Artificial Intelligence – An AID for Subjective Evaluation of Food and Food Products

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Abstract: In the past few decades, manufacturing has gotten more efficient and modern industry has reached productivity peaks because to the revolution of artificial intelligence (AI) and automation. The food industry is ready to take advantage of new opportunities and advancements. More food companies will be utilizing big data and artificial intelligence to enhance product quality, meet consumer needs, and guide the food service sector toward a more intelligent and sustainable future. From farm to fork, where research begins with horticulture and ends with food product processing, artificial intelligence is applied in the food business. Food companies may increase mass demand, reduce waste, improve food safety and quality, and retain consumers by putting this cutting-edge technology into practice. Along with theses the most important area in food processing is sensory evaluation which is having a key role in product formulation and marketing. Sensory scientists are discovering links between individuals' self-reported hedonic reactions to various food and beverage products and their subconscious biometric responses. The primary objective of the article is to elevate the level of applicability and approachability of sensory developments in the food processing units.

Keywords: *Artificial Intelligence; Food Industry; Product Formulation; Processing; Sensory Evaluation.*

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I. INTRODUCTION

The manufacturing sector was the first and many other industries were changed later by technological breakthroughs. Early in the 20th century, there was always hope that machines will one day replace human labor in every field by performing jobs with better precision. Artificial Intelligence or AI as it is recognized scientifically has been exceptional persons in a number of areas in recent years, together with object identification and computer vision. This scenario appears to take a significant step forward as learning algorithms and computer capacity continue to progress. Mechanization has its roots in the industrial revolution of the early 1800s, which paved the way for later inventions of contemporary technology (Xu et al, 2021). Automation is now present in every potential business and the market is trading above expectations. The majority of the 18th century's equipment was designed to knob straightforward processes like spinning, wielding and repetitive labor so that human labor could focus on more difficult tasks. In addition, the outline of Industry 4.0 into the food sector has tinted technologies like robotic farming, smart agriculture, drones, 3D printing, and digital twins. However, the food sector still challenges issues with smart operation and sustainable development in the future. These technological progresses were necessary to confirm food quality in light of the escalating demand for food. In the early phases of the food industry, improving crop quality and output required changes to farming techniques and equipment (Elahi et al, 2023). Besides, the expansion of a more systematic supply chain administration system has enabled the entire food industry chain from the manufacturing of raw materials to the end users-to realize well-organized connectivity and collaboration, laying a dense foundation for the sector's expansion and prosperity. Sensory science is another key area; AI has incorporated innovative techniques from other scientific disciplines during the past years. The decidedly variable humanoid responses depend on numerous biological and emotional factors. The applications of AI in sensory combination of system with further devices such as electronic nose, electronic tongue, and computer vision system and near infrared spectroscopy (NIR) which will benefit both the industry and consumers (Ding et al, 2023). These present innovative methods are used for the sensory evaluation of different foods and beverages.

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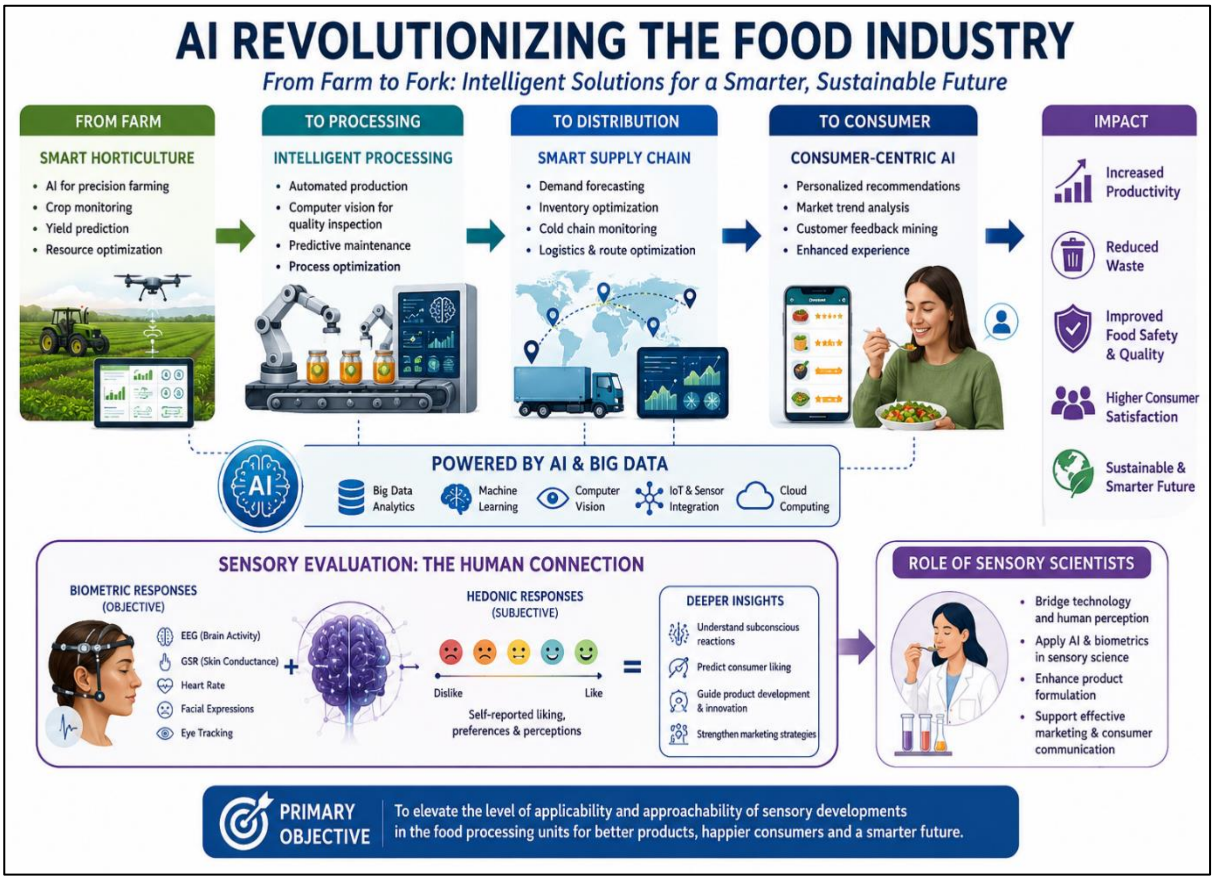

Fig 1 Functions of AI @ Food Industry

II. ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is a selection of technologies that mimic human intellect. By pretending social assumed methods and behaviors, computers can learn, reason, plan, and make decisions on their own. Machine learning (ML), deep learning, computer vision, natural language processing, and other technologies that are appropriate to a wide range of fields and segments form the foundation of artificial intelligence. The term artificial intelligence (AI) describes computer programs that are able to carry out sophisticated operations that were previously limited to human performance, such as problem-solving, thinking, and decision-making. Natural language processing (NLP), machine learning, deep learning, and other technologies are all included under the broad term artificial intelligence (Kakani et al, 2020). Although the term "artificial intelligence" is often used to refer to a wide range of technologies, the technologies employed today actually fall within this category. On the other hand, other people think that a significant amount of contemporary technology consists only of extremely advanced machine learning, which is only a prelude to actual artificial intelligence, or "GAI" general artificial intelligence (Kumar et al, 2021).

➢ *Functions of Artificial Intelligence in Food Segment*

In order to progress the efficiency of food production and processing, a great deal of attention was placed throughout the early stages of the food industry's development on the creation of more advanced machinery, equipment, and creative processing methods. The goal of this project was to increase food production and processing operations' productivity. These technological developments were required to maintain food quality standards due to the growing demand for food. At the beginning of the food business, crop quality and output were greatly enhanced by the adoption of changes in agricultural machinery and techniques (Ben and Hanana, 2021). In addition, as processing technology and equipment advanced, the early food industry concentrated on creating effective links throughout the whole food supply chain. Ineffective supply chain management, excess inventory, and considerable food waste resulted from a lack of cooperation and information exchange between raw material producers, processors, and merchants. In an attempt to resolve current disparities, the food industry has started the transition to an improved supply chain management framework. Information technology integration has greatly aided this advancement by enhancing data sharing and exchange across multiple levels (Goyache et al, 2001). Additionally, there has been a marked improvement in cooperation and trust among the disparate components of the food supply chain, achieved through measures such as standardization and quality certification. These initiatives are instrumental in ensuring the traceability of the food source and its quality. In response to the escalating demand for food products, the industry has also engineered more efficacious machinery, equipment, and innovative processing technologies. This advancement has markedly enhanced the productivity and efficiency of food production and processing processes from their initial stages.

➢ *Current State of AI in Food Industry*

A wide range of businesses, including agriculture, fisheries, and livestock, as well as other fields like food service, processing, and retail, are included in the field of food manufacturing. Every phase of the food value chain, from food production to final consumption, is involved in this vast international economy (Kler et al, 2022). Food provides consumers with an increasingly diverse selection of choices, ensuring their demand for safe and secure food is met. Among the array of technologies (Fig.2) being utilized in this sector are big data, blockchain, 3D printing, artificial intelligence, and 3D printing. The adoption of these innovative technologies enables food producers to stimulate widespread demand, reduce waste, progress food safety and excellence, and maintain customer satisfaction (Kumar et al, 2021).

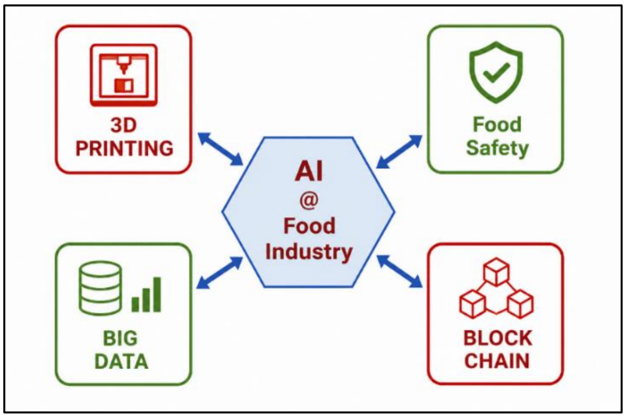

Fig 2 Major Role of AI in Food Industry

- Big data analytics discusses to the systematic processing and study of large volumes of data and complex data sets, recognized as big data, to extract valuable insights.
- 3D printing is a process of manufacture three-dimensional objects from a digital file. In an additive process a thing is shaped by laying down successive layers of material until the object is created. Each of these layers can be seen as a thinly sliced cross-section of the object.
- Block chain is a common, unchallengeable ledger that facilitates the process of recording transactions and tracking assets in a commercial network. Almost anything of value can be tracked and traded on a block chain network, reducing risk and cutting costs for all involved.
- Food safety, by applying a learning algorithm to scrutinize various variables present in the production process, including temperature, humidity, and chemical composition, it is possible to effectively manage and mitigate food safety concerns.

➢ *Role of Sensory Evaluation in Food Sector*

Sensory Evaluation of foods is one foremost activity exhausted nearly all the food manufacturing industries within the world. They perform sensory investigation, in order to decide the product's appropriateness for utilization, which is done by either a trained or untrained panellist. The choice is made from their final result, either verbally or composed. There's a high plausibility of getting the result mis-interpreted. During the taste discernment, the brain transmits brain waves indicated to each taste concentrated (Sirangelo, 2019). By separating those delicate waves, it is plausible to compare the results about of the specialists, the genuine feeling of the test subject. This strategy, a numerical esteem for the like or dislike can be obtained.

The field of sensory evaluation is developing and integrates methods from other scientific fields. Descriptive analysis, which offers a comprehensive qualitative and quantitative picture of the sensory characteristics of products and their sensory intensities, discrimination tests, which deal with determining whether products are different or similar in terms of general or specific attributes, and consumer tests, which concentrate on understanding the hedonic and emotional responses of consumers toward products, are the three main applications of traditional sensory evaluation (Meiselman, 2013). The methods applied in these categories are regarded as conventional sensory methods/protocols, which are used for assessing a wide range of stimuli, including foods and beverages, in industry and/or academics. Affective testing include hedonic category-ratio scales such as just-about-right (JAR), sorting, and check-all-that-apply (CATA); fast descriptive techniques include sensory profiling, projective mapping, and flash profiling. Perceptual biases arise from cognitive bias, which happens when consumers create skewed representations in comparison to the objective reality (Thakur et al., 2022).

- *Downsides of Traditional Sensory Evaluation*:

The very distinct human responses from panels are difficult to capture using traditional sensory approaches. For example, human reactions to consumer, descriptive, and/or discriminatory tests can be influenced by a number of physiological and psychological biases. By employing various sensory procedures, effects from assimilation or contrast can increase or decrease perceptual differences between goods (Wakihira et al., 2022).

III. ADVANCES IN SENSORY EVALUATION METHODS

Other approaches have been put forward by sensory scientists to investigate human perception from various perspectives and to identify other pathways to comprehend how the senses interact with stimuli. Customers gave familiar items higher sensory and hedonic liking scores than new ones in cross-cultural eating research (Torrico et al,2023). Recently, new techniques have been created to obtain a more comprehensive response from participants. Several sensory researchers are currently investigating the latest innovations as tools to comprehend the sensory evaluation, such as the use of biometric techniques (facial expressions, heart rate, body temperature, skin conductance, and eye-tracking), contextual environments (virtual and augmented reality), artificial intelligence, and smart sensors (e-nose and e-taste). Deeper understanding of human perception may result from combining these innovative approaches with conventional sensory protocols. This transitory evaluation delivers a snap of these current novel methods, which are used for the sensory evaluation of diverse foods and beverages.

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➢ *Role of Artificial Intelligence in Sensory Evaluation:*

During the past few decades, as food demands have increased in conjunction with the global population, artificial intelligence (AI) has become synonymous with the latest technology in the food sector. The demand for the previously mentioned intelligent systems in the food sector has increased due to their proficiency in a variety of tasks, including food quality determination, control tools, food classification, and prediction objectives.

Table 1 Applications of AI in Sensory Evaluation

Artificial Intelligence @ Sensory Evaluation		
✓ Electronic Nose	✓ Fuzzy Logic	✓ Computer Vision System
✓ Electronic Tongue	✓ Machine Learning	✓ Near Infrared Spectroscopy

Predictable techniques have been used for sensory analysis that can only be perceived by sight, smell, in terms of qualitatively but are unable to provide the analysis in the accurate way. Experimental procedures are often too expensive, time-consuming, and may lack a generalized theoretical description of the process (Pavani et al, 2023). Different types of AI and their recent application in food industries which comprises several AI techniques including expert system, fuzzy logic, Artificial neural network ANN, and machine learning. In addition integration of AI with External Sensors for Real-time Detection in Food Industry, FL or Artificial neural network ANN is often integrated with several sensors for real-time detection such as electronic nose (E-nose), electronic tongue (E-tongue), machine learning (ML), computer vision system (CVS), and near infrared spectroscopy (NIRS) for real-time detection and to obtain higher accuracy results in a shorter time (Chiu & Tang, 2013). These sensors have also combined their fundamentals together for enhancing their accuracy and targeted results (Mavani et al, 2022). The integration of these sensors with the artificial intelligence methods has been shown quite a number in food industries over the past few years.

- *Electronic Nose:*

E-nose, also called Electronic Nose, is a device designed to detect scents or taste similar to the human nose. It includes a series of electronic organic sensors that can detect together basic and intricate odors (Yan et al, 2015). E-nose has been employed in gas detection for situations that require the investigation of individual components or mixtures of gases/vapors. Additionally, it serves a crucial function in the food sector by overseeing the quality of goods. Because of its capability to identify intricate scents, it has been utilized for ecological protection and detecting explosive substances (Deshmukh et al, 2015).

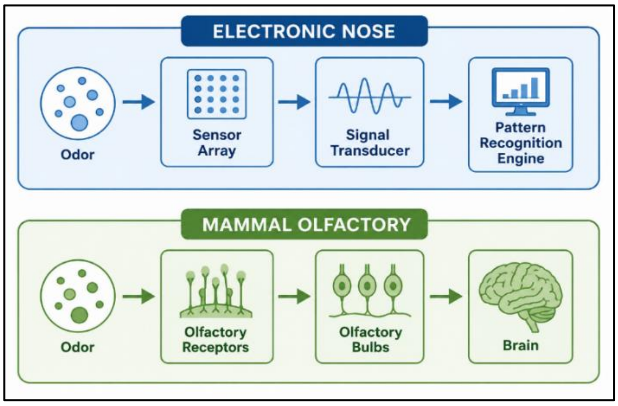

Fig 3 E-nose Vs Human Sense

This novel method is utilized to enhance product characteristics, consistency, and uniformity, leading to quality control opportunities across all stages of industrial production. Electronic noses are expected to be used in the food industry for purposes such as quality control, monitoring processes, evaluating freshness, investigating shelf-life, and assessing authenticity. Significant research has previously been done on meat, grains, coffee, mushrooms, cheese, sugar, fish, beer and other drinks, as well as on assessing the smell of food packaging material. The human sense of smell is intricate, with numerous receptors that attach to odour molecules and are capable of detecting certain scents at extremely minute levels (Dhar et al, 2018). The signals are interpreted by the brain to identify the substance consumed through judgment and/or classification.

Usually, the electronic nose has a variety of sensors that react with volatile compounds and cause a chemical or physical change. This modification transmits a signal to a computer, which uses training and calibration to classify it and eventually recognize patterns. These days, a variety of industries, including commercial, agricultural, biomedical, food, and scientific research, have benefited from the e-nose (Schaller and Escher, 1998).

- *Electronic Tongue (E-Tongue):*

It is a gizmo that can recognize and assess flavor. An electronic tongue, sometimes referred to as a multisensory system, has several low-selectivity sensors. Complex mathematical techniques are used for signal processing employing multivariate data analysis and pattern recognition (PARC). For example, an E-tongue can be used to separate different chemicals in liquid phase samples (Lvova, 2016). E-tongue's electrical devices are equipped with about seven sensors that enable it to differentiate between organic and inorganic substances. The combined sensors with different reactions in their spectrum produce a unique thumbprint. The statistical software in E-tongue makes it possible to recognize and comprehend flavor. An electronic tongue entails of three components: a sample-dispensing chamber or automatic sample dispenser, a variety of sensors with different selectivity, and an image recognition system for data processing (Podrazka et al, 2017). A vast range of sensors can be incorporated into the manufacture of these instrumental systems, particularly in the case of "e-tongues", providing many convenient uses. The features of sensors and potential uses of e-tongue technology in the food sector has practical applications in quality control for the food industry and pharmacy.

- *Machine Learning :*

It is an instrument that is able to identify and assess flavor. The food processing and handling business, which is the most significant manufacturing sector and offers the greatest employment prospects worldwide, has a large number of non-specific sensors. For food production and packaging to be completed successfully, manual labor is essential. The food businesses are finding it difficult to maintain the supply-demand chain and guarantee food safety because of human involvement. The best way to solve the problems that the food industry encounters are through industrial automation. Automation depend on entirely on algorithms such as artificial intelligence (AI), machine learning (ML), or deep learning (DL). Utilizing the AI-powered system can effectively manage food production and delivery operations while also improving operational efficiency (Kumar et al, 2021). ML is commonly recognized as a subset of AI that can observe, attain knowledge, and adjust without requiring direct guidance. Computer algorithms and statistical models progress autonomously through experience and a learning model that analyses and originates insights from data. Machine learning comprises of three main categories: supervised learning, unsupervised learning, and reinforcement learning. Machine Learning (ML) can assist in effectively addressing issues like determining delivery routes, managing raw material supply, forecasting food item demand, and organizing logistics. More advanced AI techniques like deep learning (DL) can be used to conduct this type of analysis, giving a competitive edge (Chandra, 2019).

- *Computer Vision System (CVS):*

Image processing and pattern recognition techniques are combined in this domain of artificial intelligence. This non-destructive technique makes it possible to analyze and extract information from images in order to help create and develop the categorization pattern. It is also acknowledged as a helpful instrument for measuring external features like size, shape, color, and flaws. Generally speaking, it was made up of a digital camera, lighting, and software for processing and analysis of the photos. There are two types of the system: 2D versions and 3D versions. It is not limited to different uses in the food sector, like assessing ripeness in apples, forecasting pork loin color, identifying coffee roast levels, evaluating table grape quality, and spotting pork defects. The integration of CVS with soft computing methods has been deemed a valuable and crucial asset in the food sector. This is due to the fact that the merging of these systems provides many benefits, including the ability to quickly achieve precise predictions (Mavani et al, 2022).

- *Fuzzy Logic:*

Innovative methods, including fuzzy set theory, have proven useful in evaluating the sensory qualities of both conventional and new food products created by fortification and altered processing methods. The goal of fuzzy set theory is to express the degree of incomprehensibility in human thought and relate it to a real number while treating ambiguous phenomena logically. Fuzzy logic also simulates human reasoning and decision-making behavior. When describing the sensory qualities of food products (such as color, aroma, taste, texture, and mouth feel) that are obtained through subjective evaluation, fuzzy modeling uses linguistic entities like "not satisfactory, fair, medium, good, and excellent." These are combined with the accurate and precise data obtained through objective evaluation to draw conclusions regarding acceptance, rejection and ranking, along with strong and weak characteristics of the food under study. Additionally, this study helps determine the preferred quality qualities and establishes standards for accepting or rejecting newly designed meals. Using one or more panelists, the fuzzy logic technique can be used to assess unpredictable and subjective data in order to draw significant conclusions about the acceptance or rejection, strong and weak qualities, and ranking of food products. Up till now, a lot of research has been done on the fuzzy logic-based sensory assessment of food goods. These consist of chana poda, soup mix and enriched millet bread with dietary fiber, drinks, mango drinks, litchi drinks, milk with barberry juice, and various additional food items (Mavani et al, 2022).

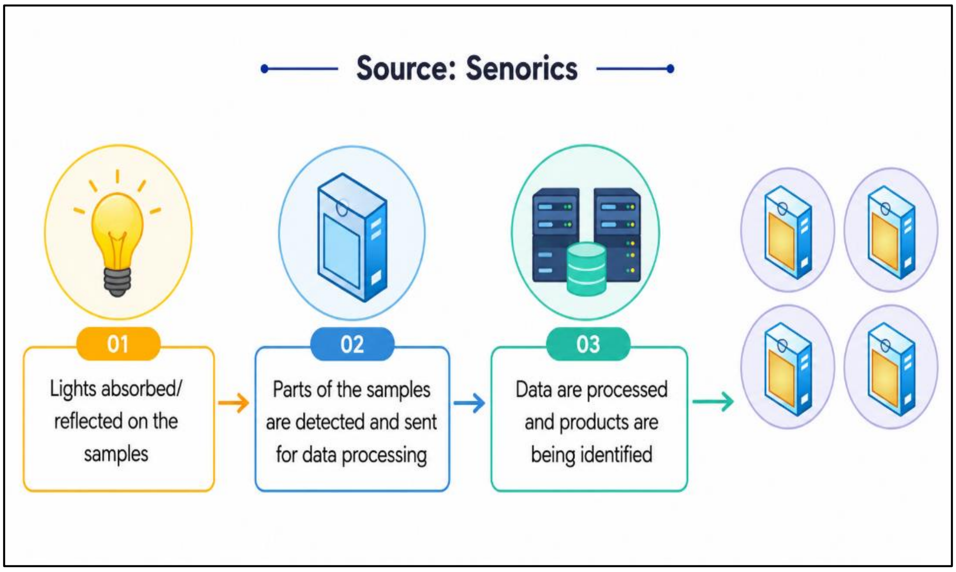

Fig 4 Working Mechanism of Near Infrared Spectroscopy

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- *Near Infrared Spectroscopy (NIRS):*

Another method used in the food sector is near-infrared spectroscopy (NIRS), which produces results precisely and accurately in a matter of minutes or even continuously without the need for chemicals. It is also recognized to be non-destructive, economical, rapid, and simple, which makes it a viable substitute for the labor-and money-intensive older methods that take a long time to complete. NIRS's chemical-free approach qualifies it for usage as a sustainable substitute because it won't harm people's health or the environment. Fig. 5 illustrates the basic concept of NIRS operation. NIRS has recently attracted interest in the food industry for inspecting food quality, managing the study's goal, and assessing the safety. Numerous studies have used the NIRS in food to extract its qualities for a variety of purposes, such as figuring out the fat groups and fatty acid composition of goat milk. In addition, it can help anticipate the composition of salted meat at various temperatures as well as the amount of sodium present in processed meat products. Using the NIRS technology, it was also possible to detect and grade the wooden breast syndrome in chicken fillets on the process line (Mavani et al, 2022).

IV. BENEFITS OF ARTIFICIAL INTELLIGENCE

AI is necessary for ensuring quality control and food safety. Artificial intelligence systems have the capability to recognize possible contaminants, spoilage, or flaws in food products. This capacity helps to avoid the spread of contaminated food, diminish health hazards, and maintain consumer trust. AI-powered analytical analytics models have the capacity to anticipate quality issues as well, allowing for the taking of preventative measures to maintain high product standards. AI is also transforming food product development by enhancing nutritional profile, component selection, and flavor optimization. AI algorithms that analyze consumer preferences and nutritional data may be able to generate personalized suggestions and create innovative food products that cater to particular tastes and needs (Ding et al, 2023). This makes it possible for food corporations to offer custom-made services that encourage healthy choices and customer satisfaction.

V. CONCLUSIONS

Conventional methods have been experimental that the farming is immobile and old formed in many sections of the entire globe. Artificial intelligence (AI) has been widely used in the food business for a change of purposes, together with modeling, prediction, control tools, food drying, sensory assessment, quality control, and the resolution of challenging issues in food processing. To one side from that, the capacity of AI to approximation sales and permit produce upgrades allows it to improve commercial approaches. Artificial Intelligence is renowned because of its comfort of use, accuracy and economical approach in the food sector. Given its many benefits over the conventional approach, artificial intelligence (AI) has found widespread use in the industry. A critical overview provides information on the usages of AI, its profits and problems, and how algorithms are unified with various sensors, including E-nose and E-tongue, in the food sector. Additionally, a guideline that outlines a methodical process for creating the right algorithm before utilizing the AI model in a field related to the food industry has been proposed. All of these things will help and motivate researchers and industry participants to explore the current technology, which has been shown to yield superior results.

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