The taste or smell of end products manufactured in the food, beverage or dairy industries can be of vital importance to the commercial success of the product. The expectations of consumers regarding the quality of products in these fields are continually increasing as a result of greater range of choices in the marketplace, which emphasizes product quality. Competition for market share and the added emphasis on quality have increased pressure on product development and rigorous QA/QC to meet consumer expectations. Ideally taste analysis, both in the development of new products and their routine production, should be carried out by tasting panels composed of human experts. In practice such panels are extremely expensive and especially problematic when used for production control purposes. With rapid growth in electronic hardware technology and spurt of software-based computation and processing, standardized identification through artificial sensors like E-Nose, E-Tongue have been recently used. E-Nose & E-Tongue technology has generated a lot of interest recently because of its versatile applicability in terms of identification and classification of processed food and consumer items. The emerging non destructive food quality analysis techniques are capable of evaluating the finished products quality by analyzing their sensory outputs which may be in the form of flavor, odor, color, texture and taste one of the signs of this care is development and optimization of monitoring and control methods of both, food materials and their processing. Valuable source of information about quality of the particular product is the analysis of volatile compounds based on either classic sensor analysis or application of instrumental methods. Food products flavour is mostly caused by many volatile compounds which appear in such product. Volatile compounds are mainly responsible for shaping the organoleptic quality of many kinds of food, even though they are found in relatively small quantities in such products. Sensing and perception through these organs are done through biological, physiological, chemical processes involving finally the brain as the Central Processing Unit (Bartlett et al., 1997).

**Tasting Panels**

For manufacturers, the quality of incoming raw materials and finished products are of the upmost importance to achieve maximum consumer satisfaction. The use of sensory panels in manufacturing plants is however significantly more difficult within a R & D environment. Typically, sensory panelists in the factory are staff with other main responsibilities so that their availability can be limited. In addition, the production environment is very hostile to sensory analysis with the noise, odours and pressure making it difficult to get objective and reproducible results. Unlike the typical sensory panelist in R & D, a panelist in a manufacturing environment needs continual motivation when faced with for repetitive QC tasks for evaluating new production batches. In practice, therefore, such problems make the sensory panel method of QC difficult to implement and maintain in terms of routine operation and costs. However, given that the end-consumer will judge the product on the basis of taste, it is vital that the QC process of verifying taste be maintained. Such conflicting pressures are the impetus behind the current trend to improve current sensory QC/QA methods by the introduction of alternative or complementary methods. Such methods must be fast, accurate and cost effective and of course must correlate with the results of sensory panel analyses.
Comparision Between Human Perception
And Machine Sensing

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<td>Tongue Taste</td>
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(Tan et al., 1995)

Sensor Array Systems

Now a day, odour, aroma and taste control evaluation can be performed by gas and liquid sensor array system - the so called electronic nose and electronic tongues. Due to their simplicity, rapidity and objectivity, they have started to be extensively used by major food, cosmetic and packaging companies in various applications such as quality control, product matching, origin identification, spoilage detection, and flavour quantification. Without needing any prior fractionation, electronic noses and tongues can determine the fingerprint of a complex volatile or dissolved compound mixture by an array of semi-specific sensors coupled to a pattern recognition system. Just as humans do, an electronic nose operates by recognizing the overall pattern of components. In addition, the “odour/aroma and taste fingerprints” could then be stored in a data base in a way analogous to the memorization of olfaction perception in the human brain. Many optical sensors which could detect contamination invisible to human eyes to inspect by E-vision systems.

Electronic Noses and Electronic Tongues: A Comparison

Electronic nose and electronic tongues instruments analyze different aspects of the sensory perception. The electronic nose (E-nose) measures volatile components of aroma/odour in the sample head space while the electronic tongue measures dissolved organic and inorganic components i.e. Non-volatile molecule that remain in the food/beverage. For electronic noses, the final response can be described as \( R = f (SG, H(P)) \), where \( SG \) represents the sensitivity and selectivity of the gas sensor array sensitivity and selectivity and \( H(P) \) is a variable representing the properties of the sample headspace. Electronic tongue (E-tongue) sensors detect all chemical species present directly in the liquid samples. Only some of these species can be observed in the sample headspace generated. The response \( R \) can be described as \( R = f (SL, P) \), where \( SL \) represents the sensitivity and selectivity of the liquid sensors and \( P \) represents the properties of the liquid sample. Typically, E-tongue systems measure attributes like saltiness, sweetness, bitterness, sourness and metallic taste. In general, these attributes are fairly similar for each application area. The two instruments are thus complementary in most applications.

Benefits of E-Nose and E-Tongue

E-Tongues and E-Noses have the ability to perform sensory based analyses like odour/aroma and taste rapidly and in a cost-efficient manner. Not only are the systems more rapid and objective than human based tasting panels but they are much more amenable to routine use for example in production QC applications. Since they correlate well with human sensory panels, the instruments can be described as a ‘consumer based instrumental test’. E-noses and tongues also correlate well with more classical analytical methods such as HPLC and GC/GCMS instruments which measure a specific analyte or group of analytes. E-noses and e-tongues are however much more rapid. For example the HPLC analysis of caffeine levels in a carbonated soft drink generally takes about 15 minutes. An E-tongue will give the result in approximately 3 minutes.

Electronic Nose (E-Nose)

Electronic Nose is a machine designed to detect complex odors using sensor arrays. The sensor array consists of broadly tuned (non-specific) sensors that are treated with a variety of odor-sensitive biological or chemical materials. An odor stimulus generates a characteristic fingerprint from the sensory array. The fingerprint (or smell-print) is classified and identified with suitable pattern recognition engine for declaration of odor. The system consisting of a set (matrix) of electrochemical sensors, selective for certain volatile compounds. The instrument is equipped with appropriate system of pattern recognition.
Electronic Nose Principles

The e-nose attempts to emulate the mammalian nose by using an array of sensors that can simulate mammalian olfactory responses to aromas. The odour molecules are drawn into the e-nose using sampling techniques such as head space sampling, diffusion methods, bubblers or pre-concentrators (Pearce et al., 2003). The odour sample is drawn across the sensor array and induces a reversible physical and/or chemical change in the sensing material, which causes an associated change in electrical properties, such as conductivity (Harsanyi, 2000). Each “cell” in the array can behave like a receptor by responding to different odours to varying degrees (Shurmer and Gardner, 1992). These changes are transduced into electrical signals, which are preprocessed and conditioned before identification by a pattern recognition system as shown in Fig.

The E-Nose system is designed so that the overall response pattern from the array is unique for a given odour in a family of odours to be considered by the system. In effect, the electronic nose can create odor-exposure profiles beyond the capabilities of the human panel or GC/MS measurement techniques. The electronic nose is a system consisting of three functional components that operate serially on an odorant sample—a sample handler, an array of gas sensors, and a signal-processing system. The output of the electronic nose can be the identity of the odorant, an estimate of the concentration of the odorant, or the characteristic properties of the odor as might be perceived by a human.

Characterization of E-Nose Sensors

Applications of Electronic Noses

Currently, the biggest market for electronic noses is the food industry. Applications of electronic noses in the food industry include quality assessment in food production, inspection of food quality by odor, control of food cooking processes, inspection of fish, monitoring the fermentation process, checking rancidity of mayonnaise, verifying if orange juice is natural, monitoring food and beverage odors, grading whiskey, inspection of beverage containers, checking plastic wrap for containment of onion odor, and automated flavor control.

Food Freshness, Quality, Ripeness and Shelf-Life

Electronic-nose systems have been designed specifically to be used for numerous applications in many different industrial production processes. A wide variety of industries based on specific product types and categories, such as the automobile, food, packaging, cosmetic, drug, analytical chemistry and biomedical industries utilize e-noses for a broad and diverse range of applications including quality control of raw and manufactured products, process design, freshness and maturity (ripeness) monitoring, shelf-life investigations, authenticity assessments of premium products, classification of scents and perfumes, microbial pathogen detection and environmental assessment studies.

The age of fruits (ripeness or maturity level) determines the shelf life and future rate of quality loss due to changes in flavor, firmness and color. Harvesting fruits at an optimal physiological condition ensures good quality at a later stage (when evaluated by the consumer) by enhancing a number of quality characteristics that extend the shelf-life, slow the rate of decline in firmness or texture, and maintain a preferred level of flavor and overall appearance. Several studies have demonstrated that the aroma emitted by fruits can indicate the maturity level and thus quality and shelf-life of the marketed product. Pathange et al. (2006) used maturity indices such as starch index and puncture strength to categorize fruit of the “Gala” apple variety into three maturity groups referred to as immature, mature and over-mature fruits. Gómez et al., (2006) studied volatile production of unripe, half-ripe, full-ripe and over-ripe tomatoes using the PEN 2 E-nose (10 different metal oxide sensors) with principal component analysis (PCA) and linear discriminant analysis (LDA). The results demonstrated that the electronic nose could differentiate among the ripeness states of tomatoes and classify them with 100% reliability in each ripeness group.

The process of coffee production has been widely investigated by e-nose technologies to distinguish
different types of coffee beans (Aishima, 1991),
to identify various brands and mixtures, to
classify commercial coffee blends and separate
samples with different roasting levels. Falasconi
et al., (2005) provided evidence for the efficacy
of predicting the perfect ripening moment by
analyzing roasted coffee with a new thin film
semiconductor metal oxide gas sensor e-nose
(Electronic Olfactory System EOS835). The human
panel expert-taster assessment indicated that the
best coffee quality resulted when samples lots were
ripened for 96h. The electronic nose effectively
recognized ripening progression and allowed the
determination of necessary coffee quantity and
operating condition needed to detect samples
at the perfect 96-h ripening times
Other studies
involved in predictions of fruit maturity level and
shelf life have been done on various fruits. For
example, fried mango chips were evaluated for the
presence of deteriorative aromas (Niruntasuk et al.,
2006). Fuji apples were evaluated for the effects
of different storage conditions, storage periods and
days o shelf-life on ripening and condition
investigated the specific aroma of a pentane extract
in snake fruit. Others have examined the pre- and
post-harvest characteristics of kiwifruit (Costa et
al., 2003) and fresh-cut vegetables like chicory
(Riva et al., 2002). Utilizing e-noses as a means
of monitoring fruit freshness and shelf-life prior
to marketing can have a number of benefits that
maximize corporate profits and optimize customer
satisfaction.

Milk and Dairy Products

Dairy products contain off-flavor compounds
created by a variety of mechanisms such as
through the action of natural and microbial
enzymes and chemical changes catalyzed by
light or heavy metals. In cheeses, quality, flavor
and taste are closely connected to the ripening
process which depends on the growth of bacteria,
lipid degradation and oxidation, and proteolysis.
Traditionally, sensory analysis was used to
determine the product identity of cheese. However,
detection of aroma compounds using electronic
noses has become more and more important.

It has been first focused on the classification of
Parmesan cheeses with differing rates of maturity.
The Aromscan e-nose successfully distinguished
the two types. They also were able to characterized
Gorgonzola and Cottage cheese using polypyrrole
semi-conductor sensors. Electronic nose has to be
classified block milk products, subjected to various
heating processes, in order to predict the most
favorable heating method. In this case, the results
were moderate to good. Ampuero and Bossel, 2005
found the electronic nose has a lower detection
limit (0.5 mg/kg) and better precision compared
to dynamic headspace gas chromatography (GC)
for determining the presence of trimethylamine in
Swedish milk samples.

Riva et al., (2002) demonstrated that NIR spectra
(NIRS) collected from Crescenza cheese were
influenced both by raw material and by its high
moisture content. NIRS, like the classical measures
such as acidity and texture chances, was able to
detect only chemical modifications that occurred
during the first stages of storage, whereas the
results obtained by spectroscopy and electronic
nose analyses were more useful because they
could be used to monitor the shelf-life of these
products as online.

The shelf-life of milk also has been studied
(Labreche et al., 2005). A Fox 4000 electronic
nose equipped with 18 sensors and an auto sampler
was used to evaluate the growth of total bacteria
in milk stored at ambient temperature and 5°C
The results showed that measurements generated
by the electronic nose could be used to detect
both bacterial growth in milk and shelf-life. Other
studies that have focused on the feasibility of the
electronic nose in evaluating the shelf-life of several
other dairy products including yogurts (Navrátíl
et al., 2004), Taleggio cheese (Benedetti et al.,
2002), Danish Blue Cheese (Trihaas and Nielsen,
2005), seasonal changes in whole milk powder
aromas (Biolatto et al., 2007) and the selection of
bacterial strains of Lactobacillus casei as flavor-
producing adjunct cultures (Irmler et al., 2006).

Meat Products

Much work has been done in the electronic
detection of quality characteristics of meat
products within the food industry. It has been
studied that the applicability of an electronic
nose for the quality control of modified-
atmosphere packaged broiler chicken cuts with
different temperature regimes. The electronic nose results were compared with those obtained by microbiological, sensory, and head space GC analyses. The e-nose could clearly distinguish broiler chicken packages with deterioration from fresh packages either earlier or at the same time that sensory changes indicated significant deterioration. Counts of Enterobacteriaceae and hydrogen sulphide-producing bacteria were most consistently associated with the electronic nose results indicating that the electronic nose was capable of detecting even early signs of spoilage in modified atmosphere packed poultry meat. It has been found the storage time of a pork-meat pizza topping product was predictable using an electronic nose. The study included two independent test sets composed of “known” production samples and “unknown” production samples. The results showed that storage time of “known” samples was very well predicted, while the “unknown” storage time was fairly well predicted. This provided evidence that the electronic nose system was a relevant and useful device for on-line implementation in quality control of pork meat products.

**Fish and Seafood Products**

Haugen et al. (2005) confirmed the feasibility of the Fish Nose on direct quality measurements of smoked salmon. Quality changes were monitored by the Fish Nose and compared with results of traditional sensory, chemical and microbial measurements. In this case, gas-sensor selection was optimized for the detecting of changes in the highly volatile compounds mainly representing microbial metabolism during spoilage. The system was further tested on-site in a smoked salmon production plant. Due to varying ambient air conditions at the production plant during the measurements, the sensor readings had to be corrected by subtracting the background ambient air signal from the sensor readings. High rates of correct sample discrimination were obtained for fresh (95%) and tainted (93%) meat samples, respectively. Chantarachoti et al. (2006) evaluated the capability of a portable electronic nose in detecting spoilage of whole Alaskan pink salmon stored at 14°C and in slush ice. In 92% of the samples, the instrument could correctly classify the fish as either fresh or spoiled.

**Practical applications of E-Nose in food industry**

**Electronic Tongue (E-Tongue)**

An Electronic Tongue is an instrument which comprises of electrochemical cell, sensor array and appropriate pattern recognition system, capable of recognizing simple or complex soluble non-volatile molecules which forms a taste of a sample. An electronic tongue is a system for automatic analysis and recognition (classification) of liquids, including arrays of non-specific sensors, data collectors and data analysis tools. The result of an electronic tongue can be the identification of the sample, an estimation of its concentration or its characteristic properties. This technology has many advantages. Problems associated with human senses, like individual variability, impossibility of on-line monitoring, subjectivity, adaptation, infections, harmful exposure to hazardous compounds, mental state, are no concern of it.

The electronic tongue uses a sensor array with partially overlapping selectivity to get information on quality parameters such as sample condition, the state of a process, or expected human perception. Sensors forming the array should exhibit various selectivity patterns to minimize correlation between sensor responses, which provides more information about the sample (Ciosek et al., 2006). The logic behind the application of low-selectivity sensors is based on an analogy to biological organization of the olfactory and taste systems in mammals. Millions of nonspecific olfactory receptors are located in the nose and tongue which respond to various substances in gas or liquid form. The signal is transmitted to the brain where olfactory neurons process the signal and the image of the sensed substance is formed. As the electronic tongue classifies particular properties in complex systems, the results are not necessarily compared to human sensation but with other quality properties in a sample.

**Principle of E-Tongue**

Human have long been thought to detect four basic taste types viz. sweet, salty, sour and bitter. Very recently, a fifth candidate basic taste was identified: umami, the taste of monosodium glutamate (MSG), characteristic of protein rich
foods. Taste buds are believed to contain receptor molecules that trigger nerve signals when they encounter flavor imparting molecules. The details of this system are still not understood. Each taste sensation may correspond to a fingerprint signal induced by the differential activation of the various taste receptors. E-Tongue works on this principle. It works by measuring dissolved compounds and taste substances in liquid samples (Giese, 2001).

It contains four different chemical sensors. The sensor comprises very thin films of three polymers and a small molecule containing ruthenium ions. These materials are deposited onto gold electrodes hooked up to an electrical circuit. In a solution of flavor some substances, such as sugar, salt quinine (bitter) and hydrochloric acid (sour), the thin sensing films absorb the dissolved substances. This alters the electrical behaviour of the electrodes in a measurable way. Each sensor responds differently to different tastes. A composite sensor that incorporates all four there four there four produces an electronic fingerprint of the taste. The researchers combine these responses into a single data point on a graph. The position on the graph reflects the type of taste: sweet lies towards the top left. For example sour towards the top right.

Various recognition techniques are applied in electronic tongues; potentiometry, voltammetry and conductometry being most commonly used. The data obtained from the electronic tongue is processed by multivariate data analysis (MVDA), primarily by principal components analysis (PCA) which explains the variance in the experimental data. Potentiometric electronic tongues using lipid/polymer membranes have a concept of global selectivity which implies the ability to classify vast kinds of chemical substances into several groups, as really found in the taste reception in biological systems. The measuring principle is based on the potential of electrodes across an ion-sensitive membrane with zero current flow. Voltammetric electronic tongues are based on metal electrodes with different selectivity and sensitivity patterns. Through these electrodes a varying potential is applied to change the current/voltage characteristics of an electrolytic solution which is then measured. Conductometry is the direct measurement of the conductance between two inert identical electrodes, so that most specific effects due to electrodes are eliminated.

The use of sensor arrays in food analysis grew rapidly in the last decade. It has been used in wine analysis, honey classification, soy sauce analysis, water analysis and other beverages like soft drinks, beer, tea, coffee and milk. Other uses, which do not include food analysis, are microbial species detection, heavy metals detection etc. Sensor arrays combined with multivariate data analysis are a powerful tool for monitoring quality control in various fields of dairy industry. Both the electronic nose and electronic tongue were used in the assessment of dairy products. Winquist et al. (1998) started to use the voltammetric electronic tongue to monitor the deterioration of milk quality due to microbial growth. Winquist et al. (2005) also implemented the voltammetric electronic tongue into the production line to follow different sources of milk coming into the process and to monitor the cleaning process after pasteurization. It has been developed a potentiometric electronic tongue and used it in the detection of goat milk adulteration with bovine milk. It has been developed a disposable voltammetric electronic tongue and it was used to differentiate among milks with different pasteurization processes and adulterated milk with hydrogen peroxide. The use of voltammetric electronic tongue to monitor yoghurt production in a pilot facility also been observed.

Applications of E-Tongue

E-Tongue has a multitude potential application, which includes its uses in quality control laboratory. The E-Tongue has been designed to replace human tasters. E-Tongue can also taste cholesterol levels in blood and toxins in water.

In brewing industry, E-Tongue can be used to monitor batch to batch variation of the beers following the brewing process. E-Tongue allows product conformity testing, taste default detection, origin identification (Giese, 2001). The objective of the instrument is to complement the E-Nose and more important, allow the food and beverages industry to cover a large proportion of the sensory perception of consumers in essence, covering both aroma/odour and taste (Tan et al., 1995). For orange juice and apple juice, E-Tongue will more
typically measure the non volatile components, including chemical molecules, responsible for sweetness, bitterness, saltiness and sourness (Tan et al., 1995). This instrument has also been used to detect off flavor in beer, as in a pale ale lager containing too high a concentration of dimethyl sulfide (DMS), formed from a malt derived precursor during worth production or by contaminant bacteria during fermentation (Tan et al., 1995). An extremely important taste attribute of beer is its bitterness. A range of beers has also been analyzed using E-Tongue. Result shows the good linearity of quantification of BU (Bitterness Unit) using PLS.

E-Tongue has also been used for analysis of quality of high fructose corn syrup to detect some taint compounds responsible for the off flavors, such as fish taste/flavor formed by microbiological oxidation of protein residue and other taste/odour descriptors including fruity, astringent, So₂, salty, corn-caramel and moldy. It has been tested a series of nine 100% apple juices, including a three apple blend, vitamin C fortified apple/pear juice and apple cider using E-Tongue.

Application of E-Tongue would allow the taste quality of a food to be monitored continuously from the raw material stage right through to final product. In recent years, E-Tongue finds food and beverage industry as the challenging environment for its routinely application in taste control and analysis.

Conclusion

E-Nose and E-Tongue technologies for measurement of quality are particularly suitable for the carrying out, mainly within a QC/QA environment, of rapid and objective sensory measurements, that are important in the food and beverage industries. Systems exist for either quantitative or qualitative analyses and have been shown to be useful in a wide variety of applications. When operated correctly, and calibration, validation and training process, the technology has been shown to be able to contribute significantly to the maintenance or improvement of quality for products destined for both the consumer market and the industrial market and to improve quality for both consumer and industrial products in these domains.

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I think none of us are unaware about it,
   So please pay attention a bit.

I am confused that from where to start,
   In our life, microbes play very important part.

Start from the food that we eat,
   Microbes are needed to digest it.

It is very easy and cheap to manufacture,
   And it also gives the product, a handsome structure.

It is true that Probiotic products have live organisms,
   So people think that how can they eat that one?

But my friends microbes are already present in our body,
   Probiotic foods just balance that flora and make it steady.

Since centuries people used to consume it,
   Probiotic foods are like our health kit.

Microbes are our beneficial friends, present everywhere,
   Just try to think about it, sitting on your chair.

As a student of Dairy Technology, I can just suggest,
   You are free to eat, whatever you can digest.

Harshil Patel
Sixth Semester, B.Tech. (DT)
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