A REVIEW | International Journal of Agricultural Engineering | Volume 13 | Issue 2 | October, 2020 | 276-282

ISSN–0974–2662 ■ Visit us : *www.researchjournal.co.in* ■ **DOI: 10.15740/HAS/IJAE/13.2/276-282**

Electronic sensors and biosensor used for automation in the food industry

Priyanka Handa and Bhupinder Singh

Received : 03.07.2020; **Accepted :** 27.09.2020

See end of the Paper for authors' affiliation

Correspondence to :

Bhupinder Singh
Department of Food Technology, Ch. Devi Lal State Institute of Engineering and Technology, Panniwala Mota, **Sirsa (Haryana) India**
Email: bhupimander@rediffmail.com

■ **ABSTRACT :** The current health pandemic and crisis has added a mountain of challenges across the food and beverage industry, as consumer buying patterns are changing and both production of goods and other business operations have been disrupted. Human touch should be minimized to reduce such kind of infections. So automation of food industry should be increased. The food industry has traditionally lagged behind other industries in adopting new technology, and plant automation is no exception. However, rapid advances in computer technology and heightened expectations of consumers and regulatory agencies for improved food quality and safety have forced the food industry to consider automation of most manufacturing processes. Though the food industry presents many unique challenges to complete automation, the industry has been successful in putting many automatic processes into place. Sensors and controllers are electronic devices and are the main backbone for the automation of food industry. In this paper some important electronic sensors and biosensors used for food automation are described.

■ **KEY WORDS :** Biosensors, Automation, Electronic sensors, Controllers

■ **HOW TO CITE THIS PAPER :** Handa, Priyanka and Singh, Bhupinder (2020). Electronic sensors and biosensor used for automation in the food industry. *Internat. J. Agric. Engg.*, **13**(2) : 276-282, **DOI: 10.15740/HAS/IJAE/13.2/276-282.**

One of the most important reasons for increased interest in automating the food industry is its cost structure. Food processing is highly labour-intensive, with labour costs at anything upto 50 per cent of the product cost (Gunasekaran, 2009). The automation of manufacturing plants has been actively pursued for more than 50 years and it will continue to be so, even more aggressively, during the next 50 years (Catherine, 2014). In the last five years or so there have been huge steps in automation and robot design. There has been an emergence of a wide range of standalone robots, with fully hygienic pick and place capabilities that in theory appear to be able to handle a wide array of raw ingredients. Recent developments in factory optimization have forced the need to adapt machinery and other processes to make manufacturing more effective. Automation is opening many opportunities for technology companies that are innovative and can cater to automotive companies (Jijo and Ramesh Kumar, 2014). For the manufacturer of such technology, the future of automation for the food industry looks very promising indeed. The increased zeal in industrial automation is mainly due to the explosive growth in computer hardware and software technology. As computer invade a high level of automation in every part of the manufacturing processes. In automatic control, the process parameters measured by various sensors and instrumentation may be controlled by using control loops. A typical control loop consists of three basic components. First component is Sensor, it senses or measures process parameters and generates a measurement signal acceptable to the controller. Second component is controller, it compares the measurement signal with the set value and produces a control signal to counteract any difference between the two signals. Third is control element, it receives the control signal produced by the controller and adjusts or alters the process by bringing the measured process property to return to the set point, e.g. liquid flow can be controlled by changing the valve setting or the pump speed (Keshavan *et al.*, 2006).The automation always gives fruitful results in industry. This plays a fundamental part in any business decision about whether to automate the primary part of the process or not, where this process isn't complex or does not require flexibility. A good example of this is the dairy industry where the process of milk skimming, pasteurization, homogenization and even filling into a standard bottle format has long been established. The same can also be largely said for the brewing and bottling industries as a whole. Raw materials and ingredients preparation areas are normally targeted to provide more and more capacity. Usually, as an organization grows and the need for capacity increases, within the preparation areas there is a shift away from batch production processes towards a continuous flow of prepared ingredients. The continuous-flow process will not be a significant leap away in technology from the tried-and tested batch processing methods because it is essential to maintain the same taste and texture as the batch method. Along the way, there may be some labour savings associated with a new continuous flow together with a redesign of the process area, but the majority of the investment is usually aimed at gaining further capacity from a similar proven technology.

At the same time, there may be focus on the secondary packaging end. At this point, the product is already packaged neatly into boxes and can be handled much more easily with automation. Recently, with the introduction of pick and place robots, auto palletizing and dispatching, automation in this area has seen a huge growth within the food sector. This type of automation is common; food is now packaged and has entered a low risk environment – the low risk being far fewer opportunities for contamination by external foreign bodies or organisms. Standard industry robots are used throughout the secondary packaging process as the norm and extend into auto ware housing facilities and automated dock loading. Within the food industry, primary pack – aging processes requiring the manipulation of raw food into its initial carton or wrapper are difficult because many basic products or components of a product – whether it is pasta, sausages, tomatoes, cheese or potatoes – vary in size, shape, quality, weight and texture, making it a formidable challenge for highly automated robots to manipulate them at the required line efficiencies and still maintain quality and integrity of the product. Automation of raw food product also requires high standards of machine sanitation. This requires components that are easily accessible and can be dismantled for cleaning or washing with chemicals. Reassembly must be simple and quick, as the cleaning process may not necessarily be at the end of the shift it could be for a product changeover where the previous product may have contained allergens such as nuts or celery. In fact, most automated systems are capable of performing their functions with greater accuracy and precision, and in less time, than humans (Nayik *et al.,* 2015). Following diagram shows why Automation is required in food industry (Gunasekaran, 2009 and Keshavan *et al.*, 2006).

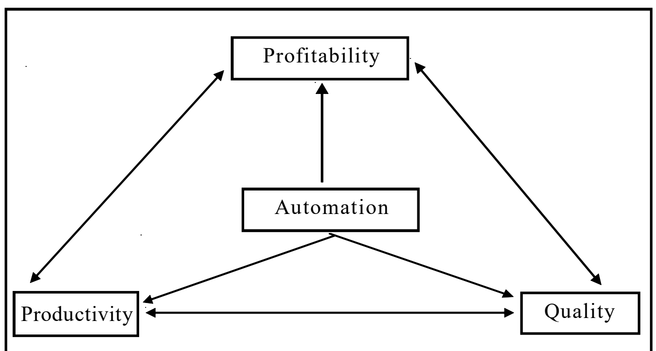

Fig. 1 : Requirement of automation in food industry

Improved productivity :

Plant productivity may be defined as the quality of the end products manufactured per unit of operating parameters – plant size, number of workers, time of operation, etc. Therefore, productivity is directly related to how efficiently the input resources are utilized in translating them into marketable end products. This is possible because automation allow for efficient schedule of work flow and labour use. The ability to maintain good record and information used past process can clearly highlight areas that can be targeted for more efficient allocation of resources.

Improved quality :

Quality assurance is one of the most important goals of any industry. The ability to manufacture high quality products consistently is the basis for success in the highly competitive food industry. High quality products encourage customer loyalty and result in expanding market share. Quality assurance methods used in the food industry have traditionally involved human visual inspection. Such methods are tedious, tolerance tightened; it became necessary for the food industry to employ automatic methods for quality assurance and quality control.

Improved profitability :

Increased profit is perhaps most important from the perspective of management. Improved profitability not only adds to shareholder value but also allows management to invest strategically in expanding plant operations, increasing product lines, further improving product quality and productivity. Both of these contribute directly to improve.

Electronic sensors and biosensors for food industry automation:

Sensors are used for the measurement of key processing parameters, such as temperature, pressure, mass, material level in containers, flow rate, density, viscosity, moisture, fat content, protein content, pH, size, colour, turbidity, etc (*www.cafe project.org.*). Electronic sensors and biosensors offer many advantages in applications in the food industry and help to reduce costs. Sensors developed for industries such as the motor industry are been translated to human heart and motion monitoring. Sensors and biosensors have been widely used in food industry to provide safety and quality control of food products as contamination caused by bacterial pathogens may result in numerous diseases. Electronic sensors and combination of electronic components to sense the material property. There are some electronics methods based on sensor technology to measure food safety e.g. e-nose, e-tounge etc (Handa and Singh, 2016 and Singh and Handa, 2017). Biosensors act as analytical devices employing a biological material as a recognition molecules integrated within a physico-chemical transducer or transducing Microsystems (Singh *et al.* (2015). Detection of microbial pathogens in food is the solution to the prevention and recognition of problems related to health and safety. New biomolecular approaches for foodborne pathogen detection are being developed to improve the biosensor characteristics such as sensitivity and selectivity, also which is rapid, reliable, cost-effective (Arshak *et al.,* 2009). Following is the description of some important electronic sensors and biosensors.

Temperature sensors :

Temperature is an important food processing parameter to monitor and control because correct processing and storage temperature assures the quality of food products. Incorrect temperature, during dairy-product manufacturing for example, will dramatically shorten its shelf-life. In canned food production, a wrong temperature will probably introduce various bacterial contaminations. Accurate temperature control is also crucial in freeze drying, pasteurization and related food processes.

Temperature can be measured by the following three effects:

– Force, which includes bimetallic strips. It may be used for continuously reading gauges or switching devices. It may also appear in filled thermal systems (e.g., thermometers).

– Electricity, for example through semiconductors, resistance temperature detectors (RTD), thermocouples, or silicon resistors. Only RTDs and thermocouples are mainly used in food-processing automation.

– Radiation, which represents the phenomenon used in pyrometers. Radiation temperature measurement devices are mainly used in high-temperature applications (e.g., furnaces) (Selwyn and Wei, 2016).

Gas sensor :

Food containing a toxin, chemical or infectious agent (like a bacterium, virus, parasite) causes symptoms in body which are considered as different types of food poisoning by most healthcare professional. Contaminated food is usually detectable by odor. A small gas sensors and low-cost tailored to the type of food packaging and a communication device for transmitting alarm output to the consumer are key factors in achieving intelligent packaging (Ahn *et al.*, 2008 and Samaneh *et al.,* 2016). The important aspects in intelligent food packaging are affordability and reliability of food in the production consuming process and ensuring the health matters. Using a single or a group of gas sensors enable us to detect several kinds of vapors emitted from the spoiled food. In recent years, efforts have also been devoted to monitoring food quality and in particular, fruit/vegetable ripening/degradation in horticultural industry, for which ethylene is an important. Among the various devices for acetonitrile and ethylene detection, chemoresistive gas sensors based on metal oxides with tailored morphology offer manifold advantages, including robustness, stability, low cost and ease of operation. So far, acetonitrile detection has been performed by SnO_2 powders and nanowires, along with $In2O_3$ and WO_3 thin films, $Cr0.8Fe0.2NbO_4$ and $LaCoO_3$-based films. Ethylene sensing has been reported by the use of SnO_2 and WO_3 films/powders, SnO_2–WO_3 composites, ZnO and WO_3 nanoparticles (Davide *et al.,* 2018).

Ultrasonic sensors :

Ultrasonic sensors investigate the propagation of acoustic waves in a media. Waves are reflected, transmitted and absorbed. The acoustic properties of materials depend generally on the density (amount of material moved by the wave) and the mechanical resistances (resistance to movement). There are several examples of applications of ultrasounds to the characterization of foodstuff (*www.cafe project.org*).

Electric impedance measurement :

The dielectric properties of foods are studied because of their implications with microwave cooking and processing. However, the impedance even at lower frequency can provide interesting information about the content and the structure of the food. Dielectric properties depend on a wide range of physical and chemical properties of the material, including: conductivity, Viscosity, density, composition, temperature.

Amperometric biosensors :

These biosensors are able to detect only the electrochemically active analyte, an analyte capable of being oxidized or reduced on the electrode. Generally, these are prepared with thin-film technology and consist of gold (Au), platinum (Pt) or carbon. Inks in form of thin films in a particular pattern and thickness were deposited on the electrode substrate (glass, plastic or ceramic) for screen printing. Different inks can be used for getting different dimensions and shape of biosensors. These days screen-printed electrochemical cells are widely used for developing amperometric biosensors because these are cheap and therefore, can be produced at large scale. This could be potentially used as disposable sensor that decreases the chances of contamination and prevents the electrode from fouling which results in loss of sensitivity as well as reproducibility of the biosensor. Amperometric biosensors generally rely on an enzyme system that catalytically converts electrochemically nonactive analytes into electrochemically active products (Arora *et al*., 2011).

Optical biosensors :

Optical based sensing systems that measure luminescence, fluorescence, reflectance and absorbance, etc., are some of the areas of applications of optical immune sensors. There is a very good potential for application of biosensors for monitoring food quality and safety in food and bioprocessing industries in India (Thakur and Ragavan, 2013). Optical biosensors are a powerful detection and analysis tool that has vast applications in biomedical research, healthcare, pharmaceuticals, environmental monitoring, homeland security and the battlefield (Narayanaswamy and Wolfbeis, 2004) recent progress in optical biosensors that use the label-free detection protocol, in which biomolecules are unlabeled or unmodified, and are detected in their natural forms. Optical biosensors utilize the refractive index change as the sensing transduction signal (Fan *et al.,* 2008).

Piezo-electric biosensors :

Piezo-electric crystals vibrate under the influence of an alternating electrical field. The frequency of this oscillation (f) depends on their thickness. Each crystal is having a characteristic resonant frequency. This resonant frequency changes as molecules adsorb or desorbs from the surface of the crystal, obeying the relationships. Where, Δf is the change in resonant frequency (Hz), Δm is the change in mass of adsorbed material (g), K is a constant for the particular crystal dependent on such factors as its density and cut, and A is the adsorbing surface 2 area (cm). A simple use is as formaldehyde biosensor, utilising a formaldehyde dehydrogenase coating immobilised to a quartz crystal and sensitive to gaseous formaldehyde. The major drawback of these devices is the interference from atmospheric humidity and the difficulty in using them for the determination of material in solution. However, they are inexpensive, small, robust and capable of giving a rapid response (Prasad *et al.*, 2009).

Some challenges :

Following are the challenges faced by food industry for the automation process.

– Some times disassembly and reassembly of machinery components is required and it can prove difficult in a high staff turnover environment, where training and retraining in the process are likely to be an ongoing problem.

– Machinery must also be manufactured from quality grade stainless steel and designed to avoid microbiological traps or water stagnation.

– The selection of food-grade oils and greases for gearboxes and lubrication systems must be considered. These all impact on the ability to automate successfully.

– Another major influencer in the decision to automate or not is the food retailers' demand for choice of product on their shelves. Consumers like to have choice, and choice is a constantly varying phenomenon that contrasts sharply with how lines may automate.

– Automation usually means the standardization of product, packaging and appearance. many line automation projects fall foul of a packaging reformat or ingredients change.

– There has been an emergence of a wide range of standalone robots, with fully hygienic pick and place capabilities that in theory appear to be able to handle a wide array of raw ingredients.

Advantages of automation:

In terms of actual control devices and sensors, the emphasis has been on reducing energy consumption and increasing versatility that will enable cost effective operation of the manufacturing process. Reducing the air consumption of pneumatically operated valves for example, minimising heating times for sterilisation processes and optimising product interchangeability all have long term benefits for the end user.

Better quality control :

Along the food and beverage supply chain, there are so many involved processes, workers and touch points that it can be difficult to not only keep track of food, but also to monitor its quality. Quality is of incredible importance in the industry. With the appropriate automation systems, defects and issues can be noticed much earlier in the supply chain. By detecting problems during packaging or processing, you can cut down on the total number of problematic goods that enter the market If something along your supply chain is the culprit, automation will help you hone in.

End-to-end traceability:

Automation and modern analytics tools can be deployed to track products and goods from inception to fulfillment. Because the systems in question are designed to track and monitor on their own with little to no input, you can tap in anywhere along the chain to seek the information you need. End-to-end traceability and all the data that comes with it is about more than just watching where food comes from, where it is handled and where it goes. Data can be used to build an accurate profile and predictive system for future gains.

Improved worker safety:

Automation systems, AI and modern robotics are often used to control rote, repetitive and sometimes even dangerous tasks. In this way, human labourers can be saved from the dangers of a particular activity or even the monotony of busy work. It frees them upto handle more important demands, which is another benefit. Of course, increased safety and protection for your loyal workforce can also work to alleviate operation or maintenance costs in the long run.

Efficiency boost :

A machine never tires, never gets bored and can never slack off—unless it has a malfunction. That's not to say modern technologies will be used to replace workers outright, but instead, they might be deployed alongside them to help them work faster, better and safer. Improved control and monitoring reduces wastage of expensive compounds, provides improved production reliability and also delivers the continuous data required to meet regulatory standards. By making significant reductions in energy and raw materials costs, a carefully designed production control system can deliver high quality products using the most efficient process.

Conclusion and future scope :

An early warning system for timely recognition of emerging infections is required to prevent the epidemics. The on time initiated research, awareness and preventive measures can hinder their effect before they become prevalent public health troubles. It's no secret that when deployed and developed properly, a machine or automation system can perform work faster and better than human labourers, at least in some cases. Broadly-selective sensors for physical and chemical quantities can provide useful information to monitor the evolution of processes in food industry. Electric and acoustic impedance can be used to estimate composition, density and texture properties. The headspace composition can reveal changes in activity in the liquid material and to signal the presence of compounds affecting the quality. Research evidence suggests that huge opportunities exist within the food industry for automation to take place, especially within the primary packaging processes. As technology improves and the ability to manipulate complex and varying shapes becomes easier, further opportunities for higher levels of automation to take place will be presented. Further consideration for the harsher environment in which the food industries have to operate should also be a factor in equipment design, as these can often be in chilled, damp conditions created from constant wash downs and changeovers. Improving the levels of automation within a process of any scale can deliver improvements to maintenance costs, production costs, reliability and, most importantly, quality.

Authors' affiliations:
Priyanka Handa, Department of Electronics and Communication, Ch. Devi Lal State Institute of Engineering and Technology, Panniwala Mota, **Sirsa (Haryana) India**

■ REFERENCES

Ahn, M.W., Park, K.S., Heo, J.H., Park, J.G., Kim, D.W., Choi, K., Lee, J.H. and Hong, S.H. (2008). Gas sensing properties of defect-controlled zno-nanowire gas sensor. *Appl. Phys. Lett.*, **93** (26) : 263103.

Arora, P., Sindhu, A., Dilbaghi, N. and Chaudhury, A. (2011). Biosensors as innovative tools for the detection of food borne pathogens. *Biosens. Bioelectron*, **28** : 1–12.

Arshak, K., Velusamy, V., Korostynska, O., Oliwa-Stasiak, K. and Adley, C. (2009). Conducting polymers and their applications to biosensors: Emphasizing on foodborne pathogen detection. *Sensors J. IEEE,* **9** : 1942–1951.

Catherine C. Adley (2014). Past, present and future of sensors in food production, *J. Foods,* **3**:491-510; doi:10.3390/foods 3030491.

Davide, Barreca, Alberto, Gasparotto, Filippo, Gri, Elisabetta, Comini and Chiara, Maccato (2018). Plasma-assisted growth of β-MnO_2 Nanosystems as Gas" Adv. Mater. Interfaces Sensors for Safety and Food Industry Applications.

Fan, X., White, I.M., Shopova, S.I., Zhu, H., Suter, J.D. and Sun, Y. (2008). Sensitive optical biosensors for unlabeled targets: A review. *Anal. Chim. Acta,* **620** : 8–26.

Gunasekaran, S. (2009). Automation of food processing, *Food Engg.,* Vol. IV.

Handa, Priyanka and Singh, Bhupinder (2016). Electronic nose and their application in food industries. *Food Sci. Res. J.,* **7** (2) : 314-318, DOI : 10.15740/HAS/FSRJ/7.2/314-318.

Jijo, K. J. and Ramesh Kumar, K. R. (2014). Process automation for a food processing plant, *IJSETR,* **3**(6) : 1744-1750.

Keshavan, Niranjan, Araya Ahromrit and Khare, Ahoks (2006). *Process control in food processing,* Wiley-vch verlag Gmbh and Co. Kgaa, Weinheim.

Mahdavian, L., Monajjemi, M. and Mangkorntong, N. (2009). Sensor response to alcohol and chemical mechanism of carbon nanotube gas sensors, *Fullerenes, Nanotubes & Carbon Nanostructures,* **17**: 484–495.

Narayanaswamy, R. and Wolfbeis, O.S. (2004). *Optical sensors*, Springer, New York, U.S.A.

Nayik, G.A., Muzaffar, K. and Gull, A. (2015). Robotics and food technology: A mini review. *J. Nutr. & Food Sci.*, **5** (4) 384, doi:10.4172/2155-9600.1000384.

Prasad, K., Ranjan, R.K., Lutfi, Zubala and Pandey, H. (2009). Biosensors: applications and overview in industrial automation. *Internat. J. Appl. Bioengineering,* **3** (1) : 66-70.

Samaneh, Matindoust, Majid, Baghaei-Nejad, Mohammad Hadi, Shahrokh, Abadi, Zhuo, Zou and Li-Rong, Zheng (2016). Food quality and safety monitoring using gas sensor array in intelligent packaging, *Sensor Review,* **36** (2) : 169-183.

Selwyn, Piramuthu and Wei, Zhou (2016). *RFID and sensor network automation in the food industry*. by John Wiley & Sons Ltd.

Singh, Bhupinder, Handa, Priyanka and Kamboj, Promila (2015). Role of biosensors and image processing for improving quality inspection of food products: A review, *Current Trends in Signal Processing,* **5** (1) : 21-25.

Singh, Bhupinder and Handa, Priyanka (2017). Electronic tongue and their applications in food industry. *Engg. &Tech. in India,* **8** (1&2) : 98-102; DOI : 10.15740/HAS/ETI/8.1&2/ 98-102.

Thakur, M.S. and Ragavan, K.V. (2013). Biosensors in food processing. *J. Food Sci. Technol.*, **50** : 625–641.

WEBLIOGRAPHY :

Corrado di natale, ed jones, gustavo alcuri, " New sensors for food industry", *www.cafe project.org.*