EXPLORING THE HISTORY AND PROSPECTS OF ARTIFICIAL INTELLIGENCE IN AGRICULTURE AND FOOD- A REVIEW

G. PadmaPriya[*1], Thiyagaraj S[*2], Greeshma R[*1], Suhasini Chopra[*1]

1. *Jain University, School of Sciences, Bangalore , Department of Chemistry and Biochemistry.*
2. *Jain University, School of Sciences, Bangalore , Department of Physics and Electronics.*

Corresponding author: g.padmapriya@jainuniversity.ac.in

ABSTRACT

The uses of artificial intelligence (AI) in supply chain efficiency, customer interaction, and precision farming are transforming the agricultural and food industries. Through the utilization of AI-powered technologies, including robots, computer vision, and machine learning, the sector is attaining previously unheard-of levels of sustainability and efficiency. AI-driven insights about crop health, soil properties, and weather patterns are useful for precision agriculture, which maximizes resource utilization and increases yields. Traditional agricultural methods are being transformed by AI-enhanced automation, which makes better harvesting, planting, and weeding procedures possible thanks to robots and automated systems. Artificial Intelligence (AI) in supply chain management enables predictive analytics, optimizing inventories and cutting waste. Furthermore, AI guarantees food safety by means of stringent quality control and anticipatory equipment maintenance. The way people purchase for food is changing due to consumer-facing technologies like interactive chatbots and tailored nutrition advice. All things considered, artificial intelligence (AI) is propelling major developments in the food and agriculture sectors, encouraging sustainability, raising production, and raising customer pleasure.

Key words: AI, food and agiculture sector, sustainability.

INTRODUCTION:

For thousands of years, any country's ancient civilization has focused on agricultural pursuits as a means of overall development. Agriculture has an impact on humans in terms of energy requirements for healthy eating. The three main stages of every crop's growth cycle are cultivation, monitoring, and harvesting, each of which entails a range of tasks. Crop selection, land planning, soil preparation, irrigation planning, seed preparation, and seed sowing are all included in the cultivation phase. The main responsibility of farming is to monitor and manage crop growth after cultivation. Time-dependent tasks include pesticide application, fertilizer use, disease and weed detection, and scheduled crop health monitoring throughout this phase of the monitoring process. Harvesting, which includes tasks like crop cutting, segmentation, storage, and commercialization, is the last and most significant stage of the agricultural cycle.

One of the main areas of computer science study is artificial intelligence (AI). Artificial Intelligence (AI) is rapidly gaining traction because to its broad variety of applications and rapid technological advancement. It is particularly useful for solving issues that people and conventional computing architectures find difficult to solve. Concerns concerning future food production and demand are being raised as a result of the detachment that many younger generations are experiencing from agricultural operations owing to a lack of knowledge, experience, and obstacles. Between 1.0 and 4.0 (today), there was a revolution in agricultural development to solve all of these issues. The most advanced artificial intelligence (AI) technology, which uses machine learning to address issues in real time, is taking the place of the conventional agricultural approach.

Currently, there is a great deal of effort being put forth by young scientists and engineers to improve agriculture in order to make it more intelligent, simple, economical, productive, sustainable, healthy, and lucrative for society. Intelligent decision-making algorithms, robots, sensors, IoT, data management, and sophisticated processes are examples of AI-based systems.

EARLY USE OF TECHNOLOGY IN AGRICULTURE

The agricultural industry has seen a significant technological transformation in the recent century, which has made it possible to integrate artificial intelligence into many facets of farming and crop management. A major influence on agricultural productivity was the introduction of high-yield crop varieties, mechanized farming, and a rise in the usage of synthetic pesticides and fertilizers during the Green Revolution. However, environmental and ecological concerns arose with this technological advance, opening the door for research into more intelligent and sustainable agricultural methods.

AI integration in agriculture has been largely driven by developments in precision agriculture, which has been made feasible by advancements in GPS, remote sensing, and data analytics. AI-driven innovations like computer vision, machine learning algorithms, and the Internet of Things have revolutionized agricultural productivity, resource use, and decision-making. In order to provide real-time insights into soil conditions, insect infestations, and fertilizer requirements, AI-powered systems can analyze enormous amounts of data from sensors, satellite images, and weather predictions. This allows for focused and exact treatments.AI has benefited vertical farming, which is a promising solution to environmental issues and food security. AI-powered systems have the potential to significantly improve agricultural yields and resource efficiency by optimizing temperature control, irrigation, lighting, and other factors under regulated conditions.

PRECISION FARMING

In contrast to the conventional whole-field approach, precision agriculture involves integrating new technologies like Geographic Information Systems (GIS), Global Positioning Systems (GPS), and Remote Sensing (RS) to enable farmers to manage within-field variability to maximize the cost-benefit ratio. Precision agriculture is growing because to the considerable advancements in Variable Rate Technology (VRT) in agricultural equipment, such as yield monitors and applicators for fertilizer or pesticides. Farmers are drawn to site-specific management because it increases yields while reducing inputs. Reducing inputs also improves the environmental condition of the agro-ecosystem by lowering fertilizer and pesticide runoff.

The development of decision support systems or other expert systems that easily combine GIS, GPS, and RS technologies is also necessary, as is the availability of timely, reasonably priced remote sensing data or derived value-added goods. To hasten the adoption and use of this technology in the agro sector, a campaign for technology transfer and training is also necessary.

Following almost a decade of study, PA is at a turning point in its development, with much of the necessary technology available but the economic and environmental benefits need to be shown. While there have been many technical advances made, agronomic and ecological principles for optimal input recommendations at the local level have frequently not kept up. Regarding the usage of current PA technology in their crops, many farmers are undecided. The widespread application of PA technology might be spurred by strict environmental regulations, public outcry over the overuse of agrochemicals, financial benefit from reduced input costs, and improved farm management effectiveness. Ultimately, the financial and ecological advantages of PA technologies will dictate their level of development

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ROBOTICS IN AGRICULTURE

During the past 20 years, a number of autonomous vehicles, mainly agricultural robots, have been able to be integrated thanks to specialized sensors like machine vision, global positioning systems (GPS), real-time kinematics (RTK), laser-based equipment, and inertial devices; actuators like hydraulic cylinders, linear, and rotational electrical motors; and electronic equipment like embedded computers, industrial PCs, and PLCs.

When equipped with the proper tools, these autonomous and semi-autonomous machines can conduct precision agricultural tasks since they can give precise location and navigation in the field. The same sensors and actuators that are used in autonomous vehicles such as range finders, GPS, and machine vision are also being utilized to automate these tools, which include mechanical inter row weed management, adjusting the rates at which fertilizer or spray is applied, and seed planters.

Robotic fleets have several advantages. An developing and essential idea for the application of autonomous systems in routine agricultural tasks is the utilization of many robots working together to accomplish a clear goal. Smart robots have the potential to replace significant and expensive repetitive labor in high-value crops, making the adoption of sophisticated and pricey systems alluring. But a robotic agricultural application has to handle a lot of actuation signals and interpret a lot of information, which might lead to a number of technological difficulties. As a result, a significant drawback is that the total number of devices (such as sensors, actuators, and computers/controllers) rises proportionately to the number of fleet units, leading to a sharp decline in the mean interval between failures since a malfunction occurs.

PEST CONTROL USING AI

There are several difficulties facing contemporary agriculture today. Farmers and other suppliers of agricultural inputs now have to take into account regional and climatic variations in addition to international economic and political factors since the agricultural manufacturing industry has grown to be a highly competitive and worldwide industry. To fulfill the nutritional needs of the world's expanding population, food production must rise annually, but arable land is scarce.

Unexpected precipitation, global warming, droughts, and the frequency of extreme weather occurrences have all risen in recent decades due to climate change. These adverse circumstances put traditional producing regions in jeopardy and add new dangers and uncertainties to the world of agriculture. Due to climate change, infestations of existing pests are expanding or taking the lead in areas where they were previously non-problematic. The unexpected insect issues that farmers face have increased the amount of affected material that is exchanged globally (soil, plants, and seed).

In addition to all of these worldwide challenges, pest-related difficulties such as pesticide resistance, secondary pest outbreaks, and breakdown in host plant resistance have exacerbated the agricultural output crisis. To address these issues, continual and sustainable increases in productivity in all agricultural production sectors are required, as well as careful and efficient use of water, energy, pesticides, and fertilizers, among other resources. As a result, agriculture needs assistance in overcoming these challenges and uncertainties, as well as new solutions for all elements of agricultural production, ranging from better and more predictable product planning to precision agriculture and resource optimization.

Integrated Pest Management (IPM) is currently the most popular and sustainable pest management method. However, this strategy is highly sophisticated and necessitates a high level of knowledge, competence, and observation. In practice, it is required to monitor the pests in the field, determine the most susceptible stage of pests, decide on the most effective control approach (pesticide or other alternative methods), and apply it at the optimal moment. As a result, IPM necessitates thorough field observation, skilled personnel, and data mining. In this context, it has become clear that the employment of artificial intelligence (AI) algorithms is required for efficient control, tracking, and utilization of agricultural inputs.

ORGANIC SUPPLY CHAIN OPTIMIZATION USING AI

A well-functioning supply chain is critical to the success of any business. Having an accurate inventory forecast provides a significant competitive edge. Many internal elements, such as product releases and distribution network development, as well as external factors such as weather, excessive seasonality, and changes in customer perception or media coverage, all have an impact on supply chain performance. In recent years, Artificial Intelligence (AI) has been demonstrated to be an extension of our brain, increasing our cognitive capacities to levels we never imagined conceivable. (Dash)

Though many people fear AI will replace humans, this is not the case; rather, it will enable us to realize our full strategic and creative potential. AI is a collection of computing technologies designed to sense, learn, reason, and behave correctly. With technical advancements in mobile computing, the ability to store large amounts of data on the internet, cloud-based machine learning and information processing algorithms, etc. (Dash)

AI has been integrated into a variety of industries and has been shown to cut costs, increase revenue, and improve asset usage. AI is assisting businesses in obtaining nearly 100% accurate projections and forecasts of customer demand, optimizing their R&D and increasing manufacturing with lower costs and higher quality, and assisting them in promotion (identifying target customers, demography, defining the price, and designing the right message, among other things), and providing their customers with a better experience. (Dash)

The four domains of value generation are critical for achieving a competitive edge. Supply-chain leaders employ AI-powered technology to a) create efficient designs that remove waste; b) provide real-time monitoring and error-free production; and c) promote shorter process cycle times. These methods are critical for bringing innovation to market as quickly as possible. (Dash)

ANALYZING AGRICULTURAL BIG DATA

After entering the twenty-first century, various data explosions occurred as a result of the continuous development of Internet technology, cloud computing technology, and sensing technology; these massive amounts of data can be stored, analyzed, and utilized using storage and cloud computing technology. Based on this context, big data technology was born. Big data are frequently employed in fields such as medicine, metallurgy, mining, agriculture, and aerospace, and they have an impact on human lives. Using big data in agricultural production allows for the timely monitoring of agricultural products and increases agricultural productivity.

Big data refers to data that exceeds the acquisition, storage, management, and analysis capabilities of management analysis tools and traditional databases. Big data are also considered an information asset. It is also a data set that employs standard software tools to acquire, organize, and process data that exceeds the allowable time frame. Big data is fundamentally a data set, and its features can be identified by comparing it to previous data management analytical methodologies.

Agricultural Big Data is a collection of technologies that enable farmers to meet the difficulties of the new data era. Farmers can utilize data in conjunction with machine learning to solve challenges related to decision-making, water management, soil management, crop management, and livestock management. Crop management encompasses yield prediction, disease and weed detection, crop quality, and species identification. On the other hand, livestock management takes into account both animal welfare and livestock productivity.

To provide sustainable agricultural output, cutting-edge technologies such as blockchain, IoT, Big Data, and machine learning (ML) are required, among others. Among these technologies, data-driven agriculture appears to be the most promising for addressing present and future concerns. Most global food problems could be solved if it were able to collect a huge amount of data from farms and utilize it to inform agricultural decisions. Farmers, for example, could use data sets or maps to apply techniques like smart farming, precision farming, vertical farming, and others. It has been proven that data-driven agriculture increases crop yields, lowers costs, and ensures sustainability.

The detection and early warning through the analysis of the collected meteorological data, combined with meteorological simulation, land analysis, plant root situation analysis, and other elements, enhance the prediction accuracy of natural disasters and improve the disaster assessment method to improve the accuracy of prediction; and through agricultural big data, we can provide feedback crop growth data and provide important information and intelligence for crop Big data processing and analysis technology can be used in agricultural decision-making to combine crop growth and development with climate and soil in the crop-growing environment. Provide agricultural producers with more accurate, real-time, and efficient agricultural decision-making while considering economic, environmental, and sustainable development. Sufficient and correct data provide the technical support required for the establishment of a rural integrated information service system.

BENEFITS OF AI IN AGRICULTURE

1. Enhanced Productivity and Efficiency

• AI technologies can automate repetitive processes like planting, weeding, and harvesting, decreasing manual labor and increasing efficiency.

• AI systems can accurately predict weather conditions, pest outbreaks, and agricultural yields, enabling farmers to make informed decisions and optimize their practices.

2. Improved resource management.

• AI-powered technologies enable farmers to apply water, fertilizers, and pesticides at optimal times and locations, decreasing waste and maximizing resource efficiency.

• AI systems can optimize irrigation schedules based on soil moisture and weather forecasts, conserving water and ensuring crops are properly hydrated.

3. Improved crop health and yield.

• AI-powered imagery and sensor technologies enable early detection of diseases and pests, preventing agricultural loss.

• Optimal Planting Strategies: Machine learning algorithms may offer optimal planting dates and patterns based on soil conditions, weather forecasts, and crop attributes, resulting in increased crop health and yields.

4. Sustainable farming practices.

• AI technologies help optimize resource consumption and reduce chemical inputs, resulting in more sustainable farming methods and a lower environmental effect.

• AI can enhance biodiversity conservation on farms by monitoring and managing beneficial insects, birds, and wildlife.

AI IN THE FOOD INDRUSTRY

The Food Industry is an intricate network of diverse businesses that produce and collectively supply food around the globe. It encompasses various stages, from farming and food production to packaging, distribution, retail, and catering. Some key aspects of the food industry include: agriculture, marketing, manufacturing, food services, wholesale and distribution, regulation, etc. The food industry is of utmost importance, as it connects consumers, producers, and the various in a complex cycle. The food industry plays a crucial role in any country's economic and social growth.

Artificial intelligence, or AI, is a collection of technologies that mimic human intelligence. By simulating different facets of human thought and behaviour, machines 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 applicable to a wide range of fields and industries form the foundation of artificial intelligence. Big data is the term used to describe extremely large and varied datasets that come from a wide range of different sources. Together, big data and artificial intelligence (AI) stimulate innovation in a number of industries, including manufacturing, healthcare, and finance, resulting in increased productivity and better services. In the food industry, big data analytics predict market demand, enhance supply chains, and improve safety and quality. Various technologies, including expert systems, fuzzy logic, ANFIS (adaptive network-based fuzzy inference system), big data, blockchain, and smart sensors, enhance food classification, production, marketing, and supply chain management. These innovations improve food safety and quality, while AI aids intelligent production and management, encompassing quality testing, production control, and safety monitoring. (mdpi, n.d.)

EVOLUTION OF THE FOOD INDUSTRY

During the early stages of development, the major focus of food industries was on developing new and efficient hardware, and new processing techniques to improve the efficiency of food production and food processing. These technological innovations were essential to meet the growing demand for food and to ensure food quality. During the nascent stages of the food industry, agricultural advancements were pivotal. Farmers and cultivators focused on improving tools and techniques to enhance crop yield and quality. Innovations included better seed selection, soil management, and irrigation practices. These efforts aimed to maximize agricultural productivity and ensure a steady supply of raw materials for food production.

As the food industry matured, machinery and equipment became essential. Stone mills, presses, and other mechanical devices were gradually introduced. These innovations streamlined food processing, making it more efficient. For example, stone mills helped grind grains into flour, while presses extracted oils from seeds. The goal was not only to process food but also to maintain its freshness and nutritional value.

Simultaneously, food processing techniques have evolved. Methods such as curing, drying, and smoking have emerged. These practices extended the shelf life of food products, allowing for better storage and transportation. For example, drying (Sun-drying fruits, vegetables, and herbs to remove moisture, preventing microbial growth.)

These preservation methods were crucial for ensuring food availability beyond immediate harvest seasons. They laid the foundation for a more diverse and resilient food supply chain.

The early food industry was also concerned with the efficient connection of the entire food chain, in addition to the development of processing technology and hardware. Producers of raw materials, processors, and retailers did not work closely together or share information, which resulted in inefficient supply chain management, excess inventory, and food waste. The food industry has begun to implement a more extensive supply chain management system in an effort to address this issue.

Thus, technologies such as AI, ML, Big Data analytics are readily being incorporated into the food industry, in order to improve food quality and security, supply chain optimization, personalised nutrition, farming optimization, and product development. (mdpi, n.d.)

TECHNOLOGICAL ADVANCEMENTS IN THE FOOD INDUSTRY

The food industry is currently going through a digital revolution as a result of ongoing technological advancements. While big data analytics has improved understanding of customer needs, automated production and smart manufacturing technologies have increased production efficiency. Furthermore, blockchain technology improves the supply chain's traceability and transparency, ensuring the safety of food. Simultaneously, new technologies like virtual reality and 3D-printed food also created new opportunities for food innovation in the future. In the last few decades, modern technologies like AI and ML have effectively helped food companies in generating more revenue and improving their productivity. AI has also enabled the world to efficiently optimise the supply chain problems, computerise the food industry, and transfigure food industries products.

However, the future of AI in the food industry is not just limited to these kinds of tasks. Moreover, food processing, storage, and delivery can all benefit from it. Minimising the cost of packaging can also be greatly aided by intelligent devices like robotics and intelligent drones. It will also assist with the delivery of food items, finishing tasks in dangerous environments, and supplying excellent-quality products. AI's significant contributions to the food industry can be broadly divided into two categories: food security management and food quality management. (Wiley, n.d.)

APPLICATIONS OF AI IN THE FOOD INDUSTRY

The world population is projected to reach 9.8 billion by 2050 (UN). In order to feed such a vast population, the agriculture sector would need to increase its productivity by about 70%. To successfully achieve this, technologies like AI will have to be a core unit in the food industry. Here are some applications of AI in the food industry:

SORTING

Sorting food requires an extra amount of focus in order to ensure the quality of food, helping companies make decisions on the processing of diverse foods, ultimately increasing the purchase rate of consumers. Companies in the food industry such as TOMRA Food, utilise artificial intelligence with the help of cameras and near-infrared sensors, to create, design, and modify steam peeling and food sorting. For fresh produce and processed foods, such as fruits, vegetables, nuts, meat, fish, confections, grains, seeds, and pet food, they provide AI-based industry-leading solutions. By eliminating foreign objects, product flaws, and cross-contamination, their technology contributes to the protection of food safety. Furthermore, TOMRA Recycling, a TOMRA division, has created applications that use deep learning technology to distinguish between plastics that are suitable for food and those that are not. (Analytics of life, n.d.)

REDUCING EQUIPMENT REPAIR AND MAINTENANCE COSTS

A high portion of a company's resources are utilised in equipment repair and maintenance. Recent studies suggest that an AI-based system known as the Self- Optimising-Clear-In-Place (SOCIP) can improve the cleaning time and drastically reduce the number of resources utilised for it. This AI-based technology employs features such as optical fluorescence imaging and ultrasonic sensing, to detect even a minute quantity of food waste and microbial debris present in the machine. This can thus aid in the optimization of the maintenance process. Food companies can also utilise AI in optimization of equipment repair and periodic optimal functioning check. It can swiftly detect any fault in the equipment and group them for immediate replacement of inoperative components, optimising employee work efficiency. (Analytics of life, n.d.)

OPTIMISED SUPPLY CHAIN MANAGEMENT

The food industry can employ AI to minimise delays in product supply and maximise profit margins by providing a focused monitoring of each and every supply chain operation. This assist companies to predict optimal management of cost and stock food products accurately.

AI combines technologies such as 2D/QR codes to offer end-to-end traceability. From farm to plate, these codes enable smooth supply chain monitoring at every stage. This openness guarantees the quality and safety of the food.

Campbell Soup, a well-known food company employs AI for a number of functions, such as supply chain optimization, predictive maintenance, and quality control.

Another food company, Panera, utilises AI to help in increasing customer satisfaction, optimising operations, and improving its menu selections. Data is analysed to customise meal options and streamline supply chains. (foodindustryexecutive, n.d.)

REVOLUTIONIZATION OF IN-STORE EXPERIENCE

Based on the currently available demographic statistics and data, various food companies have been able to provide various location-specific food-flavour combinations, targeting a focused area of consumers. Food companies can utilise AI, to analyse a plethora of consumer data and identify different sentiments or behaviours, enabling them to not only build positive experiences, but also in the development of new and unique food and beverage product lines. This can help the food industry to offer a wide variety of food combinations, spices, beverages and ingredients.

Wingstop utilises AI to streamline operations throughout its chain of restaurants. AI improves productivity and customer experiences in a variety of fields, including inventory management and personalised marketing. (Analytics of life, n.d.)

PERSONALISED CUSTOMER SERVICE

In recent times, food companies have realised that customers prefer a more personalised experience while they shop. By utilising AI- powered food assistance (employing natural language processing), companies can access consumer shopping history data to provide a personalised and automated customer service experience. Customers can now receive recommendations based on their personal preferences and dietary needs.

Prominent retailers like Domino's and McDonald's have integrated AI-driven voice assistants into their drive-thrus and stores. Orders are handled effectively by these systems, which are always learning from user interactions to increase accuracy and enhance the user experience. (foodinstitute, n.d.)

CHALLENGES AND FUTURE PROSPECTS

Artificial intelligence (AI) is transforming the food sector in a number of ways, including distribution, customer service, production, and processing. In fact, in the food and beverage industry, the AI market is projected to reach USD 9.68 billion in 20241.Over the course of the forecast period, it is anticipated to grow at a CAGR of 38.30% to reach USD 48.99 billion by 2029 (Modorintelligence, 2024).

Nevertheless, in order to fully realise its potential, a few issues need to be resolved. AI systems need vast amounts of high-quality data, yet the food industry's data can be inconsistent, fragmented, or unstructured, requiring standardised data gathering and sophisticated processing techniques. The deployment of AI comes with high upfront costs for infrastructure, software, and personnel acquisition. To mitigate these costs, public-private collaborations, government subsidies, and staggered implementation are recommended. In order to ensure smooth integration and efficiency, the industry's intricate supply chains, which involve numerous stakeholders ranging from farmers to merchants, necessitate interoperable AI solutions and improved communication.

Furthermore, AI systems must be created with safety and quality standards in mind, as well as attention to stay up to date with regulatory changes, due to strict regulatory compliance that varies by location. Investment in training and development programs and cooperation with academic institutions are required to close a sizable skills gap in AI expertise. Strong ethical rules, openness in AI applications, and workforce transition plans are required in response to ethical and social concerns about data privacy, job displacement, and the moral use of AI.

Despite various obstacles, AI's prospects in the food sector are very bright. AI can improve supply chain management by anticipating demand and cutting waste. It can also maximise precision agriculture using technologies like drones and IoT devices to increase yields and sustainability. Finally, AI can improve food safety by monitoring and analysing data in real-time to detect potential contamination. AI-driven customer care can provide more individualised and effective interactions, while personalised nutrition can be customised based on dietary preferences and individual health data. AI may also help environmental projects by encouraging resource efficiency and lowering food waste, and it can speed up product creation by assessing consumer preferences and optimising formulations.

By working collaboratively with governments, technology providers, and industry stakeholders to overcome these obstacles, artificial intelligence (AI) will be able to create major improvements that will shape the future of the food sector with greater safety, sustainability, and customer satisfaction. (Tijssen, 2019)

CONCLUSION

The food industry is experiencing a significant transformation through the integration of artificial intelligence (AI). Initially focused on developing new hardware and processing techniques, the industry now incorporates advanced technologies like machine learning, big data analytics, and blockchain. These innovations enhance production efficiency, supply chain management, food safety, and personalised customer experiences. In the food and beverage industry, the AI market is projected to reach USD 9.68

billion in 2024. Over the course of the forecast period, it is anticipated to grow at a CAGR of 38.30% to reach USD 48.99 billion by 2029.

AI applications such as sorting, reducing maintenance costs, optimising supply chains, revolutionising in-store experiences, and providing personalised customer service have shown substantial benefits. Companies like TOMRA Food, Campbell Soup, and Panera are leveraging AI to improve food quality, optimise operations, and enhance customer satisfaction. In India, AI advancements are evident in ventures like The Yellow House Robot Restaurant, the "Robot" Restaurant in Chennai, and Mechanical Chef.

Despite promising prospects, challenges remain, including the need for high-quality data, high initial costs, complex supply chain integration, regulatory compliance, and a skills gap in AI expertise. Addressing ethical and social concerns is also crucial.

Collaborative efforts among industry stakeholders, policymakers, and technology providers can overcome these challenges. AI has the potential to drive significant advancements in the food industry, ensuring increased safety, sustainability, and consumer satisfaction. This digital revolution holds the promise of meeting growing global food demand and creating a more efficient, resilient, and innovative food industry.

References

1.Di Vaio, A., Boccia, F., Landriani, L., & Palladino, R. (2020). Artificial intelligence in the agri-food system: Rethinking sustainable business models in the COVID-19 scenario. *Sustainability*, *12*(12), 4851..

2. Kakani, V., Nguyen, V. H., Kumar, B. P., Kim, H., & Pasupuleti, V. R. (2020). A critical review on computer vision and artificial intelligence in food industry. *Journal of Agriculture and Food Research*, *2*, 100033.

3. Kumar, I., Rawat, J., Mohd, N., & Husain, S. (2021). Opportunities of artificial intelligence and machine learning in the food industry. *Journal of Food Quality*, *2021*(1), 4535567.

4. Liu, Z., Wang, S., Zhang, Y., Feng, Y., Liu, J., & Zhu, H. (2023). Artificial intelligence in food safety: A decade review and bibliometric analysis. *Foods*, *12*(6), 1242.

5. Taneja, A., Nair, G., Joshi, M., Sharma, S., Sharma, S., Jambrak, A. R., ... & Phimolsiripol, Y. (2023). Artificial intelligence: Implications for the agri-food sector. *Agronomy*, *13*(5), 1397.

6. Hajkowicz, S., Sanderson, C., Karimi, S., Bratanova, A., & Naughtin, C. (2023). Artificial intelligence adoption in the physical sciences, natural sciences, life sciences, social sciences and the arts and humanities: A bibliometric analysis of research publications from 1960-2021. *Technology in Society*, *74*, 102260.

7.Babu Loganathan, G. (2021). Recent Scope for AI in the Food Production Industry Leading to the Fourth Industrial Revolution. *Webology*, *18*(2), 1066-1080.

8. Zakeri, A., & Lei, Y. (2024). AI in the Swedish Food System: Exploring Adoption, Challenges, and Opportunities in Primary Production through a Socio-Technical Lens.

9. Nayak, J., Vakula, K., Dinesh, P., Naik, B., & Pelusi, D. (2020). Intelligent food processing: Journey from artificial neural network to deep learning. *Computer Science Review*, *38*, 100297.

10. Gao, R., Liu, X., Xiong, Z., Wang, G., & Ai, L. (2024). Research progress on detection of foodborne pathogens: The more rapid and accurate answer to food safety. *Food Research International*, 114767.

11. Anggraeni, M. C., Silaban, C. A., Anggreainy, M. S., & Cahyadi, E. (2021, September). Role of artificial intelligence in the management of food waste. In *2021 2nd International Conference on Artificial Intelligence and Data Sciences (AiDAS)* (pp. 1-6). IEEE.

12. Bulbulia, A., & Safdar, M. (2022). Effect of Artificial Intelligence in Digital Era on Service Accuracy in Food Industry. *Business Review of Digital Revolution*, *2*(2), 19-27.

13. Prakash, G., Mishra, R. K., Meena, P., Pandey, D., & Pandey, V. K. (2023). Application of Computer-aided Artificial Intelligence Techniques in Food Industry. *Current Journal of Applied Science and Technology*, *42*(34), 23-31.

14. D'Amore, G., Di Vaio, A., Balsalobre-Lorente, D., & Boccia, F. (2022). Artificial intelligence in the water–energy–food model: a holistic approach towards sustainable development goals. *Sustainability*, *14*(2), 867.

15. Dora, M., Kumar, A., Mangla, S. K., Pant, A., & Kamal, M. M. (2022). Critical success factors influencing artificial intelligence adoption in food supply chains. *International Journal of Production Research*, *60*(14), 4621-4640.