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SIGNIFICANCE OF ELECTRONICS IN FOOD TECHNOLOGY AND FOOD INDUSTRY

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Abstract-Food Technology is a professional and scientific multidisciplinary topic connected to food manufacture that covers the practical applications of food science. It began an academic study in the era of 1950s. This developing field aims to further implement the application of effective industrial processing in the transformation of biologically derived raw materials into edible forms, encompassing distribution, storage, and packaging. Food engineers are hired by government agencies, businesses, and academic institutions along with private consultants to evaluate issues related to food production, food quality, process and plant design, and food regulation. They carry out studies and create unit processes including freezing, irradiation, concentration, extrusion, and sterilisation. Because to the growing demand on food supply systems, traditional processes including milling, dehydration, and fermentation have been replaced by automated installments.The automation of the food business heavily relies on electronics. Various sizes and functionalities of automated food production systems vary greatly, largely depending on the type of food and the manufacturer's individual requirements. The idea of electronics' function in the food industry is presented in this paper. Image processing, e-nose, e-tongue, and biosensors have all been covered in this work. This paper also discusses the role that the government plays in the food processing and food industry. Government programmes are highlighted in several ways.

Keywords*; Electronics,e-tounge,e-nose,biosensors*

1. Introduction

The majority of the food that people in the world consume comes from the sophisticated food business. Each year, eating tainted or hazardous food causes millions of individuals to suffer from severe and occasionally fatal health issues. Chemical risks or foodborne illnesses could be present in the contamination. In addition, the food business loses billions of dollars a year due to ineffective production and inspection procedures and insect damage. For the purpose of producing lucrative and high-quality goods, the food business needs automation. An important factor in the automation of the food business is electronics. Before being sold, food products must undergo some processing. For instance, if apples need to be categorised, their qualities, tastes, shapes, and sizes may vary. For other fruits, vegetables, and grains, the same holds true. Significant manual labour is needed to choose the fruits with the same attributes [3]. Labour costs in the food industy are very expensive, accounting for about half of all costs. Long-term cost reduction through automation of the food business can be achieved. Plant automation, as illustrated in Fig.1, can increase a plant's output, profitability, and quality. Thus, although automating the food sector requires a one-time investment, the cost may be lower over time. Only advances in computer technology and software will allow for more automation.

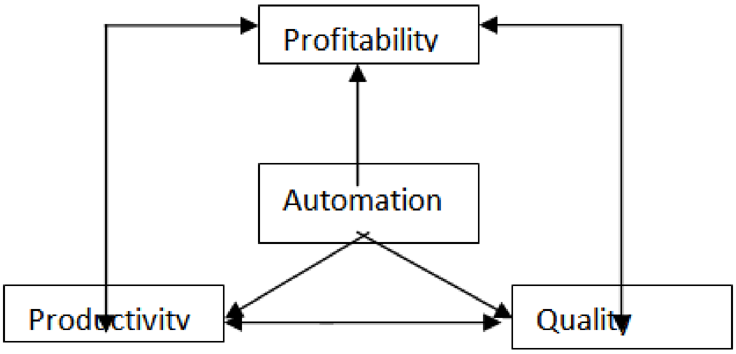

Fig.1: Plant automation [1]

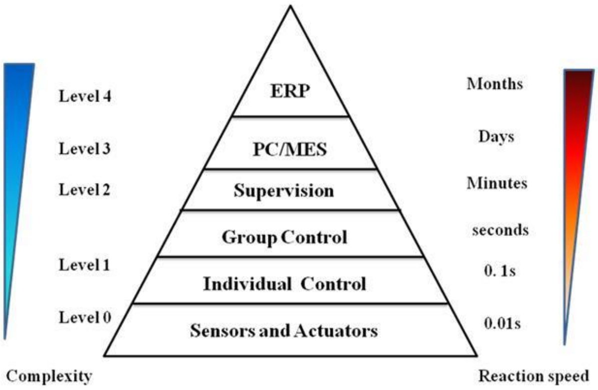

Fig-2 Architecture of Automation System

The foundation of instrument design for food industry automation is electronics. The following are important electronics tools used for automation in the food industry.

2. THE ROLE OF ELECTRONICS IN THE FOOD INDUSTRY

The food automation sector relies heavily on electronics. Below are some efficient and important applications of electronics in the food industry and food technology

2.1 BIOSENSORS

Sensors designed to detect and identify food pollutants. Foods are raw, processed, or prepared materials that humans or animals take orally for development, health, fulfilment, pleasure, and the fulfilment of social demands. Food preservation is the action or process of preserving foods at a desired level of characteristics or nature in order to maximise their advantages. In general, every step of food handling, processing, storage, and distribution has an impact on its properties, which can be favourable or unwanted. So biosensors can assess food quality [1]. A high specificity for the fast and sensitive detection of various food and beverage constituents, water- and food-borne diseases, poisons, and pesticide residues is required. Biosensors offer enticing, effective alternatives by delivering dependable and rapid results.A biosensor is an analytical device that combines a biological component (such as an enzyme, antibody, receptor, or nucleic acid) with a physicochemical detector component to detect and quantify a specific analyte or substance.

The main components of a biosensor are:

- Biological Recognition Element:
- Transducer:
- Signal Processor:

- Data Acquisition and Processing System:

Operating Principle Of Biosensors

Utilising biological material as a recognition molecule incorporated into a physicochemical transducer or transducing microsystems, biosensors function as analytical equipment. A digital electrical signal proportionate to the concentration of a certain analyte or analysis is the result, as depicted in Fig. 3. Bioreceptors are substances that are physiologically active and interact with the analyte that is being studied, such as bacteria, antibody enzymes, etc. Biosensors can employ a wide variety of naturally occurring compounds as its detecting element, including nucleic acids, protein lipids and their derivatives, enzymes, antibodies, cell receptors, etc. Enzymes serve as the catalytic component in many biosensors and catalyse a wide range of biological reactions. The key component of a biosensor is the transducer.Transducers are electronic devices that function as a detecting element and change one type of energy into another. In biosensors that use a physical change that accompanies the reaction, the main transducers utilised are electrochemical, optical, piezoelectric, and calorimetric. Numerous reactions facilitated by enzymes are exothermic, meaning they produce heat that can be utilised to gauge the reaction's pace and analyte concentration. Calorimetric biosensors are transducers that produce heat as a result of a response. Because an electrochemical biosensor directly converts a biological event into an electrical signal, it offers an appealing way to analyse the contents of a biological sample [1, 2].

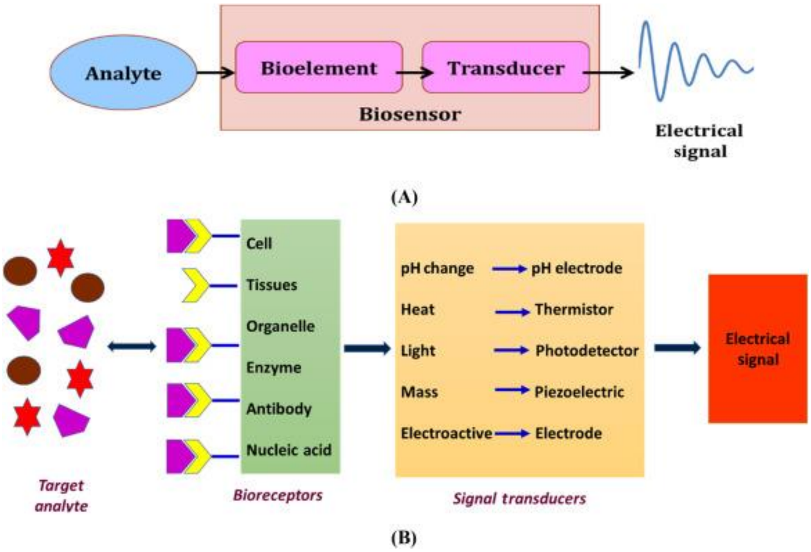

Fig-3: Biosensors and its parts.

Several principles, such as the impact of biological activity on light absorption and other optical characteristics, provide the foundation of optical transducers. Among the uses for optical immunosensors are optically based sensing devices that quantify fluorescence, luminescence, reflectance, absorbance, and other properties. When biological responses occur, thermometric transducers monitor the change in temperature. The fundamentals of a shift in the important frequency of wave propagation via a piezoelectric material are followed by piezoelectric transducers. Measurements of mass, viscosity, or density changes at the sensor surface can be made using these principles. A signal processor is used to present the outcome in an easy-to-read manner as electrical signals.

Frequently, the transducer's electrical signal is weak and heavily distorted. Utilising a "reference" baseline signal from a comparable transducer that lacks a biocatalytic membrane from the sample signal can improve the signal to noise ratio. A readable result is produced by amplifying the very slight signal difference. The signal's undesirable noise is eliminated by the procedure described above. Typically, a microprocessor receives the digital signal created by the amplifier after it has been transformed from analogue to digital. After being processed, the data is output to a display device or data repository after being transformed into concentration units.

Applications of Biosensor

Biosensors have a vast range of applications across various fields due to their ability to detect and quantify specific analytes with high sensitivity and selectivity. Some of the major applications of biosensors include:

- Biosensors are a viable alternative to traditional approaches, offering advantages in size, cost, specificity, rapid response, and sensitivity.
- They also play a technological role in food security [1, 2].

• These techniques aid in detecting and controlling food pollutants in agriculture and the food industry [3].
• Biosensors offer rapid, specific, and sensitive detection to manage biological risks [4].
• Biosensors are used in goods with high vitamin, mineral, and antioxidant content.
•They are useful in quantifying various food components for evaluating rancidity, maturity, decline, and shelf life, as well as detecting compounds to identify the amount of food freshness.
• Incorporating nanotechnology into biosensors can assist expand nanoscale instruments for biosafety and food packaging [1].

- Healthcare and Medical Diagnostics:
- Environmental Monitoring. Food and Agriculture:
- Pharmaceutical and Drug Discovery:
- Biosecurity and Biodefense:
- Research and Scientific Applications:

The versatility of biosensors, combined with there ability to provide rapid, sensitive, and selective detection, makes them valuable tools in a vast range of applications, from healthcare and environmental monitoring to industrial and research settings.

Ongoing advancements in materials science, nanotechnology, and bioengineering are further expanding the capabilities and major applications of biosensors, paving the way for more sophisticated and integrated solutions in various fields.

2.2 THEUSEOFIMAGEPROCESSING TECHNOLOGY

Digital image processing techniques are increasingly being utilised to assess the quality of food materials. Fruits and vegetables may be easily classified using image processing based on size, shape, colour, and other characteristics. Huge postharvest losses during handling and processing, as well as rising demand for high-quality food items, have lead to the development of methods for accurately, quickly, and objectively determining the quality of food and agricultural goods [5]. Machine vision can estimate size by measuring the projected area, perimeter, or diameter.The shape is very essential visual quality factors of fruits, vegetables, and other items that people can easily understand but are difficult for computers to quantify or define; nonetheless, employing image processing, this work can be handled by machines. The image processing approach is highly useful in analysing the colour and size of food products without requiring human participation. Figure 4 illustrates different stages of image processing.

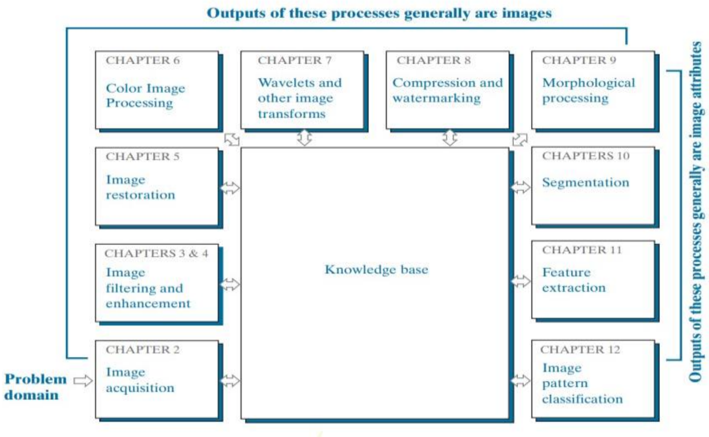

Fig 4: Different levels of image processing

Image processing is a set of image processes that improve image quality by removing faults such as poor focus, repetitive noise, geometric distortion, non-uniform lighting, and camera motion. Image acquisition techniques include charge-coupled device cameras, ultra sound and sonography, magnetic imaging resonance, computed tomography, and electrical tomography. Image pre-processing methods include pixel and local approaches. Image analysis is defined as a method that differentiates objects from their backgrounds by providing quantitative information that is used in later control systems to make decisions. Image processing can be classed into three levels: low-level, intermediate-level, and high-level.Fig- Each level focuses on suppressing unwanted distortions or enhancing key aspects of interest. Image segmentation, along with representation and description, are examples of intermediate level processing. Image segmentation is a key phase that splits an image into sections with a significant link to objects or areas of interest. Methods such as thresholding-based, gradient-based, region-based, and characterization are used for image segmentation. Size, shape, image, texture, and flaws are all examples of features examined through representation. Image description is applied to extract quantitative data from segmented images. High-level processing encompasses recognition and interpretation utilising statistical classifiers or multilayer neural networks in the area of interest [1].

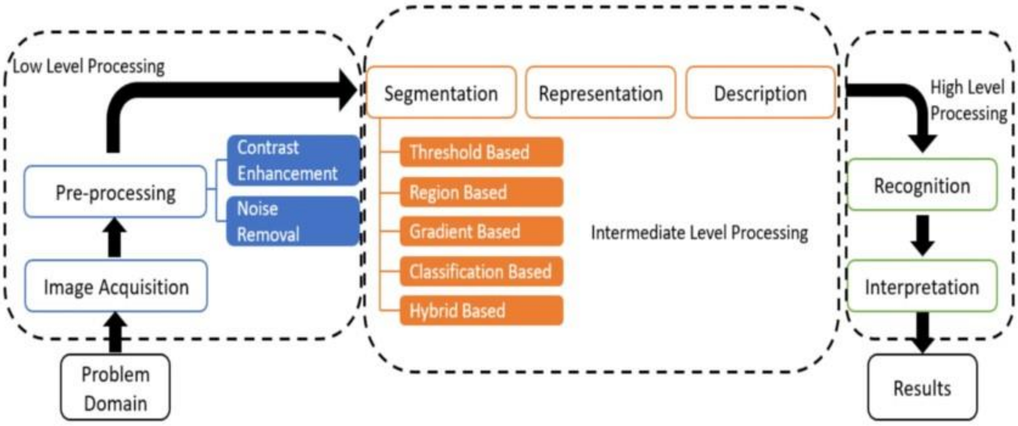

Fig 5: Flow chart of image processing

These processes give the information required for process/machine control of quality sorting and grading. Communication with an informative database at all stages of the process is critical for taking more accurate decisions and appears to be an essential component of the image-processing procedure. The functioning and effectiveness of intellectual decision-making are dependent on the availability of a comprehensive knowledge base, which in machine vision is integrated into the computer. Algorithms such as neural networks, fuzzy logic, and genetic algorithms are examples of image understanding and decision-making techniques that provide system control capabilities.

Applications of image processing

Following are some examples of applications of image processing in food industry.

- Detection of acrylamide levels in cookies. Image processing is used in food inspection to detect acrylamide, a well-known poison, in cookies [1].
- Fruit and vegetable grading and inspection examine quality attributes such as shape, size, colour, blemishes, and illnesses [7].
- Computer vision technology is widely used in the food business to evaluate the quality of grains and processed goods like chips, cheese, and pizzas.

- Image processing can analyse bakery product quality and detect fungal-damaged popcorn kernels that are difficult to separate with human vision [1].

2.3 USEOFELECTRONICNOSE(E-NOSE)

The sense of smell and taste derived from specific and non-specific atomic structures can be used to evaluate the quality of food, beverages, and food mixtures. The biological nose actively detects the quality of food. As humans, we can use our noses to determine if food is good or unhealthy depend on the odour it emits. But there is still a chance of making a mistake. Traditional electronic noses: An established definition of an electronic nose is "an equipment that comprises an array of electronic chemical sensors with partial specificity and a suitable pattern recognition system, capable of identifying simple or complex odours."[8] that attempts to detect various gas combinations.Electronic nasal frameworks are easier to create than traditional methods of analysis and produce data more efficiently. The current study emphasises on the detection mechanisms used in traditional e-nose.

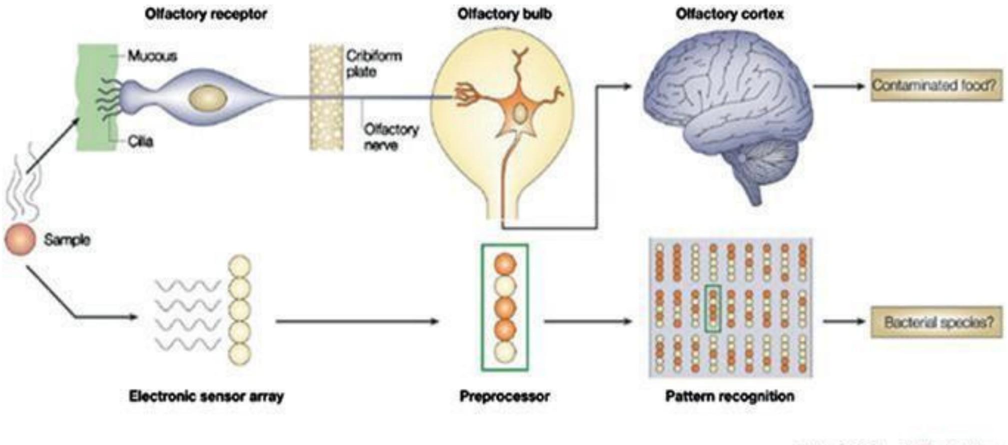

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Fig.5 : A comparison of a biological nose with e-nose

Working Principle And Structure:

The discussion is inadequate without a comparison of electronic noses to organic noses. Figure 4 depicts a comparison between a biological nose and an electronic nose. In the case of a natural nose, mucus and vibrissae in the nasal opening perform filtration and gathering of odorant particles. The lungs' strong pressure transports odorant particles to the olfactory epithelium. The olfactory epithelium comprises a large number of detecting cells, with olfactory receptors located on their layers. Receptors convert chemical impulses into electro-neurographic signals. The olfactory cortex neural system is responsible for translating a certain pattern of electro-neurographic signals. Electronic noses use the same principle as olfactory receptors, replacing pumps with lungs and replacing mucous with an electronic sensor array. Signals are routed to a preprocessor and recognised using olfactory cortex neural system patterns. Electronic noses are used to describe a variety of gas mixtures as well as the natural nose. Regardless, there are some significant differences between equipment and programming. Points of interest in correlations between these two "noses" are listed below. In short, an electronic nose is made up of two main components: a detection framework and a sign handling framework. They are examined in the accompanying areas separately.

Sensing System

Electronic sensing, commonly known as e-sensing, is a technical instrument for quality to control in the food industry that has also become essential commercially. The International Union of Pure and Applied Chemistry (IUPAC) defines synthetic sensors as "gadgets that convert chemical data into a form that can be further analysed." There are various sensors available for food analysis, each with its own set of advantages and disadvantages due to changes in structural configuration in terms of input variable, working temperature, and lifetime. A statistical programme is employed to divide the samples into groups for further examination [12]. Sensor innovation has increased rapidly over the last decade, resulting in a wide range of sensor groups and the development of complicated microarray sensor gadgets. The most commonly used sensors include metal oxide semiconductor (MOS) sensors, conducting polymer (CP) sensors, optical sensors, and piezoelectric sensors [13, 14].

Applications Of Electronic Noses In The Food Industry:

- Optimised e-nose approach for wheat storage age classification.
- An e-nose with six metal oxide sensors was utilised to categorise virgin olive oils with and without phenolic compounds for oxidative state, which correlated well with sensory analysis.

An e-nose can identify between eggs stored for varying durations of time and at chilled or room temperature [8].

An ion-mobility based e-nose was utilised to separate hard and extra-hard cheese samples, as well as differentiate between cheeses based on age (ripening time) or provenance [12].

- Biosensors with silver or platinum electrodes and immobilised putrescine or xanthine oxidases have been employed to detect bacterial deterioration in meat during ageing (8).

- The odour of fish determines whether it is accepted or rejected. Typically, the quality of fish and fish products is determined using sensory testing or gas chromatography. As a result, there is a need to establish an effective method for controlling the quality of fish and fish products. Electronic noses play an essential role in offering speedy, automated, and objective instruments for quality control of fish.Freshness of fish was assessed by measuring the important volatile components such as alcohols, carbonyls, amines, and mercaptanes, which showed normal concentration changes over time under certain storage conditions[11].
- E-nose is used to classify beer samples and identify key distinctions. Sensor-based electronic noses are used to identify efficient technology for producing several sorts of beers[10].
- Volatile components in fruits contribute to their distinct scent and flavour. Fruit scent and flavour characteristics are critical in determining consumer acceptance in commercial fruit markets. Individual preference changes during fruit ripening are also evaluated using an electronic nose.
- Electronic noses can determine the aroma and authenticity of olive oil.

2.4 USEOFELECTRONICTONGUE[E-TONGUE]

The e-tongue is a tool for measuring and comparing flavours. E-tongue was created to reduce the number of human olfactory and taste sensory organs and is made up of a variety of sensors. Scientists have made many efforts to predict the sensory profile of food articles using instrumental measurement. The e-tongue employs taste sensors to collect data from chemicals on the tongue and transmit it to a pattern recognition algorithm. The consequence is the detection of the tastes that make up the human palate.The sorts of taste produced are classified into five categories: sourness, saltiness, bitterness, sweetness, and umami. Sourness, which comprises hydrogen chloride, acetic acid, and citric acid, is caused by hydrogen ions. Saltiness is measured in sodium chloride, sweetness in sugars, bitterness in the form of compounds like quinine and caffeine in magnesium chloride, and umami in the form of monosodium glutamate from seaweed or disodium guanylate inmeat/fish/mushrooms. The purpose of this review is to establish the suitability of e-tongue in the food business to replace traditional methods of sensory analysis.This paper explores the fundamental ideas and applications of e-tongues in the food sector. It describes how to use e-tongues to reduce panellist bias while evaluating the flavour of foods. The evaluation of dairy and food products for organoleptic qualities is an important prerequisite for the development of newer items as well as their perfection during production or marketing. In the era of sensor technology, the evolution of e-tongues has sparked a revival in food sensory assessment. This study discusses the structure, primary principle, and detecting techniques utilised in e-tongue development. The primary components of an electronic taste-sensing system include a variety of sensor types attached to the arm, a sample table, an amplifier, and a computer for data processing. Figure 5 depicts the basic principle of an electrochemical taste-sensing device. This technology mimics what occurs when chemicals with specific taste properties interact with taste buds on the human tongue. Sensors represent the taste buds, which interact with molecules on the surface, causing potential alterations. These signals are compared to physiological action potentials recorded by a computer, which correspond to the neural network on a physiological scale.The collected data can be further analysed using an existing matrix of sensor responses, which can then be compared to human memory or linkage to pre-existing flavour patterns [15, 16].

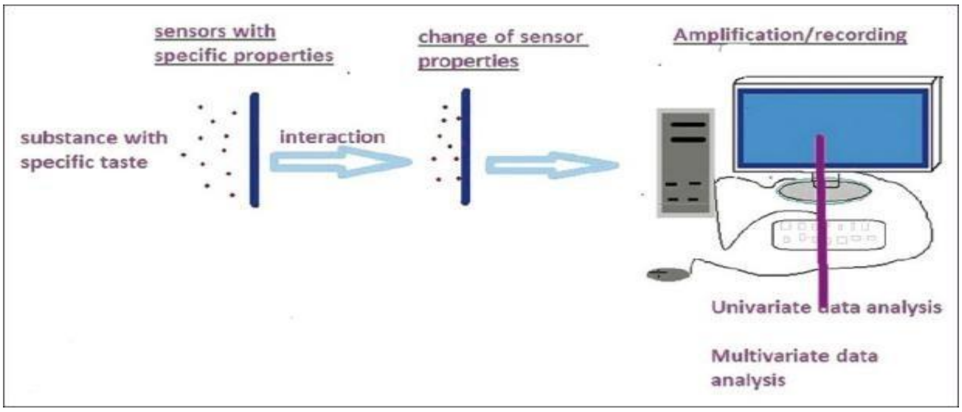

Fig5:Basicprincipleofelectronictastesendingsystem

Working Principle and Structure:

The electronic tongue is a tool for measuring and comparing flavours. Several measuring principles have the potential to be applied in electronic tongues. Electronic tongues can be designed with a variety of chemical sensors, including electrochemical (potentiometric, voltammetric, impedimetric), optical, and enzymatic sensors (biosensors). Electrochemical measurement systems are utilised for analysis in a variety of applications. Each sensor uses specific information, and the combined information from all sensors produces a specific data. The e-tongue's statistical software analyses sensor data to identify flavour patterns.The data is amplified for better results and can be recorded for further use. Results obtained by the e- tongue shows more accuracy as compare to the results obtained by sensory.

ApplicationsOfE-TongueInFoodTechnology

Followingaretheapplicationsofe-tongueinfoodsector.

- Researchers have attempted to predict coffee's sensory character based on objective measurements. The electronic tongue identified between pure origin and blended coffee samples.
- Electronic tongues are mostly used for qualitative analysis. Several studies have been conducted to recognise, classify, and identify milk and fermented milk samples.
- An e-tongue distinguishes healthy orange juice from citrus greening-affected fruit. Meat freshness is a complex notion that involves microbiological, physicochemical, and biochemical characteristics. The electronic tongue can be used to evaluate the quality of meat.
- Analyse human urine to identify urinary system malfunction and creatinine levels
- Analyze pharmaceutical stability in terms of flavour.
- Detect alcohol in beverages using porphyrin-based potentiometric electronic tongue.

3. INVOLVEMENTOFGOVERNMENTOFINDIAINFOODPROCESSINGSECTOR

Some of the significant steps conducted by the Government of India to strengthen the food processing sector in India are listed below [18]:
The Indian government seeks to increase growth in the food processing sector through reforms

such as 100% foreign direct investment (FDI) in marketing, incentives at the central and state levels, and an emphasis on supply chain infrastructure.

- The Union Budget 2017-18 established a dairy processing infrastructure fund worth Rs 8,000 crore (US$ 1.2 billion).
- The Indian government has loosened FDI requirements for food e-commerce, enabling up to 100% FDI through an automated mechanism.

- The Food Safety and Standards Authority of India (FSSAI) aims to invest Rs 482 crore (US$ 72.3 million) to improve food testing infrastructure in India. This includes updating 59 existing labs and establishing 62 new mobile labs nationwide.
- The Indian Council for Fertiliser and Nutrient Research (ICFNR) aims to embrace international best practices for fertiliser research, providing farmers with high-quality fertilisers at competitive prices and promoting food security for all.
- The Ministry of Food Processing Industries has announced a Human Resource Development (HRD) initiative for the food processing sector. Under the National Mission on Food Processing, state governments are implementing the HRD scheme.

4. CONCLUSION AND FUTURE SCOPE

The food sector is falling behind in the current technological era because traditional ways of analysing the quality of food products are still being used. Therefore, effective biosensors and image processing methods are required to deliver quick, affordable, sanitary, reliable, and impartial evaluation. The food industry will greatly benefit from the implementation of this new technology to enhance food product quality inspection. Although an instrument cannot replace human tasters or sensory evaluation of food, numerous studies have demonstrated that the use of an electronic tongue and nose can be a highly effective non-destructive way for identifying food products that are both poisonous and non-toxic. Their broad range of uses is evident in the food industry, where they are used for product identification and classification, ripening process monitoring and optimal timing determination, food spoilage monitoring, shelf life assessment, and food adulteration detection. The food business can use electronic instruments to adapt and lower labour costs, processing times, and product quality. The food industry's industrial automation has a promising future due to its achievable outcomes.

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