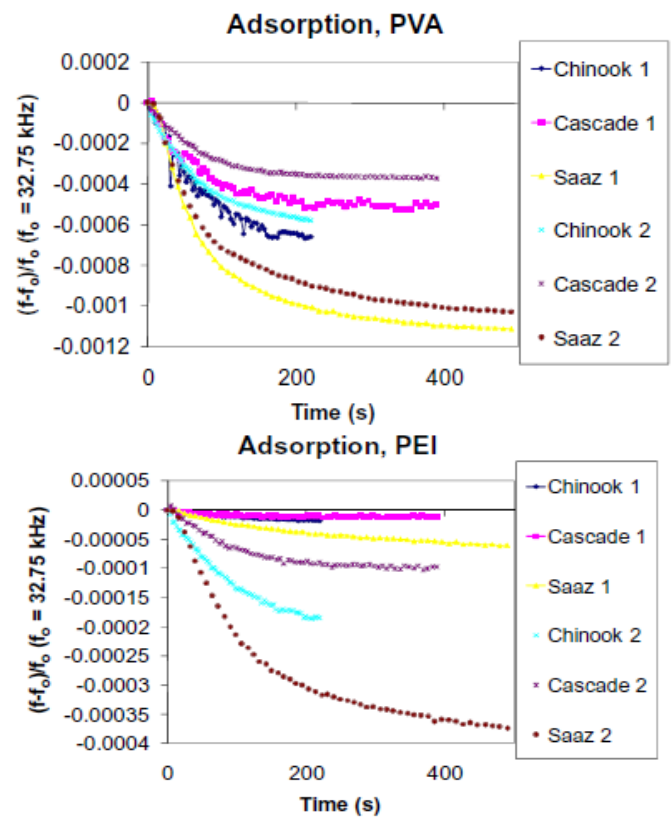

Figure 5: Shift in resonant frequency of two tuning fork resonators coated with PVA, PEI upon exposure to aroma of 3 types of hops pellets: Chinook, Cascade, and Saaz [4].

5. DATA ANALYSIS METHODS

Data analysis is required when an array of sensors and multiple samples is used for collecting information about the target aroma. Measured signal is processed, conditioned, converted to digital and then passed to embedded processors or microcontrollers for further analysis.

When number of sensors used is less than 20, result can be expressed graphically using bar chart or radar chart.

Response of every sensor is recorded and change in parameter of interest such as resistance or frequency of sensors to the same aroma is plotted with common reference. Figure 6a shows bar chart corresponding to aroma of Jasmine flowers. Envelope pattern of the bar chart can be used for classifying the aroma and sum of the peaks may be used for evaluation of quality of aroma. Figure 6b shows the Radar chart of aroma of rose flower Catherine Denuve. Literature in [3] also reports that color of flowers may be same but not the aroma. Kouki Fujioka et.al [6] have studied the smell of Amorphophallus titanum flower (one among the world's largest flower, weight≈100kg and height≈15feet, that rarely blooms and only for a short time), using Fragrance analyzer FF-2A, a commercially available equipment embedded with ten semiconductor sensors. These authors have objectively described the smell of the Titanum flower in terms of standard laboratory gases. They have made use of bar chart and radar chart for expressing the results.
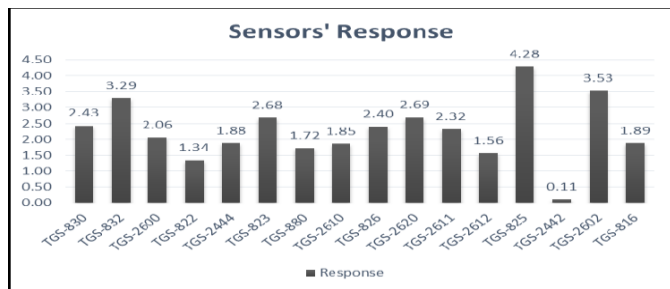

(a)
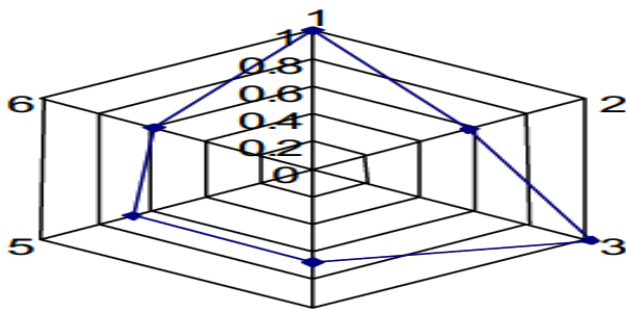
(b)

Figure 6: (a) Response of MOS sensors to Jasmine aroma [5]   (b) Radar chart of aroma of rose flower Catherine Deneuve [3].

Data processing units use statistical analysis tools such as PCA [10], A smell, Statistical product and service solutions (SPSS) statistics [6], CLA [6], Discriminant function analysis (DFA) [9], SVD [10] for classifying the components and assessing the quality of aroma. Aroma of flowers such as Jasmine, Lily, Saffron, Cymbidium etc. are analyzed using statistical data analysis methods. Seiichi Fukai et.al. [7] have demonstrated classification of aromas of three varieties of lily flowers as shown in Figure 7. These authors also demonstrated that aroma of hybrid lily flower need not follow of parent flowers.
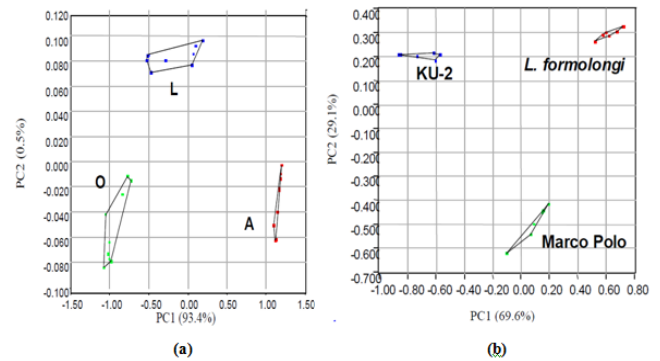

Figure 7: (a) Classification of aromas of three types of lily flowers; Oriental (O), Asiatic (A), Longiflorum(L) (b) Classification of aromas of hybrid lily and the parent lilies using PCA method [7].

Hena et. al [10] have processed classified data to generate a single numerical index corresponding to the overall aroma. This leads to objective way of assessing the quality of aroma. Figure 8a shows aroma index generated by an E-nose at different times of the day when exposed to Jasmine aroma. Results in Figure 8a have been substantiated by GC analysis for the aroma of concrete extract from same set of flowers. Figure 8b shows aroma profile of Jasmine aroma at 10.00 pm which illustrates presence of many aroma contributing components. Jasmine aroma emissions are maximum during night.
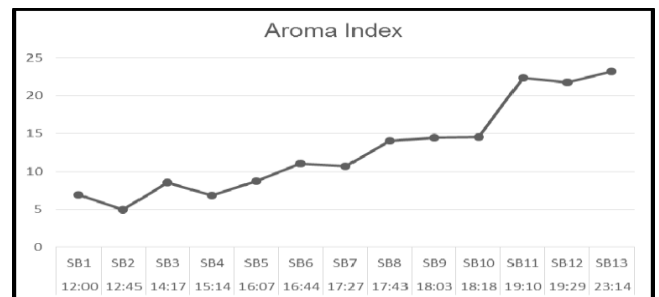

**Figure 8a:** Aroma variations of Jasmine flowers in a day from 12.00 noon to 11.14pm [10]
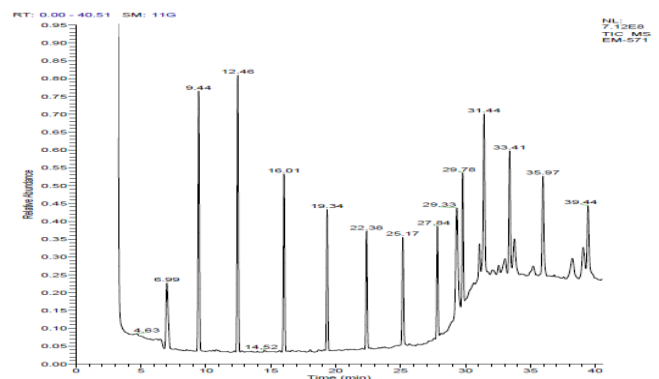
Figure 8b: GC analysis of Jasmine concrete extract, time - 10.00pm [10]

Aroma bit, an aroma imaging company, has reported development of odor imaging sensor [26] which can display the smell of a given aroma sample in the form of an image. It employs an array of quartz crystal resonator sensors to measure information of the target aroma, process data and outputs image/images corresponding to the aroma along with title of the aroma. Figure 9 shows conceptual display of the image sensor when it sniffs coffee in a coffee shop.
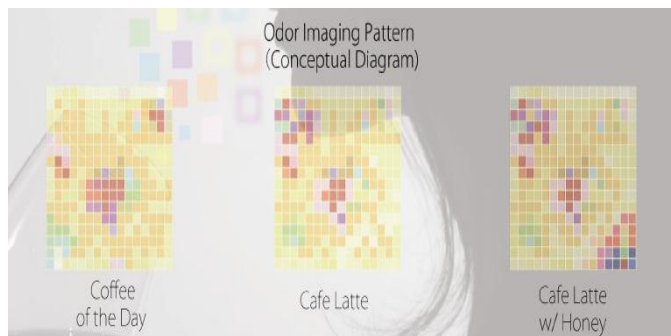
Figure 9: Display of type of coffee through image and its name by odor imaging system
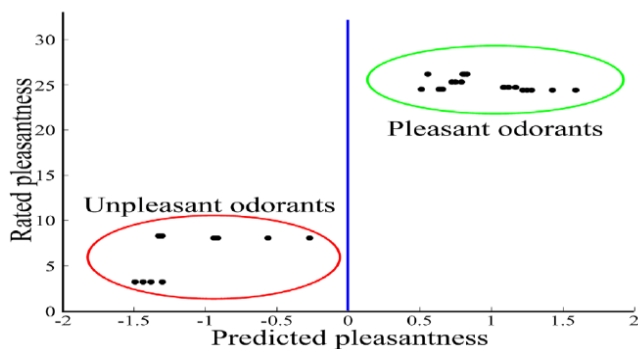
Figure 10: Classification of oil samples by E-nose using ANNs [8].

Rafi Haddad et. al [8] have used an E-nose to predict the pleasantness of an odor using ANNs. 76 odors were used to train the E-nose. Trained E-nose was exposed to 22 essential oil samples that it had never been exposed to before and the E-nose was able to rate the pleasantness on a scale from most pleasant to least pleasant. The same 22 oil samples were tested by 28 human testers from two different cultural origins (Israel and Ethiopia) and a correlation of 88% was observed between machine and human results. Figure 10 shows the classification of oil samples after aroma analysis.

6. EFFECT OF MOISTURE WHILE SENSING AROMA

Humidity in the test chamber is one of the important factors to be considered during measurements with fresh flowers. The flower invariably contains moisture and when introduced into the test chamber increases the humidity. However, it is also to be noted that humidity is the carrier of aroma [6]. Kouki Fujioka et.al [6] have analyzed the smell of Amorphophallus titanium flower with normal moisture in air and also by removing the moisture in the gasses collected from flower. They have concluded that when moisture is removed, as has been done by some, sensors do not register some of the aroma whose boiling points are lower and are soluble in water. This has shown the necessity of water vapor in carrying certain aroma.

U.S. Patent filed by Adl Shefer et.al. [27] reveals improved fragrance release by Benzyl acetate, Linalool, Geraniol, Cis-jasmone etc. in the presence of moisture; this information is useful in sensing of aroma with moisture (quality evaluation of fresh flowers).

However, Mitachi et al. [3] have reported a suitable desiccant for sensing aroma of rose in moisture free environment. Different desiccants such as silicagel, $CaCl_2$, P_2O_5, and CaO are investigated with chemical compound α-pinene as representative of rose aroma. Detailed study revealed that $CaCl_2$ effectively reduced moisture without reacting with rose aroma and sensor, therefore $CaCl_2$ is suggested as best desiccant to sense aroma of rose.

7. OBSERVATIONS FROM SURVEY

Aroma analysis by human experts is subjective and may result in inaccurate, non repetitive results. GC-MS has been used to test floral extracts but not fresh flowers. This method is accurate but time consuming and expensive. Measurement of change in resistance is simple and easy and hence the preferred choice for many researchers. Change in frequency is also easy to measure, if the change is large and has been used by many researchers. It appears that selection of sensing material and type of sensing principle is not specific to the target aroma and they are selected based on availability and sensitivity to organic vapors to some extent [10]. In all the works reported above the prime objective is either identification of a flower or method of data analysis and not the development of sensor for assessing floral quality.

Radar chart and bar chart method of expressing data is easy to visualize. Multivariate analysis such as SVD, PCA etc., is preferred when sample size is large. ANNs can make e-nose behave close to natural nose by using the right learning algorithm but, is very complex to implement and expensive. Image processing techniques for aroma analysis is a very new thought on the way of presenting the results for visual appeal. Table 1 summarizes E-noses developed for floral aroma sensing. Though literature reports, controlled operating conditions by some researchers during sensing, there is, no or very less information available about operating sensor at different temperatures and humidity with same input sample and its effect on response of sensor.

Table 1: Summary of E-noses developed for floral aroma sensing or quality evaluation.

Flower	Sensor Type	Number of sensors	Sensing principle	Analysis method	Applications	Ref.
Oil radish, mustard etc.	Conducting polymer	32	Resistance change	PCA	Pollination	[12]
Lily	MOS	18	Resistance change	PCA, Sensory Panel	Fragrance Breeding of ornamentals	[7]
Titanum	MOS	10	Resistance change	Dendrogram, CLA	Description of the odor	[6]
Chrysanthemum	MOS	Unknown	Resistance change	DFA	Screening tool for Western Flower Thirps resistance.	[9]
Jasmine	MOS	30	Resistance change	SVD	Quality assessment of Jasmine aroma	[5,10]
Cymbidium	MOS	6	Resistance change	PCA, DFA	Breeding of polypoidy Cymbidium, Analysis of flowering period, identified region of strong aroma within flower, comparing diploid and tetraploid aromas	[11]
Rose	Polymer coated QCR	6	Resonant frequency shift	Graphical, Radar plot	Identification of suitable desiccator, specified Rose species	[3]
Hop	Polymer coated QCR	8	Resistance and Resonant frequency change	Fast fourier trasform (FFT)	Wireless sensing	[4]
Conceptual Idea	Thin film coated QCR	7	Resonant frequency change	Image processing	Discriminating aromas	[26]

8. CONCLUSIONS

Sensing the aroma of flowers with high economic value and evaluating its quality is an important commercial activity. Work on evaluation of aroma quality of flowers has not been explored extensively by researchers. Amongst those who have worked on this aspect, two have tried to develop a new sensor or use a new sensing material for floral aroma sensing. Others have used commercially available sensors or equipments but have proposed different methods of data analysis. The ultimate goals of most of the researchers have been identification of a flower by its aroma and a few have worked on evaluation of quality of aroma which is an important parameter for fixing the price for flowers. Flowers with high economic value also are not explored extensively. Hence there is lot of scope for exploring new sensing materials for aroma sensing, development for simple instrumentation for evaluation of quality of floral aroma and to study influence of moisture while sensing aroma.

FUTURE SCOPE

There is a need to develop a simple field deployable aroma sensor. MOS sensors are non specific and are cross sensitive and hence could be replaced with one single sensor which is sensitive of many of the aromatic compounds. This will reduce data processing and simplify the sensing system. Sensing materials that are simple to build, stable, reusable and low cost are to be considered for developing the sensor. In this context conducting polymers are top in the list as they are easy to produce or easily available; and measuring change of resistance is simple. Out of the commercially available conducting polymers PEDOT: PSS is stated to be most stable and sensitive to many aromatic gases. Thus PEDOT: PSS can be preferred as the first choice. It is commercially available from many sources in suspension form with characteristics suited for film making. If many of aromatic compounds are soluble in water then PEDOT: PSS is best suited as the material as its dipole moment comparable to that of water.

REFERENCES:

[1] Rachel S. Herz, "The Role of Odor-Evoked Memory in Psychological and Physiological Health", Review, brain sciences, Brain Sci. 2016, 6, 22.

[2] AmaliaBerna, "Metal Oxide Sensors for Electronic Noses and Their Applicationto Food Analysis", *Review Sensors* 2010, *10*, 3882-3910, ISSN 1424-8220.

[3] S. Mitachi, "Odor Sensing in Natural Environment Using Quartz Crystal Resonators: Application to Aroma Sensing of Roses Cultivated in an Outside Garden", Proc. WOCMAP III, Vol. 5: Quality, Efficacy, Safety, Processing & Trade in MAPs Acta Hort. 679, ISHS 2005.

[4] R Paul Wali, "An electronic nose to differentiate aromatic flowers using a real-time information-rich piezoelectric resonance Measurement", Elsevier, Sciverse Science direct, procedia chemistry, 2nd International Conference on Bio-Sensing Technology 6 (2012) 194 – 202.

[5] Hena Ray, "Characterization of the Volatile Aroma Compounds from the Concrete and Jasmine Flowers Grown in India", CHEMICAL ENGINEERING TRANSACTIONS, VOL. 40, 2014, ISBN 978-88-95608-31-0; ISSN 2283-9216.

[6] Kouki Fujioka, "Objective Display and Discrimination of Floral Odors from Amorphophallus titanum, Bloomed on Different Dates and at Different Locations, Using an Electronic Nose", Sensors 2012, 12, 2152-2161.

[7] Seiichi Fukai, "DISCRIMINATION OF LILY FRAGRANCE BY USE OF AN ELECTRONIC NOSE", Proc. XX EUCARPIA

Symp. on New Ornamentals II, Acta Hort. 572, ISHS 2002.

[8] Rafi Hadda,, AbebeMedhanie, Yehudah Roth, David Harel, Noam Sobel, "Predicting Odor Pleasantness with an Electronic Nose", PLoSComuputational Biology, April 2010, Volume 6, Issue 4, e1000740.

[9] Robin C. McKellar, " Application of the Electronic Nose to the Classification of Resistance to Western Flower Thrips in Chrysanthemums", J ChemEcol, 28 September 2005, 31: 2439.

[10] Hena Ray, Nabarun Bhattacharyya, AlokeshGhosh, BipanTudu, RajibBandyopadhyay, ArunangshuGhosh, SuparnaParuaBiswas, and SabyasachiMajumdar , "Fragrance Profiling of JasminumSambacAit. Flowers Using Electronic Nose ",IEEE SENSORS JOURNAL, VOL. 17, NO. 1, JANUARY 1, 2017.

[11] Sook-Hyun Hwang, Mi-Seon Kim, Pue-Hee Park, and So-Young Park, "Scent Analysis Using an Electronic Nose and Flowering Period of Potted Diploid and Tetraploid Cymbidium", Korean J. Hortic. Sci. Technol. 34(1):163-171, 2016, ISSN : 1226-8763.

[12] E. Bloem, S. Haneklaus, R. Daniels and E. Schnug, "INFLUENCE OF SULPHUR FERTILISATION ON THE FLORAL SCENT OF FLOWERING CROPS",Proceedings - CIEC 2009, 18th International Symposium of CIEC, "More Sustainability in Agriculture: New Fertilizers and Fertilization Management".

[13] Alphus D. Wilson, and Manuela Baietto, "Applications and Advances in Electronic-Nose Technologies", Review, Sensors 2009, 9, 5099-5148.

[14] Brian Palmer, "From jasmine to rotting flesh, flowers emit fragrance to attract pollinators", Health & Science, The Washington post, September 2, 2013.

[15] http://www.compoundchem.com/wp-content/uploads/2015/02/Aroma-Chemistry-The-Scents-of-Flowers.pdf

[16] Xiao Liu, Sitian Cheng, Hong Liu, Sha Hu, Daqiang Zhang and HuanshengNing, "A Survey on Gas Sensing Technology", Review, Sensors 2012, 12, 9635-9665.

[17] Wei-De Zhang and Wen-Hui Zhang, "Carbon Nanotubes as Active Components for Gas Sensors", Review Article, Hindawi Publishing Corporation, Journal of Sensors, Volume 2009, Article ID 160698, 16 pages.

[18] Bin Sun, GuangzhongXie, Yadong Jiang, Xian Li, "Comparative CO2-Sensing Characteristic Studies of PEI andPEI/Starch Thin Film Sensors", Elsevier, SciVerseScienceDirect, ICSGCE 2011: 27–30 September 2011, Chengdu, China, Energy Procedia 12 (2011) 726-732.

[19] Bin Ding, Moran Wang, Jianyong Yu and Gang Sun, "Gas Sensors Based on ElectrospunNanofibers", Review, Sensors 2009, 9, 1609-1624.

[20] P.-J. Raugel, "Rapid Food Analysis and Hygiene Monitoring", Kits, Instruments and Systems, Book 1999, ISBN: 978-3-642-63552-6, by Springer.

[21] HuaBai and Gaoquan Shi, "Gas Sensors Based on Conducting Polymers", Review, Sensors 2007, 7, 267-307, ISSN 1424-8220.

[22] Prolay Sharma, ArunangshuGhosh, BipanTudu, RajibBandyopadhyay and Nabarun Bhattacharyya, "Development of Quartz Crystal Microbalance Sensors for Tea Aroma Chemicals", American Scientific Publishers, SENSOR LETTERS, Vol. 12, 1–7, 2014.

[23] Nahoko Kasai, Iwao Sugimoto, Masayuki Nakamura, "Discrimination of odorants of definiteconcentrations by using plasma-organic-film-coated QCR sensors", Elsevier, Sensors and Actuators B, 65 (2000), 114–119.

[24] Kazuhiko Takahashi, Iwao Sugimoto, "Remarks on Emotion Recognition from Breath Gas Information", Proceedings of the 2009 IEEE, International Conference on Robotics and Biomimetics, pg.nos.-938-943, December 19 -23, 2009, Guilin, China.

[25] Kazuhiko Takahashi, Naoki Nishiwaki, Iwao Sugimoto, "Computational Model Of Plasma-Organic-Polymer-Film-Coated QCR Sensor For Analysing Its Dynamic Response", Proceedings of the 8th International Conference on Sensing Technology, pg.nos. 85-88, Sep. 2-4, 2014, Liverpool, UK.

[26] Aroma bit, "Multi arrayed QCM type compact odor imaging sensor".

[27] Shefer et al., "Moisture triggered release systems comprising aroma ingredients providing fragrance burst in response to moisture", US patent Pub. No.: US 2003/0194416 A1.

BIOGRAPHIES

Rekha P is working as Associate professor in Dept. of ECE, BNMIT, Bangalore. She is working in the area of sensors using conducting polymers.

Prabhavathi P is working as Associate professor in Dept. of ECE, BNMIT, Bangalore. She is working in the area of Low power VLSI.

Veena S Murthy is working as Associate professor in Dept. of ECE, BNMIT, Bangalore. She is working in the area of RF energy harvesting.

Padmaja Jain, faculty at BNMIT, ECE is working in the Photonics area.