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Ashok Kumar
Assistant Professor, Department of Agricultural Engineering, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Satish Kumar
Assistant Professor, Department of Agricultural Engineering, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Mohan Kumar Sinha
Assistant Professor, Department of Agricultural Engineering, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Corresponding Author:
Mohan Kumar Sinha
Assistant Professor, Department of Agricultural Engineering, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

Integrating approach of Artificial intelligence and related techniques in Food Sector: An opportunity and future challenges

Ashok Kumar, Satish Kumar and Mohan Kumar Sinha

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Abstract
Smart processing, handling, and monitoring systems using Artificial Intelligence (AI) and related techniques have embodied the recent technology in the food sector over the past few decades due to the increasing demand for food products in line with the increasing population worldwide. The food sector faces a significant challenge as the world's population will be over 9 billion by 2050, necessitating a 70% increase in food production to meet demand. The food sector has an increased need for these intelligent systems due to their versatility in performing activities, including automation in various operations performed during food quality assessment, control tools, food categorization, and prediction. In order to choose the best approaches for advancing upcoming AI innovations in food industry, this paper studies those numerous applications and explores their benefits, drawbacks, and formulations.

Keywords: Artificial intelligence, machine learning, robotics, optimised production

Introduction
In order to feed 9-10 billion people by 2050, it is estimated that global food production has to expand by 60-110% (Ayed and Hanana, 2021) [1]. Food security and eradicating hunger for the world's expanding population depend on the agricultural sector's sustainability. Food, or rations, is also widely recognised as a human necessity and as the ultimate product of farming; it happens when farmers distribute their diversely produced commodities. The products produced by food companies are essential for the continual development of any nation (Kakani *et al*., 2020) [2]. The growth of the national economy and the global economy are also significantly influenced by it. Thus, it is crucial to ensure the safety of food sector goods and their quality through appropriate distribution. In addition, an extensively documented traceability system is now essential to the food chain's quality management. Artificial intelligence (AI), a recently developed technology, has shown potential for achieving desired goals in the past several decades (Agbai, 2020) [3]. AI-based or autonomous systems are widely used in almost every field of technology. It renders possible for around the world to effectively optimize issues, computerize the food business, and transform its products. Through the utilization of a computerized system, the industry may assess and ensure that the most favorable conditions, including seed selection, crop monitoring, watering, and temperature monitoring, can be enhanced, resulting in superior food sector goods (Vadlamudi, 2018) [4]. These are not the only applications of AI. Additionally, it can aid with food preparation, storage, and transportation. Robotics and intelligent drones are two examples of intelligent devices that can be extremely important in reducing packing costs. Additionally, it will assist in transporting food items, finishing tasks in hazardous situations, and producing high-quality goods. AI's significant contributions to the food industry may be roughly divided into two categories: food quality management and food security management. This paper offers a literature review of machine learning and AI in the food business while preserving all facets of AI in the sector (Tyagi *et al*., 2021) [5]. The role of AI in food industry is presented in Figure 1.

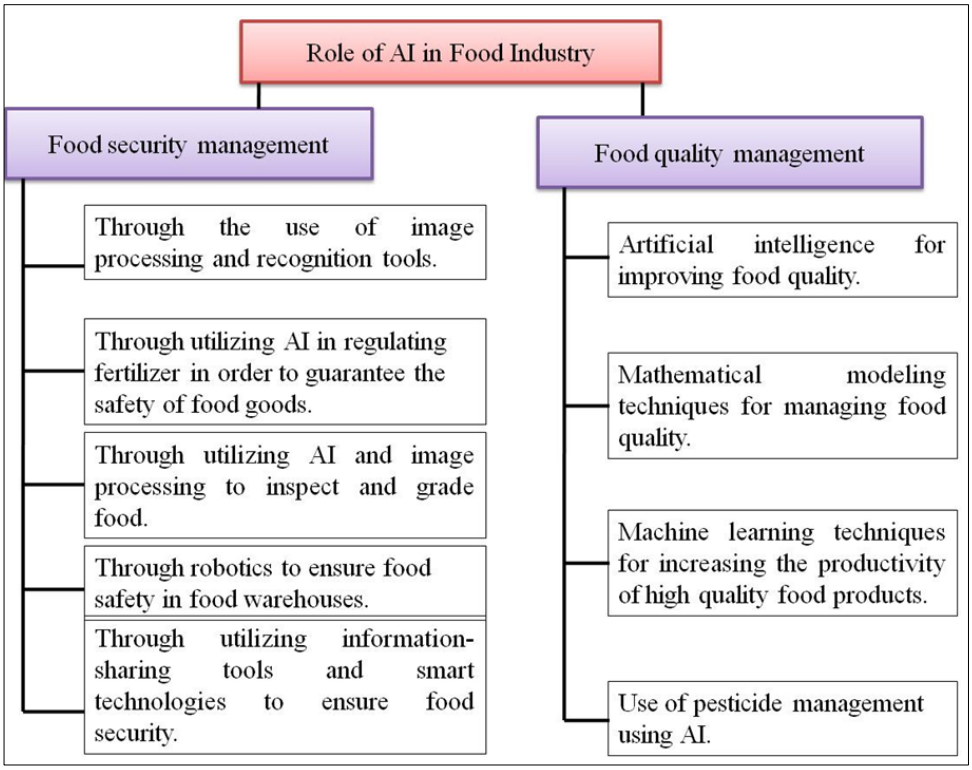

Fig 1: Role of AI in food industry (Kumar *et al*., 2021) [6]

The remaining part of the study is structured as intelligent farming and AI in the food processing sector. The function of data analysis in the food industry is next covered, followed by ML in the restaurant industry. The next section will discuss AI in food safety since it is crucial in relation to the food safety issue. The future applications of AI and ML in the food business are finally discussed, but they are not the least. In the final section, the manuscript's conclusion is presented.

Smart farming

AI has several significant uses in the food sector, including predictive analysis, rob cropping, and soil monitoring. Figure 2 represents the trendy application of AI in the food industry. The detail description of each application is presented in forthcoming dedicated paragraphs.

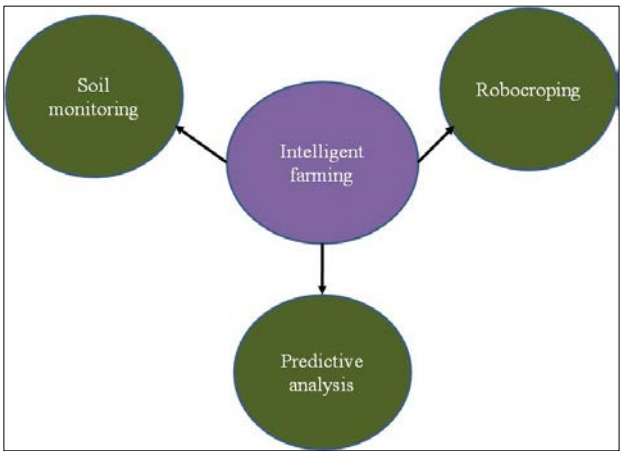

Fig 2: Smart farming

The food industries are currently thinking about the advantages of AI-based solutions. In AI-based system, computer vision and deep learning algorithms play a crucial role in examining the data or information sequence that the AI-based agents get in order to track the development of crop and soil health. Through the use of computerized systems, clients are made aware of the advantages and disadvantages of their soil. The primary goal of the developed system was to identify faulty crops and determine the most likely course of action for their healthy development (Gupta *et al*. 2021) [7].

In the current Soil Monitoring (SM) scenario, the customer will receive a comprehensive overview of the contents of their field soil after a farmer sends a sample of their farm soil to the monitoring organization. Following the outcomes, a suitable choice has been made regarding bacteria, fungus, and the broad progression of microorganisms.

In 1980, Japan deployed the first AI-powered drone for crop dusting. The majority of businesses today use drone technology and agricultural AI to monitor crop health. Reducing expenses and enhancing crop growth are the company's main goals. Users will integrate with the drone after preprogramming its route. A few images will then be captured by the computer vision system for analysis.

The new phase of technological growth is known as the Internet of Things (IoT). The IoT is crucial in crop and soil monitoring decisions. SM with IoT is an AI program that helps farmers and the food industry boost their bottom line, reduce the likelihood of illness, and make the most use of their resources. Sensors are used in these to measure temperature of the soil, nitrogen, phosphorus, and potassium (NPK) concentration, moisture content, water content, potential, photosynthetic radiation, and oxygen content. In order to make an appropriate choice and enable prompt action, the data gathered from the various sensors is once again sent to the data center or cloud. Utilizing resources is made easier by the analysis and visualization of the received data. In order to determine the system's behavior, it is necessary to recognize soil patterns and make careful decisions in certain situations in order to maximize crop

output and provide high-quality goods. Smart agriculture is the term for the Internet of Things based on agriculture. The smart food industry refers to the Internet of Things-based food sector.

Table 1: Parameters to be measured by different types of sensors (Kumar *et al*., 2021) [6].

S. No.	Parameters	Type of sensor
1.	• Soil temperature • Noncontact shell temperature	Temperature sensor
2.	• Soil wetness • Conductivity • Volumetric water content • Water potential	Moisture sensor
3.	• Active radiation • UV radiation • Solar-shortwave	Solar radiation
4.	• Rainfall • Warmth • Moisture • Air pressure • Speed of wind • Flow direction of wind	Weather
5.	• Nitrogen level • Phosphorous level • Potassium level • pH level • Temperature level • Moisture level	NPK soil sensors

The entire foundation of IoT-based agriculture is crop, weather, and soil monitoring. As is well known, IoT-based agriculture heavily relies on weather and irrigation. The explanations of smart agriculture are also accompanied by an elegant environment, such as clean air and a well-maintained irrigation system. Table 1 shows the sensors that are frequently used and the kinds of measurements that each sensor takes into consideration (Bhattacharyya *et al*., 2020) [8].

Robocrop

The food business is utilizing contemporary technology-based instruments to boost productivity in tandem with technological advancements. Robocrop is a tool that has been developed by different research groups. The yielding process is advanced by AI-based robotic system, which maximizes consistency and utility. It carries out crop tool alignment precisely and quickly. A precise and high-resolution system keeps an eye on the food industry product shrubbery ahead of the system.

A high-performance workstation processes the acquired image to pay close attention to the green band pixels that are related to the crop line. An exceptional typical crop center-line tracking is achieved because of the large area that the input devices and the several processing lines capture.

Fig 3: Robocrop picking fruits

Using the crop line area, it compares the final image to a gro und truth gridiron layout. A hydraulic based shift is then used to align the instrument in the row using the information that has been gathered. In addition to backdrop pick-over infection, the pattern based attribute makes the systems extremely healthy. Simply by using many cameras and sensors, it enhances performance and production rate. Outstanding work in the area of harvesting robots has been done by a number of authors in the field of rob cropping, or agricultural automation, which has significantly raised production in recent decades. Due to advancements and further advantages like increased productivity and a smaller labour force, these systems gained popularity. The SVM-based dual-arm robot is appropriate for harvesting fruit. Robotic weeding, a component of agricultural automation makes it easier to efficiently and mechanically control weeds around or inside crop rows.

For identifying crop plants at different growth stages for robotic weeding control, an image-processing-based system was developed. A particular system called Adaptive Robotic Chassis (ARC) was developed for strawberry blossoms out of the list of the present systems.

The mounted camera in such system takes pictures of strawberry blooms, which are subsequently processed. Ultimately, the robot takes the necessary operations after obtaining the desired coordinate. The performance of robocrop is entirely dependent on the attributes of the input image. The input image displays exceptional results if it has more dominant features. The crop shrubbery must be close to the RGB color band mean and there must be more shrubbery than wildflower in every sample of an input image. A robocrop console component, a hydraulic shaft, a three-point linkage frame, a high-definition camera, multiple speed sensor types, an ADC adapter, and other components make up a standard robocrop system (Machleb *et al*., 2020) [9].

Predictive Analytics

Weather variations are among the environmental factors that learning models are designed to track and predict in relation to crop yield. In this regard, machine learning algorithms play a crucial role. Satellites and machine learning algorithms work together to forecast the weather, study agricultural sustainability, and inspect fields for the presence of pests and illnesses.

Delivering high-quality data or information that is continuously updated at a rapid pace is why the model excels.

Additionally, the firm frequently grants access to over one b illion stacks of agronomic data, demonstrating its high level of confidence in the data it offers its clients.For predictive a nalysis, historical values and data sources including tempera ture, wind speed, precipitation, and solar radiation are crucia l. The outcome of the analysis plays a crucial element in selecting the right crops and schedule for a given piece of agricultural land.

Artificial Intelligence in Food Industry

Presently, there is a growing emphasis on the application of machine learning algorithms in the four primary clusters of the agricultural supply chain: preproduction, production, processing, and distribution. Indeed, ML technologies are employed in the preproduction stage, particularly for crop yield, soil, and irrigation requirement prediction. In the

subsequent phase of production, machine learning might be applied to forecast the weather and detect diseases. ML techniques are used in relation to the third cluster of the processing phase, particularly for estimating production planning in order to achieve a high and safe product quality. Particularly, ML algorithms could be applied to customer analysis, transportation, and storage within the distribution cluster. AI plays a key role in handling the entire processing unit task in food process industry. The food processing and handling sector provides several significant applications, as illustrated in Figure 4.

Product Sorting and Packaging

The proper ordering and packing of food products is one of the tedious and time-consuming procedures for production in the food processing industry. In order to reduce the possibility of error and boost industry production rates quickly, AI-based solutions can handle such a laborious process. A lot of data is required to develop an AI-based sorting and packaging system so that the system is properly trained and completes the task efficiently. The irregularities in shapes, colors, and sizes of fruits and vegetables make it difficult to develop AI-based systems. Different systems were developed for the same purpose by different research groups.

Among them is TOMRA, which completes the sorting process extremely effectively

It quickly increased productivity with 90% accuracy. Nowadays, automated systems handle the majority of the product sorting and packing duties. Industries were able to reduce labor costs, increase production rates, and provide high-quality yields by implementing such systems. Figure 4 shows significant applications from the food handling and processing industry (Tripathi *et al*. 2020) [10].

A variety of instruments and techniques, including high-resolution cameras, laser technology-based systems, X-ray-based systems, and infrared spectroscopy, are used in AI-based intelligent decision-making systems. These technology and instruments are utilized at the input channel to examine every facet of food products, including fruits and vegetables. The only way that conventional systems can distinguish between good and terrible products is by looking at them. It has been observed that the detaching and ordering issue with potatoes alone can be resolved by 5-10% when employing TOMRA. Using a TensorFlow machine learning system, a Japanese company also tackled the same kind of issue and produced an impressive result, greatly enhancing their assembling unit. This technology also produced outstanding outcomes for other food processing businesses. Each firm also discovered that the AI-based solution operates with more accuracy. The success of potatoes inspires the development of AI-based solutions for other applications as well. For several divisions or departments within the food processing business, it can be further extended (Pnishchuk, 2020) [11].

Personal Health Sanitation

The literature also reveals that some nations, including the United States, introduced the food processing unit sanitation guidelines. These guidelines have also been tackled through AI-based solutions. Initially, an AI-based system was developed in collaboration with the Shanghai municipal health office and KanKan. An anonymous quantity may be recognized by face and object using the first AI-based system. People who are not adhering to the rules are monitored by the system. It may be handled immediately in real time if anything matches. The system has been intended to be expanded for an increasing number of businesses due to its excellent performance (Rary *et al*., 2020) [12].

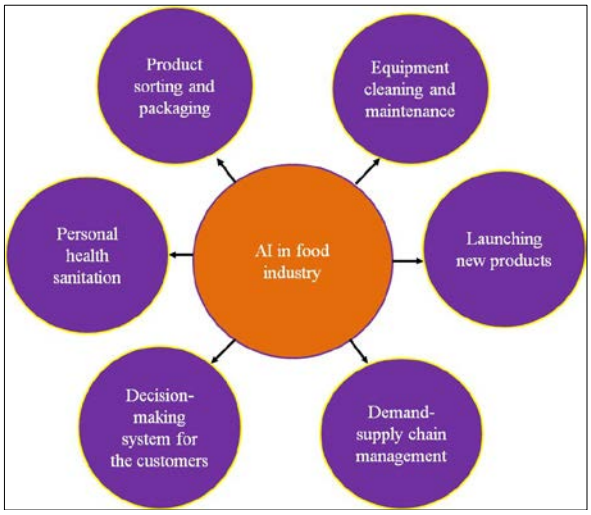

Fig 4: Application of AI in food industry

Customer Decision-Making System

Based on many different organizations, AI is helping the food processing industry create diverse taste combinations and enabling consumers pick innovative essences. In 2018, Kellog introduced Bear-Naked-Custom, which allows customers to develop their own customized granola with over 50 ingredients. It keeps track of each person's tastes, consumer preferences, and a lot more data while caring for them. Information of this kind is crucial when introducing a new product to the market. As a result, AI was helpful once more in creating consumer decision-making systems (Yost and Cheng, 2021) [13].

Maintenance and Cleaning of Equipment

Cleaning and maintaining processing equipment properly is crucial in the food processing industry. AI-based systems can readily manage such a task. Several sensors and cameras are used to carry out the work in order to do this. The muscularity of one of Whitwell and Martec's products may drop to just 50%, allowing for high efficiency and minimal time. At the moment, Martec is attempting to defend their AI-based cleaning business strategy. For this strategy, Martec uses optical fluorescence techniques and ultrasonic sensing imaging techniques to nurture the information gathered for the growth of the AI system. It counts the amount of food and microbiological material that is still within the machine. The system will go live once the full report from the testing phase is made public (Schmidt and Piotter, 2020) [14].

Introducing New Products

For every production unit, introducing innovative products is a tedious job. The interests of the customer are paramount, particularly in the food industry. As a result, the data gathered by the various consumer decision-making processes is useful for the introduction of new goods. The ML-based module processes the gathered data before

making the best choice for the final result. Questions like "what customers are exactly looking out for" have been addressed by employing an ML-based strategy. Artificial intelligence is currently being used by almost every industry involved in food processing and food product packaging to grow and introduce new goods to the market. This work has already been completed via a survey or case study. As a result, the system's success rate is extremely low. The whole situation has now altered, and AI and ML are now widely employed for these kinds of jobs (Wardah *et al*., 2020) [15].

The Coca-Cola Company has set up a self-service soft drink nook around the USA. Customers may use this to create hundreds of different cocktails by adding little taste adjustments. The system has captured this kind of behavior, and machine learning and deep learning algorithms handle the remaining analysis. These data can be used to introduce new goods. Cherry Sprite is an example of a product in real time. Additionally, it has been proposed that the majority of the food industry would use the recommendation system to create new goods in the ensuing decades.

Demand-Supply Chain Management

Food businesses need to be more transparent about how food items move through the supply chain system as long as they are more concerned with food safety regulations. AI is used to keep an eye on each step of the process (Kakani *et al*. 2020) [2]. It controls everything, including inventory management and pricing control. Additionally, it handles the forecasting and tracking of the belongings' journey from the point of cultivation to the point of consumer collection. AI-powered Symphony Retail offers the ability to schedule inventory control, billing, and transportation (Bhattacharya *et al*. 2021). Additionally, it stops a lot of commodities from ending up in exhausted material and preserves discipline.

Data Analysis in the Food Industry

There are many well-known brands and food outlets packed into the food-based business. This sector is becoming less appealing for starting a new company as a result of the increased competition. The only way to keep ahead of the competitors in the food sector is to use technology, particularly data science. Information on data analysis in the food business is presented in Figure 5.

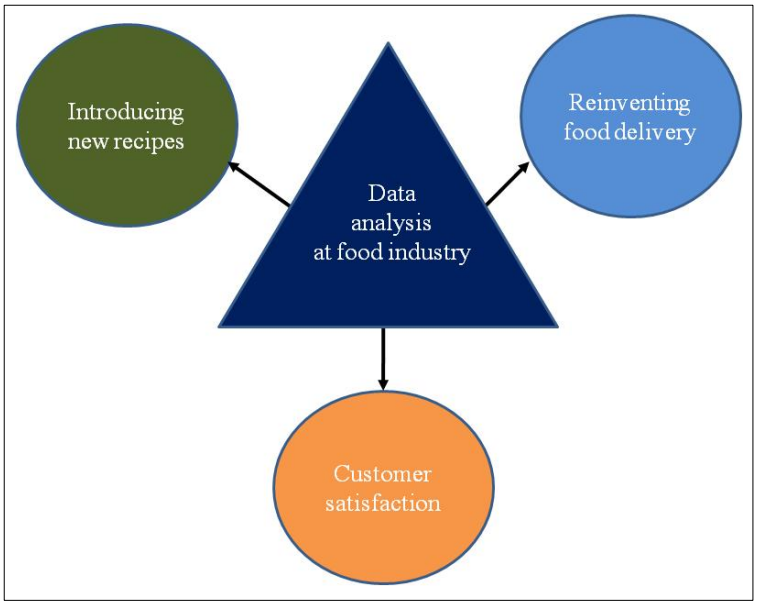

Fig 5: Data analysis in food industry

Customer satisfaction

According to Ooshma Garg, one of Gobble's founders, the food sector may be regarded of as a type of technology firm. Although the rest of the world disagreed with this claim, there is some validity to it. For today's technologically advanced industries to improve and manage their varied business procedures, data science has become essential. One such example of a business that fully depends on data science to forecast both supply and consumer demand is Gobble (Topleva and Prokopov, 2020) [17]. In addition to having thousands of regular customers with a variety of menu options, it provides its patrons with ten-minute supper kits.

Introducing New Recipes

The elements of a single recipe can be used to create a variety of cooking methods. Furthermore, the fact that those foods may be prepared in a variety of ways opens up a world of culinary culinary options. Numerous recipes and an extensive dataset are accessible online, enabling both amateurs and experts to explore ingredients in various cuisines. The researchers are able to identify both the similarities and variances across the various cuisines. For instance, the ingredients used in North American and Western European cuisines have the same flavoring components that are avoided in East Asian and Southern European cuisines (Ageikina *et al*., 2020) [18].

In conclusion, the technologists can identify a cuisine that is popular in a few regions and evaluate whether food ingredients have a respectable flavor. This fundamental knowledge also enables computers powered by artificial intelligence to suggest various ingredient combinations to chefs, which will undoubtedly increase menu options and food sector revenues.

Reinventing Food Delivery

Online meal delivery services like Swiggy, Zomato, and Uber-eat contain a lot of data about their clients' ordering

habits and preferred dishes. The food-based professional may use data science and artificial intelligence to develop more straightforward, economical, and time-efficient ways to deliver the product (Kim *et al*., 2021) [19]. Some current sectors are benefiting from AI, and there are some legitimate opportunities for market dominance. However, it is still in its infancy in the food sector, therefore food firms must optimize it more skillfully as well so that consumers may receive better food and services

Food Safety using Artificial Intelligence

Robots are commonly accepted in the food processing industry because of their sterility. This characteristic has a major role in lowering the incidence of illnesses linked to diet. Stricter sanitary requirements have been developed by the Food Safety Modernization Act (FSMA), and these requirements apply to whole supply chain systems. Cereals, spices, and other food items that don't require refrigeration and are in the most vulnerable region for contamination are the root cause. Such food items used to be free from contamination, but things have completely altered since then. AI-based solutions can undoubtedly aid in the resolution of these kinds of issues. They are not capable of spreading diseases as humans are.

On the other hand, maintaining an AI-based system is straightforward. According to a Technavio estimate, the use of robots in the food processing sector will increase by 30% and satisfy government requirements. Additionally, certain cutting-edge innovations utilizing artificial intelligence in food safety techniques are expected to gain widespread recognition in the near future. Their main goal is to drastically reduce the incidence of food-borne illnesses. Artificial intelligence in food safety is depicted in Figure 6.

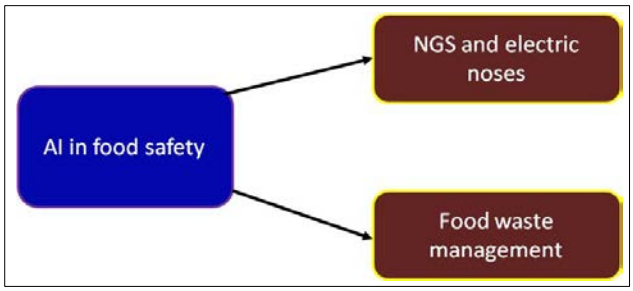

Fig 6: Artificial intelligence in food safety

Next-Generation Sequencing and Electric Noses

Electric noses (ENs) and next-generation sequencing (NGS) are the two most exciting innovations in the food sector. NGS quickly replaces the DNA technique in the area of food security. With the advent of AI-based automated systems and workflows, data collection and laboratory tests were developed far more quickly and precisely than before. The NGS can rapidly and effectively identify dangerous inclinations. Additionally, it can stop infectious outbreaks before a significant number of people are harmed. In simulated environments, ENs primarily serves as a person's muzzle substitute. There are sensors positioned that can accurately detect a variety of scents. These sensors only pick up scents in their environment, and the information they gather is sent to a data center where machine learning algorithms may use it (Yu *et al*. 2020) [20]. The manufacturing units get a warning signal depending on the judgment made by the machine learning system. Thus, EN may represent the safety of food goods in the future.

Food Waste Management

According to a survey released by the US Department of Agriculture, "between 30 and 40 percent of the food supply in the United States is thought to be wasted. Based on USDA's Economic Research Service projections, this estimate equated to around 133 billion pounds and $161 billion worth of food in 2010, representing a 31 percent food loss at the retail and consumer levels. The effects of this quantity of garbage on society are extensive.

The manufacturing units get a warning signal depending on the judgment made by the machine learning system. Thus, EN may represent the safety of food goods in the future.

McKinsey says that by 2030, AI will be able to handle these kinds of problems and remove a significant portion of opening by dipping food waste. By using additional regenerative leisure farming techniques, such startling figures can be achieved (Filimonau *et al*., 2020) [21]. It demonstrates how inefficiently people are using the resources at their disposal. Smarter agricultural techniques can take the place of conventional farming practices. This involves the deployment of many sensors that gather data. After using machine learning algorithms to interpret the gathered data, the proper judgments are made. Farmers may use them to make the most accurate and timely decisions.

The following are some recommended methods for using AI to reduce food waste:

- While some explanations focus on fruit ripeness, others state which microorganisms, independent of artificial fertilizers, can promote the growth of fruits and vegetables.
- Manufacturers can obtain cleanse of ground inspection, benefiting from artificial intelligence compensation that will preserve a significant amount of capital.
- Computer vision technology is used in farm-based food supply chain management to oversee and analyze every step of the process, which will quickly reduce food waste.
- Food tracking systems powered by artificial intelligence will allow us to sell food before it becomes trash. More farmers and consumers may connect to purchase food goods by using this.

Opportunity of AI in food industry

It is evident from the examination of the food industry literature that the food processing and manufacturing sector requires a substantial amount of investment. Compared to man-based systems, AI-powered systems can more readily detect a variety of problems in food production. Researchers have also been observed to be actively involved in this field. The Swiss agrotech company Gayama is an excellent example of one such company that has received $3.2 million for a project driven by artificial intelligence. The project's foundation consists of hyperspectral cameras, which can detect even the smallest changes in crop yields, vermin, water intensities, and nutrition. After identifying potential intimidation, the artificial intelligence system sends farmers warning messages so they may make appropriate plans. Additionally, the artificial intelligence approach will suggest compelling actions that farmers should do to make the most use of the resources at their disposal.

Satellite data may also be used to examine the Earth's surface using machine learning and deep learning techniques. The primary goal is to identify areas where the

government or its owners may provide facilities to enhance the crop and increase the yield. Further, it has been noted that in many parts of the world, farming is outdated and immobile. It could soon be superseded by intelligent farming. AI has the potential to be used in smart farming and to address the current situation in some way in the near future. A successful smart farming installation might increase yields by at least 60%. Although machine learning and artificial intelligence are promising approaches, there will be a wealth of options to end waste in the food production industry.

Constraints and Limitations

The AI technology does, however, have several disadvantages that cause difficulties in spite of all these benefits. First and foremost, the biggest societal issue is unemployment, which might pose a danger. In reality, as smart machines and robots take over most monotonous jobs and activities, human intervention will decrease, this will have a significant impact on employment standards. Another technological issue is that machines can only perform jobs that they have been designed or programmed to perform; otherwise, they frequently crash or provide irrelevant results. Furthermore, the high development and maintenance costs of smart machines and clever computers may be viewed as technological limitations of AI technologies, particularly given that AI is constantly evolving and that hardware and software must be updated to meet new demands. The cost of maintaining and repairing machines is high. Because they are extremely complicated devices, the creation comes at a tremendous expense. The high cost of these applications, which may raise the price of the items, is another problem. In addition, there may be hazards and concerns regarding sustainability beyond the potential presented by smart and computerized technology, such the enormous energy consumption, e-waste issue, market concentration, employment displacement, and even the ethical framework.

Conclusions

The food and agricultural sectors are among the most important to humanity. The initial agricultural goods are utilized as inputs in a number of multifactor dispersed supply chains, including the four clusters or phases of the agriculture supply chain (preproduction, production, processing, and distribution) to get to the final customer. Because of a number of issues facing the food and agriculture industries in the future, including population increase, climate change, technological advancements, and the condition of natural resources (water, etc.). Digital technologies, such as automated farm equipment, sensors and remote satellite data, artificial intelligence, machine learning, and better crop and water monitoring, as well as traceability of agricultural food products, are urgently needed at various points in the agriculture supply chain. In this paper, we show how AI and allied techniques are used in various agriculture supply chain clusters, as well as the undeniable expanding trend of using these techniques to enhance the food industry.

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