

FOOD SCIENCE AND TECHNOLOGY

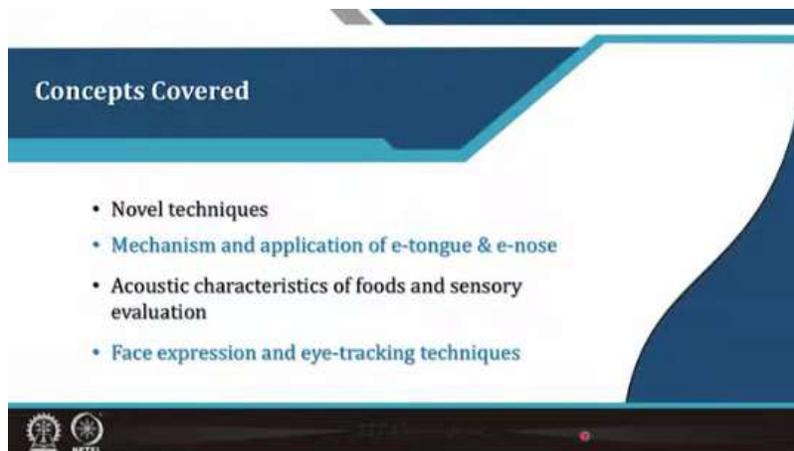
Lecture20

Lecture 20: Novel Techniques in Sensory Evaluation

Hello everyone, Namaskar. Now, we are in the last lecture of Module 4, and in this lecture, which is overall lecture 20, we shall study novel techniques in the sensory evaluation of foods.



The topics that we will cover today in this lecture include novel techniques, what are the different novel techniques, mechanism and application of e-nose and e-tongue, particularly in the sensory evaluation of food or the evaluation of food, then acoustic



characteristics of food and sensory evaluation, and also we will talk about facial expression and eye-tracking techniques.

Novel techniques

- Traditional sensory evaluation techniques face limitations, including cognitive and familiarity biases. Cognitive bias is influenced by factors like packaging, label color, health claims (e.g. organic, low salt), and external cues, which can alter sensory perception.
- Familiarity bias affects hedonic evaluations, with panelists favoring familiar products over unfamiliar ones.

To address these limitations, novel sensory evaluation techniques have emerged, utilizing

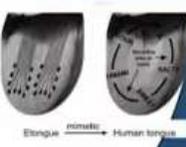
- ✓ Biometric methods, which track objective responses through facial expressions, heart rate, body temperature, skin conductance, and eye-tracking.
- ✓ Artificial intelligence (AI) and smart sensors like e-nose and e-tongue, which offer more precise, unbiased assessments.




You know that we have earlier in the earlier classes in this module itself discussed the traditional sensory evaluation techniques and these methods face various limitations, including cognitive and familiarity biases. Cognitive bias is influenced by factors like packaging, label color, health claims, etcetera, like organic, low salt, and all. Also, the external cues can alter the sensory perception. So, the traditional methods that are used for sensory evaluation many a time they are biased; sometimes, there are chances of them being biased. So, familiarity bias affects hedonic evaluation with panelists favoring familiar products or unfamiliar ones over the unfamiliar ones. So, to address these limitations, novel sensory evaluation techniques have emerged and these techniques utilize biometric methods which track objective responses through facial expressions, heart rate, body temperature, skin conductance, and eye tracking. Also, artificial intelligence and smart sensors like e-nose or e-tongues, etc. offer more precise and unbiased assessment of taste, flavor, smell, etc. So, let us talk about them one by one.

E-tongue

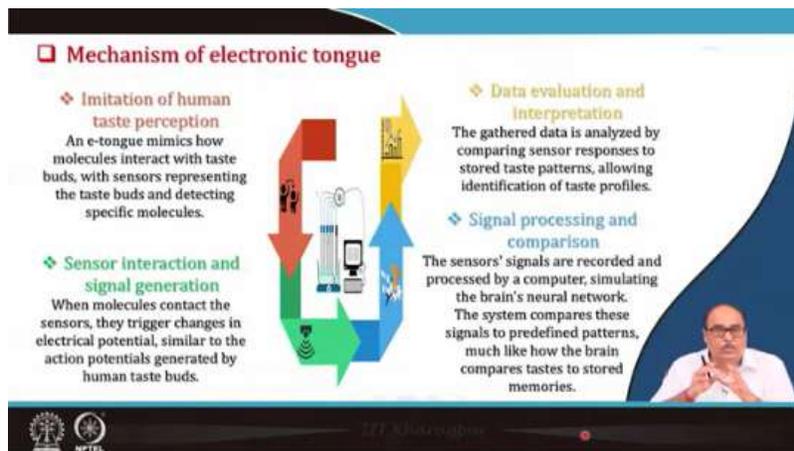
- The electronic tongue is an *in-vitro* technique that mimics the human taste system, providing an effective alternative to human sensory evaluation while avoiding associated ethical concerns.
- It can be defined as a multisensory system for liquid analysis based on chemical sensor arrays and a suitable pattern recognition method.
- It is used for recognition, classification, and quantification of components of liquid samples.
- It mimics the membrane of gustatory cells present in the taste buds of the tongue with information about the samples obtained by sensors.
- In food industry, e-tongue is used for (i) process monitoring, (ii) freshness evaluation and shelf-life investigation, (iii) authenticity assessment, (iv) food stuff recognition, (v) quantitative analysis, and (vi) other quality control studies.





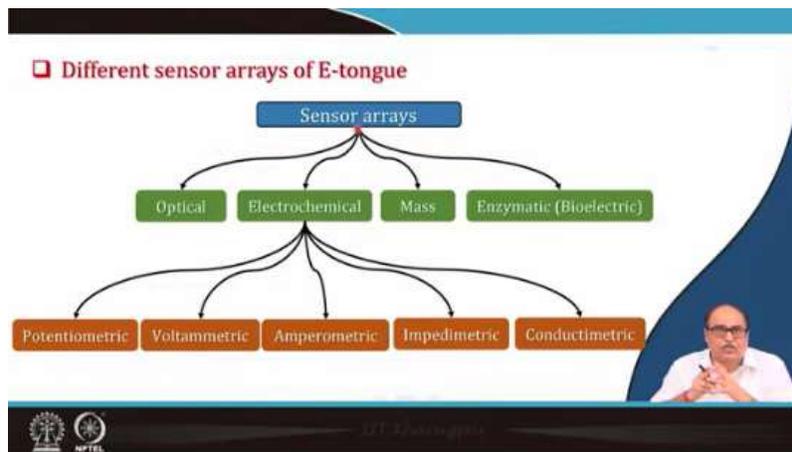
Number one is the e-tongue, like an electronic tongue. It is an in vitro technique that mimics the human taste system, providing an effective alternative to human sensory evaluation

while avoiding associated ethical concerns. It can be defined as a multi-sensory system for liquid analysis based on chemical sensor arrays and suitable pattern recognition methods. It is used for recognition, classification, and quantification of components of liquid samples. It mimics the membrane of gustatory cells present in the taste buds of the tongue, as we have discussed earlier, with information about the sample obtained by sensors. So, what do our taste buds and the tongue do? The same thing in the e-tongue is done by various sensors. In the food industry, each term is used for process monitoring, freshness evaluation, and shelf-life investigations, then authenticity assessment, food steps recognition, quantitative analysis, and other quality control services or studies.



So, let us see the mechanism of how this electronic tongue works. In the earlier class, we discussed that we studied how our actual tongue works, in a similar manner it imitates that there is a limitation of human taste perception that is, imitation of the human taste perceptions that an e-tongue mimics. How molecules interact with the taste buds, with sensors representing the taste buds and detecting specific molecules. In our tongue, there are taste buds that detect specific molecules. So, here in the e-tongue, there are specific sensors that detect. So, after that, these sensors interact, and the signal generation occurs when molecules contact the sensors, they trigger changes in electrical potential, similar to the action potential generated by our human taste buds and then this signal processing and comparison is done at the third stage, that is the sensor signals are recorded and processed by a computer, simulating the brain's neural network and the system compares these signals to predefined patterns like how the brain, computers test or store the neurons. So, finally, the data is passed to a computer which has all the software. The generated data is analyzed by the computer. Comparing sensor responses to stored test patterns, allowing identification of the test profiles. So, obviously, in the computer, different test profiles, that

is, the library, are created, and then these sensors, when they compare with the library, give the desired result. So, that is how it almost mimics the normal testing process.



So, the different types of sensors that are used in the e-tongue may be optical sensors, electrochemical sensors, even mass sensors or enzymatic or bioelectric sensors, etcetera. Electrochemical sensors may be potentiometric, voltammetric, amperometric, or impedometric or conductometric, conduction metric method, they can measure the various that impedometer or potentiometer, etcetera.

❖ Potentiometric chemical sensor

- A potentiometric sensor measures the electrical potential (voltage) difference between the working and reference electrodes when no current is present. The measured potential is then used to determine the analytical quantity of interest, generally the concentration of a specific component in the solution.
- The potential of the electrode (E) can be expressed using the Nernst equation $E = E^0 + \frac{RT}{nF} \ln[a_i]$

Where,

E is the potential difference (V) for the electrochemical cell composed of the ion-selective and reference electrode,

R is the gas coefficient (8.314 J/K),

F is the Faraday constant (96,500 C/mol),

n is the number of electrons,

a_i is the activity of the principal ion, and

E_0 is the standard potential.

So, let us talk about one by one briefly, that is, the potentiometric chemical sensors that is it measures the electrical potential, that is, the voltage difference between the working and reference electrodes when no current is present. The measured potential is then used to determine the analytical quantity of interest. Generally, the concentration of a specific component in the solution is already determined. So, the potential of the electrode E can be expressed using the equation: $E = E^0 + \frac{RT}{nF} \ln[a_i]$,

where E is the potential difference, which is V , of the electrochemical cell composed of the ion-selective and preferences. R is the gas constant, F is the Faraday constant, N is the number of electrons, and A_i is the activity of the principal ion and E^0 is the standard potential. These are, you can say, the working reference and electrode that the analytical solution is put into, which is a meter. So, you can find out the electrical potential voltage, which is analyzed.

A potentiometric E-tongue system generally consists of the following parts

- **Working electrode:** Made from inert materials like gold, platinum, or glassy carbon; it serves as the surface for redox reactions. Its surface area should be minimal (few mm^2) to limit current flow.
- **Reference electrode:** Typically an Ag/AgCl electrode, it measures the working electrode potential and maintains a constant electrochemical potential when no current flows.
- **Auxiliary/counter electrode:** A stainless steel conductor that completes circuit, allowing current to leave solution through it after entering via working electrode.

Potentiometric chemical sensor (Contd...)

Di Basso et al., 2020

So, a potentiometric e-tongue system generally consists of three types of electrodes: a working electrode, which you can call the working electrode, then a reference electrode, and an auxiliary or counter electrode. A working electrode is made of inert materials like gold, platinum, or glassy carbon. It serves as the surface for redox reactions. Its surface area should be minimal, which is a few square millimeters, to limit current flow. Then, the reference electrode, typically a silver or Ag/AgCl electrode, measures the working electrode potential and maintains a constant electrochemical potential when there is no current flow. The auxiliary or counter electrode is a stainless steel conductor that completes the circuit. It completes the circuit, allowing current to leave the solution. It enters through the working electrode. So, this is how these potentiometric electrodes work.

The advantages of potentiometric electrodes are their well-known operation principles, low cost, simple setup, easy fabrication, and the availability of a large number of different membranes with different selectivity properties, like glass membranes or lipid layers, etcetera. However, the major disadvantages of these electrodes are their temperature dependence, the absorption of solution components affecting the membrane potential, and their application, like ethanol content determination in alcohol from different sources.

Potentiometric chemical sensor (Contd...)

- **Advantages**
Well-known operation principle, low cost, simple set-up, easy fabrication, and the availability of a large number of different membranes with different selectivity properties such as glass membranes or lipid layers.
- **Disadvantages**
 - ✓ Temperature dependence
 - ✓ Adsorption of solution components affects the membrane potential.
- **Applications**
 - ✓ Ethanol content determination in alcohols from different sources.
 - ✓ Discrimination of beer types and beer bitterness.
 - ✓ Authentication of fresh cherry tomato juices adulterated with different levels of overripe tomato juices.

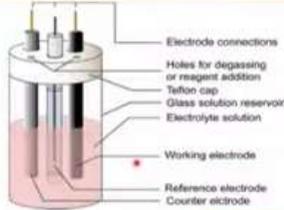





They can be used for the discrimination of beer types and beer bitterness. They can be used for the authentication of fresh cherry tomato juice adulterated with different levels of overripe tomato, etcetera or they can be used for many similar applications.

□ Voltammetric chemical sensor

- It operates by measuring the current between the working and reference electrodes in an electrochemical cell. After the initial measurement, a potential is applied to the working electrode to detect the current generated from the oxidation and reduction of analytes. The concentration of target analytes is then correlated with the measured current.
- **Advantages**
 - ✓ High selectivity
 - ✓ High signal-to-noise ratio
 - ✓ low detection limits and
 - ✓ various modes of measurement



*Source: Shym et al., 2022





Then, volumetric chemical sensors, as you can see here in the figure, operate by measuring the current between the working and reference electrodes in an electrochemical cell. After the initial measurement, a potential is applied to the working electrodes to detect the current generated from the oxidation and reduction of analytes. The concentration of target analytes is then correlated with the measured current. It has certain advantages of being highly selective. There is high signal-to-noise ratio, low detection limits, and it can detect very low limits of molecular compounds and there are various modes of measurements available.

There are two types of pulse voltammetric chemical sensors: pulse voltammetry or staircase voltammetry. Pulse voltammetry may be short amplitude pulse voltammetry or long amplitude pulse voltammetry and its application is the discrimination of wines based

on geographical origin that is, different vintage dating, different vines from different places can be discriminated.

Voltametric chemical sensor (Contd...)

- **Types**
 - ✓ Pulse voltammetry
 - Short-amplitude pulse voltammetry (SAPV)
 - Long-amplitude pulse voltammetry (LAPV)
 - ✓ Staircase voltammetry
- **Applications**
 - ✓ Discrimination of wines based on geographical origin
 - ✓ Discrimination based on grape variety and geographical origin
 - ✓ Discrimination and classification of oils (virgin olive, sunflower, corn, and soybean oils)
- **Construction materials of electrode**
 - ✓ Metal
 - ✓ Carbon paste
 - ✓ Conducting polymers

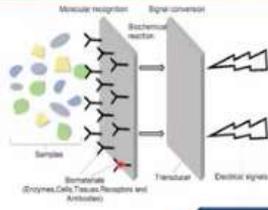



They can be found out. Then discrimination based on the grape variety and geographical origin, discrimination and classification of oils like virgin olive oil, sunflower oil, corn oil, etc. Then, the construction material of these electrodes is metal, carbon paste, or conducting polymers.

□ **Bioelectric sensor**

- Biosensors are electronic sensors employing biomaterials as their sensing medium such as enzymes, receptors, and antibodies.
- It works on the principle of interaction of a biological element with the sample as a result of a series of biochemical reactions, such as an enzyme-substrate reaction that initiates the transport of electrons, which is further transcribed into electrical signals. Generally, oxidases and dehydrogenases are used.

- **Advantages**
 - ✓ High selectivity
 - ✓ High signal-to-noise ratio
- **Applications**
 - ✓ Identification of sweets (lactate, glucose, and sucrose) as well as acids (lactic, citric, acetic, and salicylic acid)



*Source: Wang et al., 2022

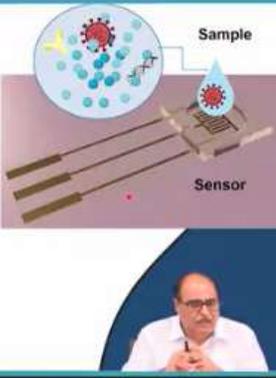



Then bioelectric sensors, these are electronic sensors employing biomaterials as their sensing medium. Such as enzymes, receptors, etcetera, cells, tissues, antibodies, and so on. It works on the principle of interaction of a biological element with the sample as a result of a series of biochemical reactions. Such as an enzyme-substrate reaction that initiates the transport of electrons, which is further transcribed into electrical signals. And generally, oxidases and dehydrogenases, etcetera, are used in this system. You can see here in the figure how it works; it has been shown.

So, the advantages of such types of sensors are that they are highly selective and they also have a high signal-to-noise ratio. You can get a good assessment here, a good judgment. Then, it can be applied for the identification of sugars like lactate, glucose, sucrose, etcetera, as well as acids like lactic acid, citric acid, acetic acid, and so on.

Impedimetric sensor

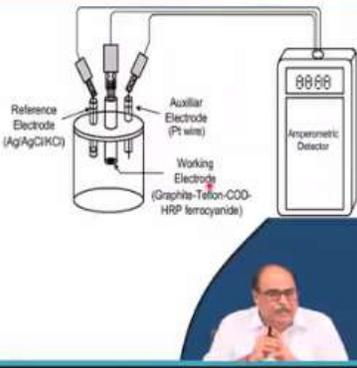
- It works on the principle of measurement of impedance either at one fixed frequency or a broader spectrum using impedance spectroscopy.
- Advantages**
 - Does not require any active species in the measuring system.
 - Does not require a standard reference electrode.
- Applications**
 - Use for recognition of basic taste substances, beverages, and mineral waters, and these have been shown to have excellent sensitivity.



Then, impedimetric sensors: they work on the principle of measurement of impedance either at one fixed frequency or a broader spectrum using impedance spectroscopy. This does not require any active species in the measuring systems, and also it does not require a standard reference electrode. It is used for the recognition of the basic taste substances, beverages, and mineral waters, and these have been shown to have excellent sensitivity.

Amperometric sensor

- In an amperometric e-tongue, an electrochemical reaction is triggered at an electrode under a controlled potential, and the resulting current from this reaction is measured.
- The amperometric method involves only partial electrolysis.
- For a compound to be detected by an amperometric e-tongue, it must be electroactive at the applied potential, within the specific solution, and under the current pH conditions.
- Advantages**
 - Detect electroactive components without the interference of the non-electroactive compounds.



Then, amperometric sensors, in this, an electrochemical reaction is triggered at an electrode. You can see here in this figure that is under a control potential, and the resulting current from this region is measured. The amperometric method involves only partial electrolysis. For a compound to be detected by an amperometric e-tongue, it must be electroactive at the applied potential within the specific solution and under the current pH

conditions. It can detect electroactive components without the interference of the non-electroactive components; that is the advantage of this.

Optical sensor

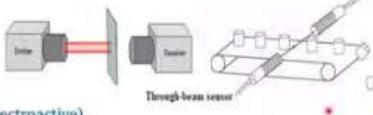
- Optical sensors work by transmitting and receiving light, and then evaluating how the light is reflected or interrupted by an object. The sensor is connected to an electrical trigger that is sensitive to changes in light, and it converts the light rays into electrical signals that can be read by an instrument.

Advantages

- ✓ Can be used where analytes are difficult to detect electrochemically (e.g. uncharged and/or non-electroactive).

Disadvantages

- ✓ Difficult to prepare sensor
- ✓ Low durability
- ✓ High signal interferences



Through-beam sensor

Then, optical sensors work by transmitting and receiving light and then evaluating how the light is reflected or interpreted by an object. You can see here in the picture that it has been shown. The sensor is connected to an electrical trigger that is sensitive to changes in light and it converts the light rays into electrical signals that can be read by an instrument. These optical sensors can be used where analytes are difficult to detect electrochemically, like when there are uncharged or non-electroactive materials. It has certain disadvantages, however, like being difficult to prepare sensors, they are of low durability, and also there might be high signal interferences.

Advantages and disadvantages of e-tongue

Advantages

- ✓ High sensitivity
- ✓ Easy to install and inexpensive
- ✓ Measure broad range of chemical from solution
- ✓ Detects toxic chemicals such as herbicides and pesticides
- ✓ Permanent data storage

Disadvantages

- ✓ Temperature and humidity sensitive
- ✓ Applicable for liquid samples only
- ✓ Provide only qualitative or sometimes semi-quantitative information



Then, after having read or studied these different types of sensors, let us talk about the advantages and disadvantages of the e-tongue. The major advantages are that they are highly sensitive, easy to install, and also inexpensive. They can measure a broad range of chemicals from solutions and can detect toxic chemicals such as herbicides, pesticides,

etcetera. Also, there is in the e-tongue, etcetera, the computers are there, there is permanent data storage, you can retrieve the data when you need. The disadvantage, however, is they are temperature and humidity-sensitive; the instrument should be placed in controlled environmental conditions. They are applicable for liquid samples only; the solid materials cannot be applicable. They have to be converted into liquid samples, and they provide only qualitative or, sometimes very rarely, quantitative information. You cannot get exactly the quantitative information by these methods. Now, let us talk about e-nose, like e-tongue, it just mimics the human tongue.

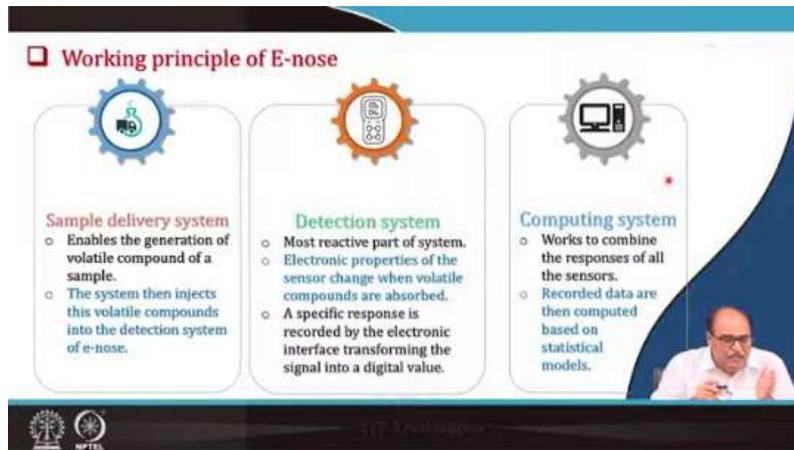
E-nose

- This instrument is designed to mimic human olfactory system.
- It detects and discriminates among complex odours using a sensor array when it is exposed to the volatile molecules on known odour and generates fingerprints for each odours.
- These fingerprints are then used to construct a database and train a pattern recognition system which further classify and identify unknown odours.
- E-nose instruments are composed of three elements, namely
 - ✓ Sampling delivery system
 - ✓ Detection system and
 - ✓ Computing system

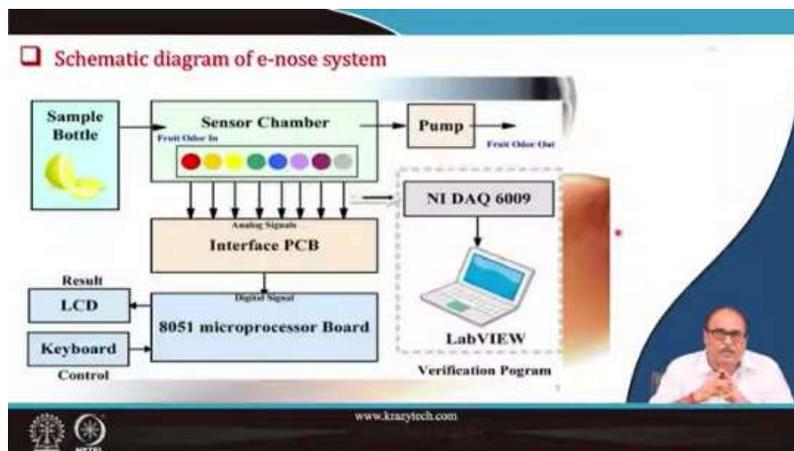
The diagram illustrates the E-nose system. On the left, a vertical flowchart shows the process: Sample -> Sampling -> Delivery -> Detection -> Computing. In the center, a human head profile shows the olfactory system with a label 'Human Olfactory System'. To the right, a computer monitor displays data, with a label 'E-nose System'. Below the computer, there are two small images of red, round samples. The text 'Manikata et al., 2021' is visible at the bottom right of the diagram area. A small inset photo of a man is in the bottom right corner of the slide.

Similarly, e-nose, electronic nose, it mimics our olfactory system. This instrument is designed to mimic the human olfactory system; it detects and discriminates among the complex odours using a sensor array when it is exposed to the volatile molecules of known odours and generates fingerprints of each odour. Similarly, in the same manner like in the nose, in the earlier class, we discussed how, in the olfactory system, receptor buds, etcetera, sense the flavour molecules. Similarly, here there are various sensors; they sense the flavor molecules and it is sent to the computer and analyzed from there. These fingerprints, which are detected by this complex sensor array, are then sent to the constructed database and train a pattern recognition system which further classifies and identifies unknown odors. E-nose instruments are composed of three elements, namely the sampling, the sample delivery system, the detection system, and the computing system and in fact, this is also very important in this library creation. So, at first, in the e-nose, you have to say, suppose you want to find a good mango. So, a good mango samples are there and then the flavor volatiles are sensed and then a library of good mango sample is created. Then when you give any bad mango or spoiled mango, it will again take the smells of those volatile compounds. So, it will sense and then finally, it will compare with that. So, there are various software that discriminate this and tell whether it is a good sample or a bad sample

like their working principle of the e-nose, you can say accordingly. There is a sample delivery system which enables the generation of volatile compounds in a sample, and the system then injects these volatile compounds into the electrical system of the e-nose. Then these compounds are detected. There is a detection system where the most reactive part of the system whole machine electronic properties of the sensor changes when volatile compounds are absorbed.



A specific response is recorded by the electronic interference transforming that signal into a digital value. These digital values are now then passed to the computing system in the computer in the press processor, which works to combine the response for all the sensor, recorded data or then computed based on the statistical methods and other things, and it compares many a time that is PC analysis or other analysis is done.



This is the schematic of how the e-nose works that are there are sample bottles, then these samples may be sometime whatever this is it has to be fragrance molecules that is the flavor molecules are to be evaporated, then it is tracked and then it is with the pumps etcetera you

these sensors molecules are introduced into the system that is interface PCB and then finally, it goes to there are LCD and keyboards etcetera which control and with the help of laptop or computer whole thing is processed. So, that is what exactly happens in our mind, that is, from the nose, it goes such as and then goes. So, the same thing is done here in the e-nose.

Sensors of E-nose system

- Metal oxide sensors**
 - Absorption of gas molecules provoke changes in conductivity
 - This conductive change is measure of the amount of volatile organic compounds absorbed
- Conducting polymers**
 - It operates in based on changes in electrical resistance caused by absorption of gases on sensor surface
- Quartz crystal microbalances**
 - Measure mass per unit area by measuring the changes in frequency
 - Can be stored in database for future references
- Surface acoustic wave**
 - Modulates surface acoustic wave to sense a physical phenomenon

The sensors of the energy are maybe metal oxide sensors like absorption of gas molecules provoke changes in the conductivity, and this conductive change is a measure of the amount of the volatile organic compounds which are absorbed. Then also there may be conducting polymers it operates in based on changes in electrical resistance. That is caused by the absorption of gases on the sensor surface. Then, the quartz crystal microbalance is another third type of sensor. It measures the mass per unit area by measuring the changes in frequency. It can be stored in a database for future reference. there is also a fourth type of sensor, which is the surface acoustic wave sensor. It modulates surface acoustic waves to sense physical phenomena.

Advantages and disadvantages of e-nose

- Advantages**
 - ✓ Provides finger print response to specific volatiles
 - ✓ Mimic human olfactory responses
 - ✓ Inexpensive and less time consuming
 - ✓ Less bias
 - ✓ More consistence
- Disadvantages**
 - ✓ Influenced by humidity, pressure and gas velocity
 - ✓ Complex circuitry
 - ✓ Energy and time consuming

The advantages of the e-nose are that it provides a fingerprint response to specific volatiles, mimics the human olfactory system, is inexpensive, less time-consuming, has less bias, and is more consistent, and you can get accurate results, etcetera. However, it again has certain disadvantages; it is influenced by humidity, pressure, gas velocity, etcetera. There is complex circuitry, and it is energy and time-consuming.

Acoustic sensory evaluation of food

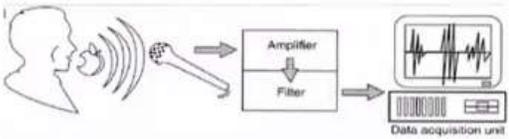
- Acoustic sensory evaluation is a technique used to analyze the sounds produced by food during consumption. This method focuses on the auditory aspect of sensory evaluation, capturing sounds such as crunching, popping, or crackling when food is bitten, chewed, or handled.
- These sounds are strongly linked to the texture and structural integrity of food, playing a key role in consumer perception and acceptance.
- For instance, the crispiness of chips is an indicator of freshness—if the expected crunching sound is absent, the chips may be perceived as stale.
- This method is fast, reliable, cost-effective, and non-destructive, making it an efficient tool for food evaluation.



Then, we talked about acoustic sensory evaluation of food. Acoustic sensory evaluation is a technique that is used to analyze the sounds produced by food during consumption. This method focuses on the auditory aspect of sensory evaluation, capturing sounds such as crunching, popping, or crackling when the food is bitten, chewed, or handled. These sounds are strongly linked to the texture and structural integrity of food. Playing a key role in consumer perception and acceptance of that particular food. For instance, the crispiness of the chips is an indicator of their freshness. If the expected crunchiness sound is absent, it means the chips may be perceived as stale or spoiled, indicating poor quality. This method is fast, reliable, cost-effective, and non-destructive, making it an effective tool for the evaluation of such foods.

Principle of acoustic sensory evaluation

- During food consumption, actions such as biting and chewing generate vibrations within the food's structure, which in turn produce sound waves.
- The type and intensity of these sounds are directly linked to the textural properties of the food. Acoustic sensors or microphones capture these sound waves.
- By analyzing the frequency, amplitude, and duration of the waves, various sensory properties of the food can be evaluated.



Then, the principle on which these acoustic sensory evaluations are done, like during food consumption, actions such as biting and chewing generate vibrations within the food structure which in turn produce sound waves. The types and intensity of these sounds are directly linked to the textural properties of the food. Like if the food is hard, or if it is soft, it is. So, it will get if it is very hard or crunchy, crispy. So, these acoustic sensors or microphones capture these sound waves. The sound waves which are created during biting, chewing, etc., are captured by acoustic sensors or microphones. Then, these are analyzed by analyzing the frequency, amplitude, and duration of the waves. Various sensory properties of the food can be evaluated, as you can see here on the right. These are prepared filters, and then finally, there is a data acquisition unit where it is analyzed.

Types of acoustic sensory evaluation

- ◆ **Direct acoustic measurement**
 - **Microphones**
 - ✓ Placed close to the mouth to capture sound during consumption.
 - **Contact sensors**
 - ✓ Attached to the food to detect vibrations directly, converting them into sound signals.
- ◆ **Indirect acoustic measurement**
 - **High-speed video analysis**
 - ✓ Uses video to observe and analyse food deformation and sound generation during consumption.
 - **Laser doppler vibrometry**
 - ✓ Measures vibrations on the food surface to infer sound characteristics.

The slide also features a waveform graph on the right side and a small video inset of a man speaking in the bottom right corner.

Then, the types of acoustic sensors, etc. Evaluation there will be direct acoustic measurements like microphones, which are placed close to the mouth to capture sound during consumption, during eating, during biting, etc. Or there may be contact sensors that are attached to the food to detect vibrations, directly converting them into sound signals. These are the direct acoustic measurements. Indirect acoustic measurements include high-speed video analysis, which uses video to observe and analyze food deformation and sound generation during consumption. Then, laser Doppler vibrometry measures vibrations on the food surface to infer sound characteristics.

Automated facial expression analysis is also used to analyze foods.

Automated facial expressions analysis

- Automated facial expression analysis (AFEA) application, as a tool for assessing consumer emotional response to food stimuli.
- It is a non-verbal methodology which communicates emotions like happiness, sadness, fear and others about the consumed food at instant.
- It is very helpful to recognize and differentiate the basic tastes and odours.
- It can more accurately measure consumers' negative perception than positive perception.
- For example, infants and children have been using facial expressions to communicate their emotions and feelings, especially in the case of sweet foods, when they smack their lips, protrude the tongue and smile; while, for bitter food, they wrinkle their nose and turn their heads.

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Like automated facial expression analysis, the AFEA application is used as a tool for assessing consumer emotional responses to food stimuli. Like, it is a non-verbal methodology that communicates emotions like happiness, sadness, or others about the consumed food of interest. It is very helpful to recognize and differentiate the basic taste of the food and odors. It can more accurately measure the consumer's negative perception than positive. For example, you can see here in the pictures where the babies are. All right. And the infants and children, or babies, are given some food. They cannot tell whether they like the food or not, but obviously, there are various expressions which they their mouth expression, facial expression, like if you are giving that is squinting or a wrinkled nose. or lowered, that is a bravo, even sweet or savoury, that you can see the flavour if it is how the expression will be there or savoury, all this. So, there are different expressions they can give. They communicate their emotions and feelings, especially in the case of sweet foods when they smack their lips, protrude their tongue, and smile while for the bitter food, they wrinkle their nose and turn their heads, etcetera, you can see this. So, this is a facial expression analysis.

Eye-tracking technique for sensory evaluation of food

- Eye movements are among the most frequent human actions and provide valuable insights into consumer behavior.
- Eye-tracking technology uses sensors to detect eye features and estimate where the consumer is looking.
- Since human pupils are constantly in motion, visual perception is difficult to interpret naturally.
- This technique operates on the "red-eye effect," where an infrared camera tracks light reflected from the eyes to identify key features.
- The system includes a standard computer, an infrared camera mounted beneath the display, and image processing software to analyze the data.

MPTEL

Then eye tracking, eye tracking techniques are also used, as you can see here in the picture, for the evaluation of the food and this is done by eye movement, which is among the most frequent human actions and provide valuable insights into consumer behavior. Eye tracking technology uses sensors to detect eye features and estimate where the consumer is looking. Since human pupils are constantly in motion, visual perception is naturally difficult to interpret. This technique operates through the red-eye effect, where an infrared camera tracks light reflected from the eye to identify key features. Infrared cameras are provided, and the system includes a standard computer and an infrared camera mounted beneath the display, along with image processing software to analyze the data. So, that is how eye tracking works.

Working of eye-tracking technology

- Eye-tracking technology uses infrared illumination to track eye movements. The system consists of a desktop computer with an infrared camera beneath the display and image-processing software.
- The infrared LED directs light into the eye, reflecting off the retina, making the pupil appear as a bright, defined disc.

- A small glint is also created by corneal reflection. By measuring the distance between the pupil's center and the corneal reflection, and using trigonometric calculations, the point-of-regard is accurately determined.

The slide features a blue header and footer with logos. A small inset video of a man speaking is visible in the bottom right corner.

The working of eye tracking technology can also be seen here in the picture. Eye tracking technology uses infrared illumination to track eye movement. The system consists of a desktop computer with an infrared camera beneath the display and image processing software. The infrared LED directs light into the eye, reflecting off the retina and making the pupil appear as a bright, defined disc. A small glint is also created by corneal reflection. By measuring the distance between the pupil's center and the corneal reflection and using trigonometric calculations, the point of regard is accurately determined.

Then, let us discuss the advantages and disadvantages of eye-tracking technology. The advantages include providing an objective assessment of the consumers' emotional responses, capturing and analysing facial expressions in real-time, being suitable for unconscious responses, and being very versatile in application. Various food products and lab-based sensory panels are used in in-store testing, etcetera, where it can be utilized.

Advantages and disadvantages of eye tracking technology

Advantages

- ✓ Provides an objective assessment of consumer emotional responses.
- ✓ Captures and analyses facial expressions in real-time.
- ✓ Suitable for unconscious responses.
- ✓ Versatility in application: Various food products and lab-based sensory panels to in-store testing.

Disadvantages

- ✓ Cultural variability can lead to interpretation of emotions.
- ✓ Complex data interpretation software.
- ✓ Requires expertise to accurately interpret and apply in a meaningful way.
- ✓ Requires costly software and equipment.
- ✓ May raise privacy concerns.



However, the system has certain disadvantages, like cultural variability can lead to the misinterpretation of emotions. Complex data interpretation software is needed, and it requires expertise to accurately interpret and apply it in a meaningful way to accurately interpret the data and its proper application, which requires expertise. Also, it requires costly software and equipment, and it may raise privacy concerns and other issues.

Summary

- Electronic systems are used to mimic the senses of smell, vision, and taste and create sensory perception of food products.
- **E-nose, e-tongue, e-eye** can be used in production line of food industries.
- All technology has limitation of detecting any particular sensory perception at a time and therefore difficult to obtain wholesome sensory data.
- An extensive research is required on these novel techniques by considering objectivity and data-driven approach of food attributes.



So, finally, I will summarize this lecture by saying that electronic systems are used to mimic the senses of smell, vision, taste, as well as to create sensory perceptions of food products. E-nose, e-tongue, e-eye, etcetera, can be used in the production line in the food industries. They may be a convenient way of testing the samples online during production. All technology has, however, limitations in detecting any particular sensory perception at a time, and therefore, it is sometimes difficult to obtain wholesome sensory data. Extensive research is required on these novel technologies by considering objectivity. And a data-driven approach for food attributes. However, finally, all these technologies are there, and they can be used. This is good. But finally, it is food, and before it is given to the market. So, it is always recommended and always desirable that yes, human subjects. They should

taste the food to prove its authenticity and to get the real. However, these novel methods can just be that They should always be used together with human subjects to get the conformance result.

References

- Azman, A., Viejo, C. G., Pang, A., & Fuentes, S. (2023). Review of technology advances to assess rice quality traits and consumer perception. *Food Research International*, 172, 113105.
- Shwifitska, M., Wisniewska, P., Dynerski, T., Wardenski, W., & Namiesnik, J. (2016). Advances in electronic noses and tongues for food authenticity testing. In *Advances in food authenticity testing* (pp. 201-225). Woodhead Publishing.
- Nowshad, F., Khan, M.S. (2021). *Electronic Tongue for Food Safety and Quality Assessment*. In: Khan, M.S., Shafiqur Rahman, M. (eds) *Techniques to Measure Food Safety and Quality*. Springer, Cham.
- Di Rosa, A. R., Leone, F., & Chiotala, V. (2020). Electronic noses and tongues. In *Chemical analysis of food* (pp. 353-369). Academic Press.
- Shen, Y., Mu, Y., Wang, D., Liu, C., & Diaconescu, P. (2022). Tuning reactivity through modifications of organometallic complexes on an electrode surface.
- Wang, A., Zhu, Y., Zou, L., Zhu, H., Cao, R., & Zhao, G. (2022). Combination of machine learning and intelligent sensors in real-time quality control of alcoholic beverages. *Food Science and Technology*, 42, e544622. Font size (14)
- Manekata, P. E., Finardi, S., de Souza, C. K., Meiner, C., Pateiro, M., Hoffmann, T. G., - & Lorenzo, J. M. (2023). Applications of electronic nose, electronic eye and electronic tongue in quality, safety and shelf life of meat and meat products: a review *Sensors*, 23(2), 672.



These are the references used in this lecture.



THANK YOU !

Thank you very much for your patient hearing. Thanks a lot.