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Importance of Electronics in Food Industry

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Abstract: *Food industry is growing fast in this era, still this is lagging behind in adopting new technology than in other industries. Food industry is dependent upon manual handling, in a wide range of activities. That is largely because of the features of the food products are variable: such as vegetables, fruits, meat, seafood etc. these food products can be divided into very good, good or bad categories on individual unit basis. To handle all these things automatically high level of automation is required because food products can vary in size, shape, fragrance, color etc. Considering the diversity of the food industry, it is almost impossible to obtain a generic automation solution. Electronics play very important role for automation in food industry. Automated systems in food production come in different functions and sizes, very much depending on the food type and specific requirements of the manufacturers. This paper gives the idea about the role of electronics in food industry. In this paper role of bio-sensors, e-nose, e-tongue, image processing has been discussed. In this paper involvement of government in food processing sector is also discussed. Different schemes of government are highlighted.*

Key words*; Electronics, e-tounge, e-nose, biosensors*

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I. Introduction

The food industry is a complex industry, that supplies most of the food consumed by the world population. Every year, millions of people experience serious and sometimes fatal health problems due to consumption of unsafe or contaminated food. The contamination may involve food borne disease or chemical hazards. Furthermore, billions of dollars are lost annually in the food industry because of insect damage and inefficient production and inspection processes. Automation is needed in food industry for high quality and profitable products. Electronics plays major role for automation of food industry. Some processing of food product is required before coming in the market for example, if we have to categorize the apples; apple may differ in size, shape, taste, color, quality. So, same is also true for other fruits, vegetables and grains. To select the fruits of same qualities huge manual efforts are required [3]. In food industry expenses on labor are very high around half of the other expenses. To minimize these expenses in long terms automation of food industry can play major role. Plant automation can improve productivity, quality and profit of the plant as shown in Fig.1. So, automation of food industry is one time investment but in long term cost may be less. Further automation is possible only due to advancement in computer software and hardware.

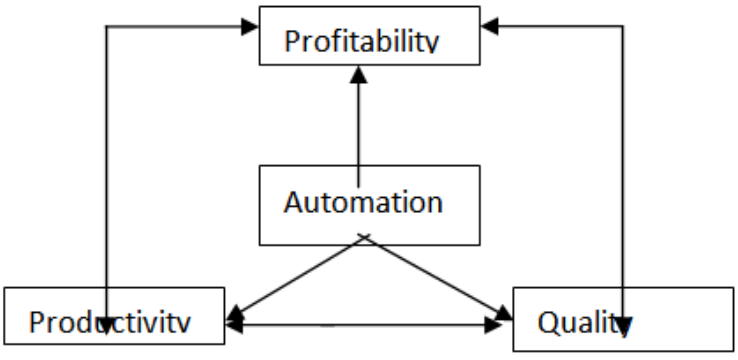

Fig.1: Plant automation [1]

Electronics is back bone for designing instruments for automation of food industry. Following are some key electronics devices used in food industry for automation.

II. Role Of Electronics In Food Industry

Electronics plays very important role in food automation industry. Following are some important applications of electronics in food industry.

1. **USE OF BIO SENSORS:** Sensors designed for the detection and identification of contaminants in food. Foods are materials, raw, processed, or formulated, that are consumed orally by humans or animals for growth, health, satisfaction, pleasure and satisfying social needs. Food preservation is an action or a method of maintaining foods at a desired level of properties or nature for their maximum benefits. In general, each step of handling, processing, storage and distribution affects the characteristics of food, which may be desirable or undesirable. So, biosensors can analyze the quality of food [1]. There exists a strong need for rapid and sensitive detection of different components of foods and beverages along with the food borne and water borne pathogens, toxins and pesticide residues with high specificity. Biosensors present attractive, efficient alternative techniques by providing quick and reliable performances.

BASIC PRINCIPLE OF BIOSENSORS

Biosensors act as analytical devices employing a biological material as a recognition molecules integrated within a physicochemical transducer or transducing microsystems. The outcome of this is a digital electronic signal proportional to the concentration of a specific analyte or analysis shown in Fig. 2. Bioreceptors are biologically active materials that interact with the analyte under study, e.g., antibody enzymes, microorganisms, etc. A varied range of naturally produced molecules such as nucleic acids, protein lipids and their derivatives, enzymes, antibodies, cell receptors, etc. can all be used as the sensing element in biosensors. Enzymes catalyze many biochemical reactions and they are vastly used in biosensors as the catalytic component. The key component of a biosensor is the transducer

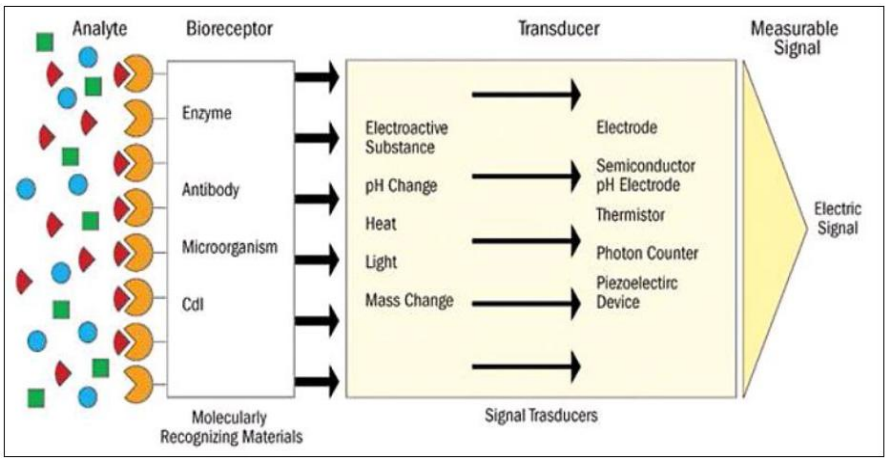

Fig 2: Biosensors and its parts.

Transducers are electronic devices that convert one form of energy into another and act as a detecting element. Electrochemical, optical, Piezo-electric and calorimetric are the major transducers used in biosensors that makes use of a physical change accompanying the reaction. Many enzyme catalysed reactions are exothermic, generating heat which may be used as a basis for measuring the rate of reaction and analyte concentration. Transducers those generate heat output by the reaction are called Calorimetric biosensors. Electrochemical biosensors provide an attractive means to analyze the content of a biological sample due to the direct conversion of a biological event to an electronic signal [1, 2]. Optical transducers are based on a number of principles like the effect of the biological activity on absorption of light and on other optical parameters. Optical based sensing systems that measure luminescence, fluorescence, reflectance and absorbance, etc., are some of the areas of applications of optical immunosensors. Thermometric transducers measure the change in temperature difference during biological reactions. Piezoelectric transducer follows the principles of change in the significant frequency of wave propagation throughout a piezoelectric material. These principles can be used to measure mass, viscosity or density changes at the sensor surface. Signal processor is used to display the result in the form of electrical signals in a user friendly manner. The electrical signal from the transducer is often weak

with heavy noise. To increase the signal to noise ratio a 'reference' baseline signal derived from a similar transducer without any bio catalytic membrane from the sample signal should be used. The difference between the signals is very weak and amplified as a readable output. The above process removes the unwanted noise from the signal. The analogue signal produced by amplifier is usually converted in to a digital signal and passed to a microprocessor. The data is processed, converted in to concentration units and output to a display device or data store.

APPLICATIONS OF BIOSENSORS

- Biosensors are promising alternatives to conventional methods as they offer advantage in size, cost, specificity, rapid response and sensitivity and play technological role in food security [1, 2].
- With respect to food quality in products originated from plant and animal, biosensors are useful for the assessment of food composition during postharvest handling and processing [1,2].
- These are helpful tools in the detection and control of potential food contaminants by agricultural and food industries [3].
- Biosensors provide fast and effective detection approach having beneficial perspective for rapid, specific, and sensitive detection to control biological hazards [4].
- Biosensors found their applications for the products that are leading in vitamins, minerals, and antioxidants.
- They are helpful in quantification of different food components for evaluation of rancidity, maturity, decline and shelf life and detect substances to find out the level of food freshness.
- A hybrid technology by incorporation of nanotechnology in biosensor is helpful in the expansion of nanoscale tools for biosafety, nanoscale compounds in case of food packaging [1].

2. USE OF IMAGE PROCESSING

Now a days, digital image processing techniques have been increasingly used for quality analysis of food material. Through image processing fruits and vegetables can be easily categorized according to their size, shape, color etc. Huge postharvest losses during handling, processing as well as increased demand for food products of high quality have generated the methods for accurate, fast and objective quality determination of food and agricultural products [5]. Size is the parameter that can be estimated using machine vision by measuring projected area, perimeter or diameter. The shape is one of the important visual quality parameters of fruits, vegetables, etc easily comprehended by humans but difficult to be quantified or defined by the computer, but using image processing this work can be handled by machine. Image processing technique is very helpful in analyzing the color and size of the food product easily without human intervention. Different levels of image processing are shown in Figure 3.

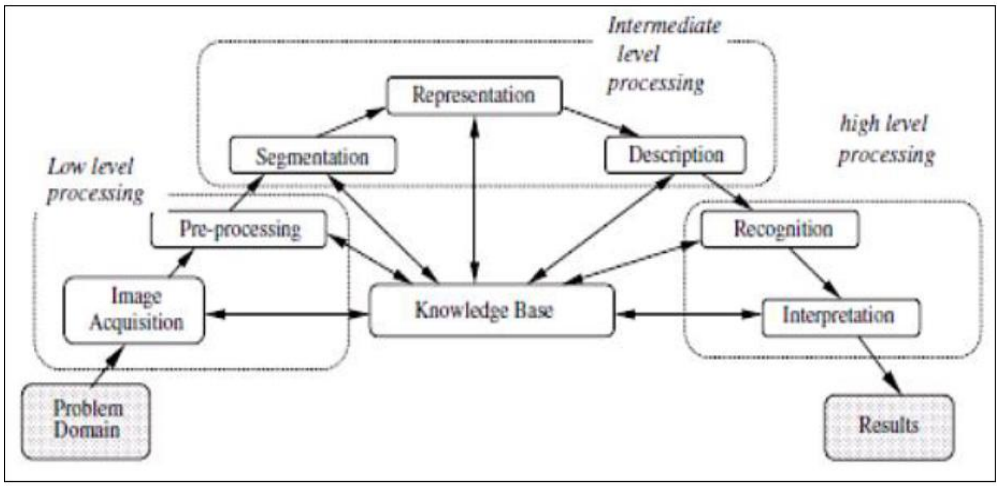

Fig 3: Different levels of image processing [6]

Image processing consists of a series of image operations that improve the quality of an image by removing various defects like improper focus, repetitive noise, geometric distortion, non-uniform lighting and camera motion. Charge coupled device camera, ultrasound, magnetic resonance imaging, computed tomography, and electrical tomography are used for image acquisition. Pixel and local pre-processing approaches are image pre-processing methods. Image analysis is defined as a process that distinguishes the objects from the background by providing quantitative information that is used in the subsequent control systems for decision making. Image processing/analysis can be classified in three levels like low-level

processing, intermediate-level processing and high-level processing by suppressing undesired distortions or by the enhancement of important features of interest. Intermediate-level processing includes image segmentation, and representation and description. Image segmentation is an important step that divides an image into regions that have a strong correlation with objects or areas of interest, methods like thresholding-based, gradient-based, region-based, and classification are used image segmentation. Representation is used to examine features like size, shape, image, texture and defects. Image description is used to extract quantitative information from the segmented images. High-level processing includes recognition and interpretation by using statistical classifiers or multilayer neural networks of the area of interest [1].

These steps provide the necessary information for process/machine control for quality sorting and grading. Communication with an informative database at all steps of the whole process is important for more accurate decision making and looks as an integral part of the image-processing process. The operation and effectiveness of intellectual decision-making is based on the condition of a complete knowledge base that in machine vision is incorporated into the computer. Algorithms like neural networks, fuzzy logic and genetic algorithms are some of the techniques involving image understanding and decision-making capacities thus providing system control capabilities.

APPLICATIONS OF IMAGE PROCESSING

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

- The detection of acrylamide level in cookies. Food inspection for acrylamide detection involves the detection of this well-known neurotoxin in cookies using image processing [1].
- Quality attributes like shape, size, color, blemishes and diseases are parameters taken into consideration during grading and inspection of fruits and vegetables [7].
- Major areas of application of computer vision technology in food industry include quality evaluation of food grains, processed foods such as chips, cheese and pizza.
- Image processing also has application to analyze the quality of bakery products.
- Image processing technique is also helpful to detect fungal-damaged popcorn kernels that are not easy to separate by using human vision [1].

3. USE OF ELECTRONIC NOSE (E-NOSE)

feeling of smell and taste coming from specific and non specific atomic structures can be utilized to analyze the nature of food, drinks, and mixture of food items. Biological nose works actively to detect the quality of foods. We, as human being can use our nose to judge the quality of food by the odor coming out of food whether it is healthy or unhealthy. But still there is probability of making a mistake. Traditional electronic nose : An accepted definition of an electronic nose is "an instrument which comprises an array of electronic chemical sensors with partial specificity and an appropriate pattern recognition system, capable of recognizing simple or complex odor"[8] and tries to distinguish dissimilar gas mixtures. Comparing with other methods of analysis, electronic nose frameworks are easy to manufacture and provides results efficiently. The focus of present study concentrates on the detecting strategies utilized in traditional e-nose.

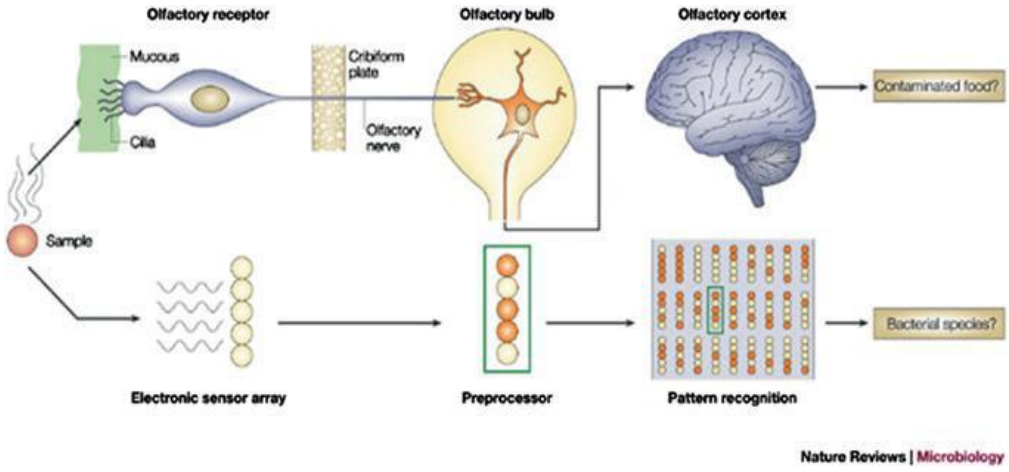

Fig. 4 : A comparison of a biological nose with e-nose [9]

PRINCIPLE AND STRUCTURE:

Discussion is incomplete without comparison of electronic nose with organic nose. Fig 4 shows a

Comparison of a biological nose with electronic nose. In case of natural nose, mucous and vibrissae in nasal hole execute filtration process and grouping of odorant particles. Odorant particles are conveyed to the olfactory epithelium due to heavy pressure supplied by the lungs.
Olfactory epithelium contains a huge number of detecting cells and olfactory receptors are situated on the layers of these cells. Receptors change these chemical signals into Electro-neurographic signals. A particular pattern of electro-neurographic signals is translated by olfactory cortex neural system. Basedon the same principle electronic noses are designed in
which pumps are replaced by lungs and the inlet examination system designed in form of electronic sensor array replaced mucous and the signals goes to preprocessor in the same way as in olfactory receptors and a pattern recognition is done on the pattern of olfactory cortex neural system . Electronic nose are utilized to describe diverse gas blends and also natural nose. Be that as it may, there still exist some crucial contrasts in both equipment and programming. Points of interest of correlations between these two "noses" are recorded underneath. In rundown, an electronic nose is made out of two principle parts: detecting framework and sign handling framework. They are examined in the accompanying areas, separately

III. Sensing System

Electronic sensing also called e-sensing refers to reproducing human senses using sensor arrays, emerged as a technical tool in quality control in food sector as well as important from commercial point of view. The International Union of Pure and Applied Chemistry (IUPAC) characterize synthetic sensors as "gadgets that transform chemical data into the form which can be further analyzed. Variety of sensors are available for the analysis of food as they have their own advantages and disadvantages because of change in structural configuration in terms of input variable, working temperature and lifetime. Statistical programme are used to classify the samples into the groups for further analysis [12]. Sensor innovation has grown quickly over the previous decade, and this has brought about a scope of various sensor groups and the advancement of complex microarray sensor gadgets. The most usually utilized sensors incorporate metal oxide semiconductor (MOS) sensors, conducting polymer (CP) sensors, optical sensors and piezoelectric sensors [13, 14].

APPLICATIONS OF ELECTRONIC NOSES IN THE FOOD INDUSTRY:
Following are some applications of e-nose in food industry.

- An e-nose technique was optimized to classify wheat based on storage age .
- An e-nose with six metal oxide sensors was used to classify virgin olive oils with and without phenolic compounds for oxidative status and correlated well to sensory analysis.
- An e-nose could distinguish eggs stored for different amounts of time and at chilled or room temperature storage [8].
- An ion-mobility based e-nose was used to determine separation of hard and extra-hard cheese samples as well as discrimination of cheeses based on age (ripening time) or origin [12].
- For meat, the e-nose has been used to detect bacterial spoilage during the aging process using biosensors that included a silver or platinum electrode on which the enzymes putrescine or xanthine oxidases were immobilized [8].
- Odor of fish is important quality parameter on basis of it is accepted or rejected. Usually, quality of fish and fish products has been done on basis of sensory or by gas chromatography. So there is need for development of an efficient technique to control the quality of fish and fish products. Electronic noses plays important role by providing rapid, automated and objective tools for quality control of fish ,For fish, freshness was determined by measuring the relevant volatile compounds consisting of alcohols, carbonyls, amines and mercaptanes which showed typical concentration changes over time under specific storage conditions[11].
- E-nose is used for the classification of the beer samples and also highlights the compound that makes the major differences. Sensor-based electronic noses are employed to identify efficient technology to make different types of beers[10].
- Fruits are source of volatile components that impart their characteristically distinct aromas and provide unique flavor characteristics. Fruit aroma and flavor characteristics are of key importance in determining consumer acceptance in commercial fruit markets based on individual preference change during ripening of fruits is also monitored with help of electronic nose.
- Electronic noses are very useful to detect of aroma of olive oil and to check the originality of olive oil .Quality parameters of olive oil is influenced by geographical location, selection of olive seed and farming method. An electronic nose also helpful for assessment of the degree of oxidation in edible oils.

4. **USE OF ELECTRONIC TONGUE [E-TONGUE]**

The e-tongue is an instrument that measures and compares tastes. E-tongue was designed to minimize human olfactory and taste sensory organs and are consisted of an array of sensors. Various efforts have been made by scientists to predict the sensory profile of food articles with instrumental measurement. The e-tongue uses taste sensors to receive information from chemicals on the tongue and send it to a pattern recognition system. The result is the detection of the tastes that compose the human palate. The types of taste that is generated is divided into five categories sourness, saltiness, bitterness, sweetness, and umami(savoriness). Sourness, which includes hydrogen chloride, acetic acid, and citric acid, is created by hydrogen ions. Saltiness is registered as sodium chloride, sweetness by sugars, bitterness, which includes chemicals such as quinine and caffeine is detected through magnesium chloride,and umami by monosodium glutamate from seaweed, or disodium guanylate in meat/fish/mushrooms. The aim of the review here is to determine the applicability of e-tongue in food industry to replace traditional methods of sensory analysis. This review describes the basic principles and applications of e-tongues in the food industry. It explains the application of e-tongues to eliminate panelist bias for taste evaluation of food products. The evaluation of dairy and food products for their organoleptic properties is one of the essential requirements for the development of newer items as well as their perfection at the stage of production or marketing. In the era of sensor technology, the evolution of e-tongues has initiated renaissance in sensory assessment of foods. This paper covers the structure and main principle along with the detection systems used in the e-tongue development. The main elements of an electronic taste-sensing system are number of different sensor types attached to arm, a sample table, an amplifier, and a computer for data recording. Figure 5 gives a basic principle of electrochemical taste-sensing system. This system imitates what is happening when molecules with specific taste nature interact with taste buds on the human tongue. The taste buds are represented by sensors which interact with these molecules at the surface initiating changes in potential. These signals are compared with physiological action potentials which are recorded by computer, which correspond to the neural network at the physiological level. The data obtained can further be evaluated on the basis of already existing matrix of sensor responses which can be compared with human memory or association to already existing taste patterns [15, 16].

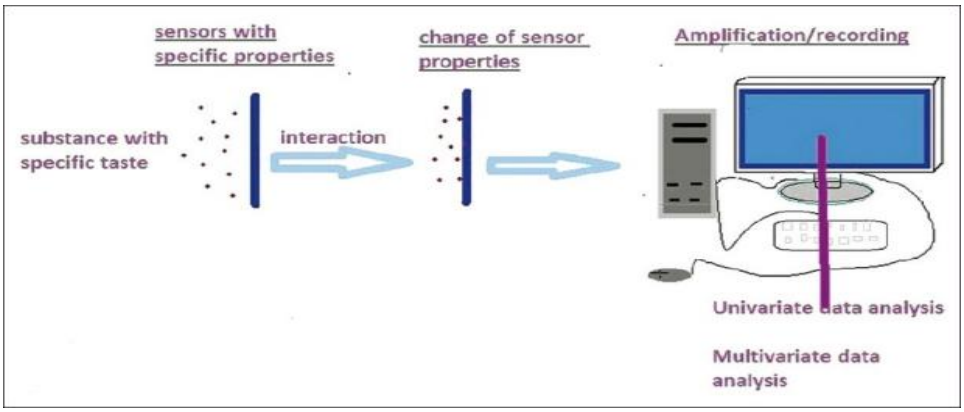

Fig 5 : Basic principle of electronic taste sending system[16]

IV. Principle and Structure

The electronic tongue is an instrument that measures and compares tastes. There are several measurement principles that have the potential to be used in electronic tongues. A wide variety of chemical sensors can be employed into the designing of electronic tongues such as electrochemical (potentiometric, voltammetric, impedimetric),optical or enzymatic sensors (biosensors). Generally, electrochemical measurement systems are used for analytical purposes in a number of applications. Each sensor uses specific information and the resultant information from all the sensors generate a particular data . This step is achieved by the e-tongue's statistical software which interprets the sensor data into taste 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.

APPLICATIONS OF E-TONGUE IN FOOD TECHNOLOGY

Following are the applications of e-tongue in food sector.

- Several efforts have been made by researchers to predict the sensory profile of coffee by instrumental measurement results. The electronic tongue distinguished the pure origin and the blended coffee samples.

- The main purpose of electronic tongues is qualitative analysis, and thus several works on the application of electronic tongue devices in recognition, classification or identification of milk and fermented milk samples have been reported.
- An e-tongue has been used to differentiate between orange juice made from healthy fruit and from fruit affected by the citrus greening
- Meat freshness is a rather complex concept, which includes different microbiological, physicochemical and biochemical attributes. The e- tongue can be used for analyzing quality of meat.
- Analyze human urine for the detection of urinary system dysfunction and creatinine levels.
- Analyze stability of medicines regarding taste.
- Detect alcohols in beverages by using porphyrin-based potentiometric electronic tongue.

INVOLVEMENT OF GOVERNMENT OF INDIA IN FOOD PROCESSING SECTOR

Some of the major initiatives taken by the Government of India to improve the food processing sector in India are as follows [18]:

The Government of India aims to boost growth in the food processing sector by leveraging reforms such as 100 % Foreign direct investment (FDI) in marketing of food products and various incentives at central and state government level along with a strong focus on supply chain infrastructure.

- In Union Budget 2017-18, the Government of India has set up a dairy processing infra fund worth Rs 8,000 crore (US$ 1.2 billion).
- The Government of India has relaxed foreign direct investment (FDI) norms for the sector, allowing up to 100 per cent FDI in food product e-commerce through automatic route.
- The Food Safety and Standards Authority of India (FSSAI) plans to invest around Rs 482 crore (US$ 72.3 million) to strengthen the food testing infrastructure in India, by upgrading 59 existing food testing laboratories and setting up 62 new mobile testing labs across the country.
- The Indian Council for Fertilizer and Nutrient Research (ICFNR) will adopt international best practices for research in fertiliser sector, which will enable farmers to get good quality fertilisers at affordable rates and thereby achieve food security for the common man.
- The Ministry of Food Processing Industries announced a scheme for Human Resource Development (HRD) in the food processing sector. The HRD scheme is being implemented through State Governments under the National Mission on Food Processing.

V. Conclusion and Future Scope

In the era of modern technology, food industry is lagging behind due to uses of conventional methods to analyze the food product quality. So there is need for efficient biosensors and image processing techniques to provide rapid, economic, hygienic, consistent and objective assessment. The adoption of this emerging technology in improving quality inspection of food products will be of immense benefit for the food industry. Although, human tasters and sensory assessment of food cannot be substituted by an instrument, many studies have shown that e- tongue and e- nose poses as an excellent non-destructive method for the determination of both toxic and non-toxic food products. Their wide application can be found in the food industry, where they can be employed in the identification and classification of products, monitoring of the ripening process and determination of the optimal ripening time, monitoring of food spoilage, shelf life determination of food as well as detection of adulteration of food. Food industry can reduce labour cost, processing time, food quality with adaption of electronic instruments. Industry automation in food industry has bright future because of realistic results

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