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# Biosensors: Monitor the Quality and Safety of Meat and Meat Products

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The meat industry has a greater responsibility to meet consumer's expectations and demands due to the industry's expansion, the state of global trade, stringent laws, and consumer awareness. The meat sector requires a tool to improve product quality and safety for consumers, as it poses health hazards such as pathogens, drug residues, pesticide residues, toxins and heavy metals. Biosensor is the latest detection technology in meat industry. Because of their high sensitivity, specificity, repeatability, and stability, biosensors and chemical indicators are becoming more and more popular as promising tools for monitoring and regulating the safety (metabolites, contaminants, pathogens, drug residues, etc.) and quality (freshness and sensory characteristics like tenderness) of muscle foods.

**Key words:** Biosenser, Meat Freshness, Tenderness, hazard, Antibiotics, Pathogen, Pesticide

## Introduction

India produces a 9.77 million Tonnes meat and the per capita availability of meat reached at 7.10 Kg/Annum during tear 2023. The annual growth rate of meat for the year 2022-23 is 5.13% (BAHS, 2023). One of the basics of the diet is meat, which has substantial amounts of highly calorie-dense fat, readily digested protein, vitamins, and other minerals. These components are required for metabolic processes to work properly (Wojnowski *et al*., 2017). During the preparation and storage phases, meat and meat products are very perishable and can undergo various forms of degradation due to enzymatic, microbiological, chemical, or environmental factors (Nanda *et al*., 2022). However, animal origin food products are most susceptible to microbial contamination, and lipid oxidation due to the high fat and water contents. Color, texture, and Odor are the main elements that cause meat products to lose their freshness and quality. Microbial intervention is the primary cause of off-flavor development, which significantly impacts on shelf life (Ahmed *et al*., 2018). Maintaining meat quality and safety at all levels, from farm to fork is crucial for consumer protection and reducing the danger of zoonotic outbreaks and food poisoning (Nanda *et al*., 2022).

In the meat processing industry, producing high-quality meat and supplying safer products are crucial (Biswas *et al*., 2021). The demand for minimally processed, ready-to-eat, and readily prepared meals, combined with the concept of clean labels, is rapidly increasing. As a result, the emerging concepts of Smart packaging are employed as novel analytical tools by providing plentiful innovative solutions for prolonging the shelf-life, or maintaining, improving, or monitoring the food quality and safety (Arvanitoyannis and Stratakos, 2012; Corradini, 2018). Intelligent packaging is a feature that is built-in to a product, package, or package/product design. It offers intelligence appropriate for identifying and tracking the state of packed food as it is distributed in reaction to internal and external environments. This helps to provide information about the items' safety and quality status to the makers, sellers, and end users (Ahmed *et al*., 2018). It include Several type of sensors such as Electronic nose, Biosensors, Colorimetric sensors, Gas sensors, Carbon dioxide sensors, Oxygen sensors etc. which are employed in the meat industry in order to improve the quality and safety of the meat by monitoring the quality indices of the products during storage and supply chain(Ahmed *et al*., 2018; Fuertes *et al*., 2016).

Biosensors, also known as indicator sensors, have been employed as monitoring tools in recent years to track different hazards, whether they are present in raw meat or arise during various stages of product processing that affect the product's quality (Erna *et al*., 2021). Over time, advancements in research and development have promoted the use of food biosensors in industry or commercial. Several effective uses of biosensors include freshness indicators, time-temperature integrators, microbial spoilage biosensors, nano sensors, barcodes, RFID (Radio Frequency Identification) tags, etc. (Park *et al*., 2015). Biosensors are analytical tools that use biological materials. They are closely related to or integrated into physiochemical transducers, which can be optical, electrochemical, thermometric, piezoelectric, or magnetic transducing microsystems (Nanda *et al*., 2022). Because of their operational stability, specificity, sensitivity, linear response range, reproducibility, quick response and recovery times, and other attributes, these are recognized as useful instruments for evaluating the quality of meat and meat products (Lim and Ahmed, 2016). Currently, advanced biosensors that utilize expanded nanotechnology applications are being created to revolutionize the current procedures for quality and safety monitoring (Sionek *et al*., 2020).

## Principle

A biological receptor is connected to a transducer and signal processing unit in a biosensor, which functions primarily on the basis of signal transduction. These components work together to convert the biological response into a corresponding electrical response, which is then converted into a quantitative output. simply, a biosensor converts a molecule's biological function into a signal that can be measured in order to analyse the molecule quantitatively (Soleymani and Li, 2017).

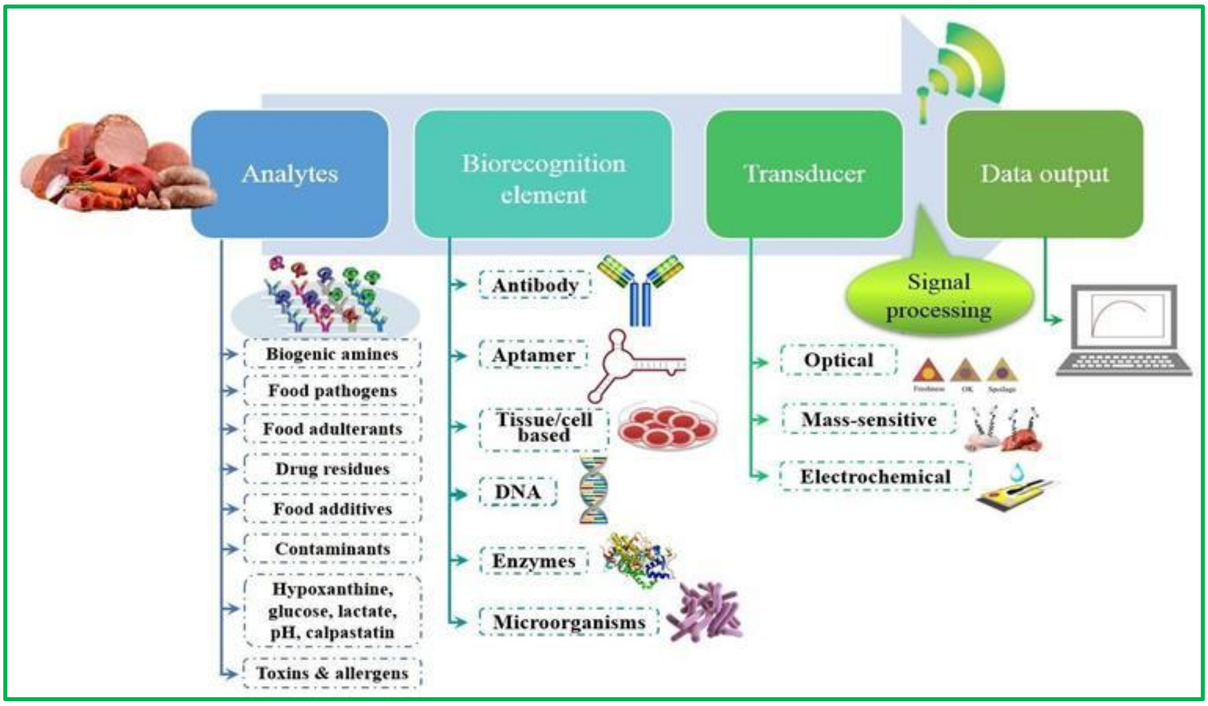


Figure 1. Diagram of the working principle of biosensors for the detection of different analytes from meat and meat products. Source : (Nanda *et al*., 2022).

## Types of Biosensor

(1) **Optical biosensor:** Optical biosensor technologies, characterized by great sensitivity, simple handling, and rapid detection, have been widely utilized to identify very large

numbers of bacteria (Qiao *et al*., 2020). Visualizing microbial activity in food with the naked eye is made possible by optical biosensors. Optical biosensors can detect microorganisms in food by measuring the thickness that forms when bacterial cells adhere to receptors on the transducer surface or by using in situ detection in the refractive index (Ali *et al.*, 2020). When the natural product deteriorates, microorganisms release analytical enzymes that break down the biodegradable polymer found in the optical biological sensor. As the number of bacteria increases, there is increasing production of enzymes that cause food degradation, which will be seen in the degradation of the polymer (Pellissery *et al*., 2020).

(2) **Electrochemical biosensor:** One of the most widely used systems for foodborne pathogen detection is electrochemical biosensing (Ali *et al*., 2020). Electrochemical biosensors have been found to be effective strategies for bacterial detection due to their low cost, accuracy, miniaturization capacity, and ability to detect changes directly based on the sensor-sample interface. However, the time necessary to detect food contamination using electrochemical biosensors has greatly lowered with the development of new technologies, some of which take as little as 10 minutes (Mishra *et al*., 2018).

(3) **Mechanical biosensor:** Mechanical biosensors can measure a mass-sensitive sensor surface deflection because the target analytes will be bound to the functionalized surface. Quartz crystal microbalance (QCM) is a mechanical biosensor that is widely used due to its capacity to track shifts in mass in sub-nanogram amounts. The change in mass using QCM biosensors is recognized by the resonant frequency of quartz crystal, and this technique is commonly used with extreme sensitivity for quantification of the whole cell of microorganisms (Yu *et al*., 2018).

## Application of biosensor in meat and meat products

(1) **Freshness of Meat:** Freshness is a crucial quality factor that has significant effects on customers' purchasing decisions. Freshness in meat and meat products refers to the product's quality and safety, which is important from the point of view of both producers and customers (Weng *et al*., 2020). The microbiological deterioration of food products produces chemical metabolites such as biogenic amines, ammonia gas, trimethylamine (TMA), xanthine, and total volatile basic nitrogen (TVB-N), which are employed as indicators of meat freshness (Galgano *et al*., 2009). The indicator undergoes an irreversible reaction with oxidative chemical compounds and microbial metabolites, hence influencing the product's visual freshness and quality indicator. Meat deterioration and aging are closely related to meat freshness as a product quality indicator. As a result, it's important to assess meat deterioration as well as aging over extended storage. Hypoxanthine (Hx), a result of ATP breakdown, is the most essential indicator of meat freshness (Sionek *et al*., 2020).

For meat freshness analysis, various biosensors are used. The Hx sensor (TiO2-G) was used to estimate Hx levels in pork held at room temperature for 7 days. Chemiluminescence biosensors based on enzyme oxidase (putrescine and diamine) were used to detect biogenic amine levels in meat products and compare them to HPLC (high-performance liquid chromatography) samples. Similarly, TVB-N analyte used for pork, putresin used for beef, pork, chicken and turkey, calpastatin used for *Longissimus* muscle of beef and Xanthin used for chicken (Nanda *et al*., 2022).

(2) **Tenderness of Meat:** One of the primary quality characteristics and a crucial feature for consumer satisfaction and meat repurchasing is tenderness. A group of enzymes known as cathepsins and calpain affects both the tenderness of meat and the metabolism of proteins. Calpain proteases are responsible for the changes in muscle/meat that occur during ageing or post-slaughter tenderization. Among many other endogenous proteolytic systems, cathepsins, caspases, and proteasomes can break down many myofibrillar proteins, which determines the eventual level of meat tenderness(Ouali e*t al*., 2013).

Biosensors use biological ligands as a bio transducer to turn biochemical information into an analytical signal, making them a valuable measurement tool. immunological biosensor for the detection of calpastatin activity in beef meat uses a SRP system (Biacore Q) (Geesink *et al*., 2005). Measured calpastatin in preserved beef using the fluorescence resonance energy transfer (FRET) method in an optical biosensor device (Bratcher *et al*., 2008). the Tendercheck system, a portable electrochemical immunosensing device with many channels that uses amperometric detection and antibody-antigen biorecognition. Calpastatin was precisely quantified by the apparatus (Zór *et al*., 2011).

(3) **Detection of Pathogen in Meat:** Food contamination is a global public health concern as it can lead to food poisoning and disease outbreaks. In order to ensure microbiological safety, a constant system of environmental surveillance for microbes is required for the early identification of harmful microorganism in the food chain (Pradhan *et al*., 2018). Recently, highly sensitive and specific analytical instruments such as biosensors are now readily available. These instruments can detect toxins, microbiological safe limits, or their metabolites in various items. These days, there are several accessible biosensors based on optical, electrochemical, photoelectrochemical, and bioluminescence (Ali *et al.*, 2020).

An aptamer-based fiber-optic biosensor was used to distinguish pathogenic L. monocytogenes from other non-pathogenic or pathogenic species in contaminated Ready to eat meat items (Gagaoua *et al.*, 2021). Multichannel surface plasmon resonance biosensor designed to specifically detect three distinct foodborne pathogens in naturally contaminated food: E. Coli O157:H7, S. Enteritidis, and L. monocytogenes (Terlouw *et al*., 2021).

(4) **Detection of Heavy metals, antibiotic and Pesticide residue in Meat:** Toxins, pesticides, antibiotics, veterinary drug residues, and hazardous food additives can infiltrate the food chain and contaminate the entire batch during any processing step (Nanda *et al.*, 2022). Heavy metals pose a significant risk to human health as they are not biodegradable and remain in the natural system. Antibiotics used to treat food-producing animals can be harmful to human health as they can be conveyed through meat, milk, eggs, and fish products (Dhara *et al.*, 2023).

Various biosensors are used for the detection of various antibiotics and drug residues, adulterants, allergens, and additives in meat and meat products. Optical biosensor used for detecting Streptomycin and dihydrostreptomycin in pig muscles and also sulphonamide group in chicken serum and porcine muscle. Bioluminescent biosensor used for detecting tetracycline in poultry muscle (Dhara *et al*., 2023). Electrochemical biosensors are useful for determining the presence of bacterial or fungal toxins in meat or meat products. An electrochemical biosensor was used to detect trichothecene (T-2 toxin) in swine meat and staphylococcal enterotoxin B in milk and pork. The SPR biosensor analyzed Staphylococcal enterotoxin B in potted beef in real-time (Nanda *et al*., 2022). A biosensor utilizing carbon nanotubes and a polypyrrole (ppy-) composite modified electrode is utilized to detect food colorants, specifically Amaranth (E123) and Ponceau 4R (E124), in processed food items (Abdalhai *et al*., 2015). Electrochemical biosensor are used to detect $Hg^{2+}$, $Cd^{2+}$, $Pb^{2+}$ and CrVi. Amperometric biosensor used for Benzamidazole, organochlorine, organothiophosphate, organocarbamate, polyphenol and pyrethroid detection (Dhara *et al*., 2023).

## Conclusion

Biosensors can accurately detect and quantify pathogenic microorganisms that cause foodborne illnesses, as well as inorganic contaminants that pose a health risk to consumers, making it easier to meet domestic and international quality standards for meat and meat products. Bio-sensing technology is increasingly used in the meat industry to monitor meat quality and safety in real-time throughout the supply chain, including transportation and storage. These technologies can be useful in determining the freshness and purity of raw meat, as well as its tenderness and degree of glycolysis. They can also be used to detect pathogens, adulterants, antibiotics, allergies, drug residues, additives, and other impurities.

## References

1. Abdalhai, M. H., Fernandes, A. M., Xia, X., Musa, A., Ji, J., & Sun, X. (2015). Electrochemical genosensor to detect pathogenic bacteria (Escherichia coli O157: H7) as applied in real food samples (fresh beef) to improve food safety and quality control. *Journal of agricultural and food chemistry*, *63*(20), 5017-5025.
2. Ahmed, I., Lin, H., Zou, L., Li, Z., Brody, A. L., Qazi, I. M., & Sun, L. (2018). An overview of smart packaging technologies for monitoring safety and quality of meat and meat products. *Packaging Technology and Science*, *31*(7), 449-471.
3. Ali, A. A., Altemimi, A. B., Alhelfi, N., & Ibrahim, S. A. (2020). Application of biosensors for detection of pathogenic food bacteria: a review. *Biosensors*, *10*(6), 58.
4. Arvanitoyannis, I. S., & Stratakos, A. C. (2012). Application of modified atmosphere packaging and active/smart technologies to red meat and poultry: a review. *Food and Bioprocess Technology*, *5*, 1423-1446.
5. BAHS, (2023). Basics of Animal Husbandry Statistics
6. Biswas, O., Kandasamy, P., Patnaik, S., Lorenzo, J. M., & Das, A. K. (2021). Effect of phytochemicals on quality and safety aspects of meat and meat products. *Indian J. Anim. Health*, *60*, 97-108.
7. Bratcher, C. L., Grant, S. A., Vassalli, J. T., & Lorenzen, C. L. (2008). Enhanced efficiency of a capillary-based biosensor over an optical fiber biosensor for detecting calpastatin. *Biosensors and Bioelectronics*, *23*(11), 1674-1679.
8. Corradini, M. G. (2018). Shelf life of food products: from open labeling to real-time measurements. *Annual review of food science and technology*, *9*(1), 251-269.
9. Dhara, D., Biswas, S., Patra, G., Biswas, O., & Sharma, G. (2023). Biosensor for maintaining the quality of meat and meat products: a review. *Journal of Food Safety and Hygiene*, *9*(1), 1-15.
10. Erna, K. H., Rovina, K., & Mantihal, S. (2021). Current detection techniques for monitoring the freshness of meat-based products: A review. *Journal of Packaging Technology and Research*, *5*(3), 127-141.
11. Fuertes, G., Soto, I., Carrasco, R., Vargas, M., Sabattin, J., & Lagos, C. (2016). Intelligent packaging systems: sensors and nanosensors to monitor food quality and safety. *Journal of Sensors*, *2016*(1), 4046061.
12. Gagaoua, M., Troy, D., & Mullen, A. M. (2020). The extent and rate of the appearance of the major 110 and 30 kDa proteolytic fragments during post-mortem aging of beef depend on the glycolysing rate of the muscle and aging time: An LC–MS/MS approach to decipher their proteome and associated pathways. *Journal of Agricultural and Food Chemistry*, *69*(1), 602-614.
13. Galgano, F., Favati, F., Bonadio, M., Lorusso, V., & Romano, P. (2009). Role of biogenic amines as index of freshness in beef meat packed with different biopolymeric materials. *Food Research International*, *42*(8), 1147-1152.
14. Geesink, G. H., Van Der Palen, J. G. P., Kent, M. P., Veiseth, E., Hemke, G., & Koohmaraie, M. (2005). Quantification of calpastatin using an optical surface plasmon resonance biosensor. *Meat science*, *71*(3), 537-541.
15. Lim, S. A., & Ahmed, M. U. (2016). Introduction to food biosensors.
16. Nanda, P. K., Bhattacharya, D., Das, J. K., Bandyopadhyay, S., Ekhlas, D., Lorenzo, J. M., ... & Gagaoua, M. (2022). Emerging role of biosensors and chemical indicators to monitor the quality and safety of meat and meat products. *Chemosensors*, *10*(8), 322.
17. Ouali, A., Gagaoua, M., Boudida, Y., Becila, S., Boudjellal, A., Herrera-Mendez, C. H., & Sentandreu, M. A. (2013). Biomarkers of meat tenderness: present knowledge and

perspectives in regards to our current understanding of the mechanisms involved. *Meat science*, *95*(4), 854-870.
18. Park, Y. W., Kim, S. M., Lee, J. Y., & Jang, W. (2015). Application of biosensors in smart packaging. *Molecular & Cellular Toxicology*, *11*, 277-285.
19. Pellissery, A. J., Vinayamohan, P. G., Amalaradjou, M. A. R., & Venkitanarayanan, K. (2020). Spoilage bacteria and meat quality. In *Meat quality analysis* (pp. 307-334). Academic Press.
20. Pradhan, S. R., Patra, G., Nanda, P. K., Dandapat, P., Bandyopadhyay, S., & Das, A. K. (2018). Comparative microbial load assessment of meat, contact surfaces and water samples in retail chevon meat shops and abattoirs of Kolkata, WB, India. *Int. J. Curr. Microbiol. App. Sci*, *7*(5), 158-164.
21. Qiao, Z., Fu, Y., Lei, C., & Li, Y. (2020). Advances in antimicrobial peptides-based biosensing methods for detection of foodborne pathogens: A review. *Food Control*, *112*, 107116.
22. Sionek, B., Przybylski, W., & Tambor, K. (2020). Biosensors in evaluation of quality of meat and meat products–A review. *Annals of Animal Science*, *20*(4), 1151-1168.
23. Soleymani, L., & Li, F. (2017). Mechanistic challenges and advantages of biosensor miniaturization into the nanoscale. *ACS sensors*, *2*(4), 458-467.
24. Terlouw, E. C., Picard, B., Deiss, V., Berri, C., Hocquette, J. F., Lebret, B., ... & Gagaoua, M. (2021). Understanding the determination of meat quality using biochemical characteristics of the muscle: stress at slaughter and other missing keys. *Foods*, *10*(1), 84.
25. Weng, X., Luan, X., Kong, C., Chang, Z., Li, Y., Zhang, S., ... & Xiao, Y. (2020). A comprehensive method for assessing meat freshness using fusing electronic nose, computer vision, and artificial tactile technologies. *Journal of Sensors*, *2020*(1), 8838535.
26. Wojnowski, W., Majchrzak, T., Dymerski, T., Gębicki, J., & Namieśnik, J. (2017). Electronic noses: Powerful tools in meat quality assessment. *Meat science*, *131*, 119-131.
27. Yu, X., Chen, F., Wang, R., & Li, Y. (2018). Whole-bacterium SELEX of DNA aptamers for rapid detection of E. coli O157: H7 using a QCM sensor. *Journal of biotechnology*, *266*, 39-49.
28. Zór, K., Castellarnau, M., Pascual, D., Pich, S., Plasencia, C., Bardsley, R., & Nistor, M. (2011). Design, development and application of a bioelectrochemical detection system for meat tenderness prediction. *Biosensors and Bioelectronics*, *26*(11), 4283-4288.