

APPLICATION OF ARTIFICIAL INTELLIGENCE (AI) AND INTERNET OF THINGS (IOT) IN FOOD PROCESSING

Abstract

In order to feed a world population that is expanding quickly while maintaining the highest standards of quality, the agricultural and food businesses must overcome enormous obstacles. In these extreme weather conditions, such as drought, flooding, restricted land, changing dietary preferences of people, as well as various issues facing the food industry, etc., they must assure the best conservation of our limited natural resources. This is a challenging task. In order to meet this demand, the food industry is converting from older ICT technologies to more modern ones like the Internet of Things (IoT) and artificial intelligence (AI). It can offer improved tracking and analysis of the movement of food from fields to plates. It might hold the key to modifying the steps from start production farming to the finished good served. Every phase of the food manufacturing process is affected. It decreases food, time, and resource waste, raises food quality, boosts yield, and increases profits. Future leaders in the agricultural and food industries will be those who make the most use of this technology's potential. The Internet of Things and artificial intelligence are the way to produce food sustainably in the future.

Keywords: Demand of food, ICT technologies, Internet of Things (IoT), Artificial Intelligence (AI)

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I. INTRODUCTION

In recent years, there have been many speculative discussions around the world on how to produce food and what factors affect commodities markets in a demand-supply chain. These revelations have caused grave concern about humanity's ability to withstand the high food demand and sustainability required to feed the expanding human population. Issues including the dramatic increase in global population, the gradual rise in income levels in developing nations, global warming, and other environmental dangers brought on by mankind over a long period of time. Particularly, the increased need for food supplies calls for sustainable production practises and comparable production values. The United Nations' Food and Agricultural Organization (FAO) predicted that the world's population will increase and reach 9.1 billion by 2050 (Godfray *et al.*, 2010). This estimate completely disproves the necessity for a growth in food supply of 70% globally and nearly double in underdeveloped nations. Food, also known as ration, is a necessity for humans and is considered the best product of farming. It is created when farmers distribute the various foodstuffs they have produced. Products from the food business are essential for any nation's development (Abassi *et al.*, 2014). It also plays a big part in how the national economy and the global economy are developing. Therefore, it is crucial to ensure the safety of food sector products and their high quality through appropriate distribution. Artificial intelligence (AI), a recently developed technology, has been successful in achieving the required goals in recent decades. Investigating the AI-based smart agriculture and advanced food business issues is crucial. Such methods satisfy social requirements and deliver high-quality goods on schedule. The food sector can create a lot of food goods quickly thanks to these current technology, which will exponentially boost the company's economy (Misra *et al.*, 2020).

Google Trends search history for topics Internet of Things, Industry 4.0, and Artificial Intelligence shows how there is increasing trend in people to know about these topics, to work on these topics, to research on these topics. Figure 1 displays the relative worldwide search traffic for these terms over the last decade. Numbers in the graph represent relative search interest to the highest point at a given time. It can be observed that although artificial intelligence was in use since long, the term Industry 4.0 is quite recent. Internet of Things has been there for more than two decades but major work in the area has been started recently.

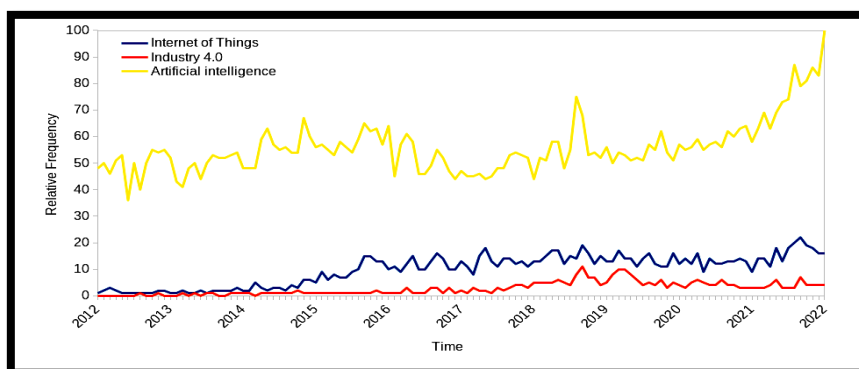


Figure 1: Relative Worldwide Search Traffic for the Terms Internet of Things, Industry 4.0, and Artificial Intelligence on Google Search Engine over the Last 10 Years. Data Accessed from Google Trends. Numbers Represent Relative Search Interest to the Highest Point at a Given Time.

Artificial intelligence-based systems or autonomous systems are widely used in almost every aspect of technology. It makes it possible to effectively transform food business products, computerise the food industry, and optimise difficulties (**Soltani-Fesaghandis, G., and Pooya, A., 2018**). The industry can evaluate and ensure that the ideal conditions, such as seed selection, crop monitoring, watering, and temperature monitoring, can be enhanced by employing a computerised system, which will result in the excellence of the food sector products (**Vadlamudi, 2018**). These are not the only applications of AI. Additionally, it can be useful for food processing, food storage, and food delivery. Robotics and intelligent drones are two examples of intelligent devices that can significantly and critically contribute to reducing the cost of packaging. It will also assist in transporting the food products, finishing the operation in hazardous conditions, and giving extremely high-quality goods (**Bera, 2021**).

With the rapid advancements in technology sector, smart devices can interact and communicate with each other with the use of the Internet. These smart devices have the capabilities to sense, communicate, and actuate. These systems are also able to retrieve, collect, store, and process real time data. Internet of Things (IoT) has now become part of our everyday life with the ever growing technology such as intelligent personal assistant (alexa by Amazon, siri by Apple, etc). IoT has application in vast range of domains as it is widely used in automation. Some of the important domains for application of IoT are Agriculture, Transportation and Logistics, IT sector, Smart Offices/Homes, Industry etc. Temperature, soil moisture, automated irrigation are some of the application of IoT in agriculture. IoT has specific application in intelligent manufacturing and modern industries known as industrial internet of things (IIoT). Since it is related to industrial domain, it is quite related to Industry 4.0, also known as fourth industrial revolution (**Georgios et al., 2019**).

The term “Industry 4.0” was coined by German government in 2011 to promote application of IoT and digitization in manufacturing (**Griffiths and Ooi, 2018**). The fourth industrial revolution is being implemented on third industrial revolution which already saw application of computers and robots in the industry. Industry 4.0 can be characterized by application of information and networking technologies for manufacturing process. Due to networking of all the system in the industry, cyber-physical production systems are evolved leading to smart factories. In the smart factories, people, all the components of production system communicate with a network leading to nearly autonomous production in the industry.

II. ROLE OF AI AND IOT IN FOOD INDUSTRY

Nearly every profession is impacted by artificial intelligence. Big data, robots, and the Internet of Things have all been developed as a result of it, and it will continue to be a technological trailblazer in the foreseeable future. In order to remain and succeed in the market, restaurants must now digitalize their entire end-to-end operation, from production to manufacturing floors. Restaurant entrepreneurs are using robotics, e-commerce, and smart food-management systems to digitise their end-to-end operations, from production to manufacturing floors, taking their enterprises' digital autonomy. The use of AI and ML in the food industry contributes to cost reduction and increased food output. It helps in food production, preservation, and preparation. Digital compliance documents are sent for the food

supply chain, as well as the most well-known industry, catering services, and distribution, using the cloud.

The industry that promotes the highest employability among the many industrial firms worldwide is the food processing and handling sector. The efficient manufacture and packaging of food goods depends heavily on the human workers. Because humans are interconnected, the food industries are unable to maintain the demand-supply cycle and are also lacking in food safety. The best solution for these issues facing the food sector is industrial automation. The Internet of Things (IoT) and artificial intelligence (AI) machine learning (ML) or deep learning (DL) algorithms provide the basis of all automation (AI). Food production and distribution procedures can be expertly managed utilising the AI-based system, which also improves operational proficiency. AI has the potential to greatly improve packaging, self-life extension, menu arrangement utilising AI algorithms, and food safety by facilitating a more open supply chain management system. Robotic farming, smart farming, and drones will be the foundation of the food businesses of the future, thanks to AI and IoT. The sensors used in IoT generate vast amount of data which can be used in AI for various improvements in food industry. These data can be stored in structured database which can be used to get trends and demand in the industry. The basic area in the food industry is agriculture which is most unpredictable due to uncertainty of weather conditions due to climate change. But the same can be optimised with the application of AI and IoT. Application of AI and IoT in different agricultural operations has increased the productivity. IoT devices provide information on various factors such as environment factors, growth conditions, irrigation, soil condition and pests (**Dolci, 2017**). Several studies have been done and are being done for application of IoT in crop monitoring, automated irrigation and crop cultivation. Integration of global positioning system (GPS) can provide various environmental condition related information. With the use of sensing technology such as RFID, management of livestock has become very efficient. It is being used in livestock industry to monitor livestock behaviour. Application of IoT and AI has led to increased production in livestock based food items from milk to meat.

According to FAO, one third of all food produced is either lost or wasted. Horticultural and livestock products are most perishable in nature. They are most sensitive to changes in temperature. Transportation is one such part of supply chain of food products where efficient management of produce and monitoring of temperature is crucial. 14% of world's food loss takes place between harvesting and retail. In India, post-harvest loss amount to 25-30% of total produce. For perishable produce, loss during transportation stage is 10-20%. With the application of new technologies such as AI and IoT optimum temperature can be maintained throughout the transportation resulting in reduced food loss.

During the retail phase, application of IoT and AI can bring good profits to retailers. One of the application in retail phase is on-shelf availability of products. By tracking the on-shelf availability, retailers can ensure maximum benefits and can satisfy the customer demand. Similarly, retailers can track the consumer's food habit and trend to pre-order products. IoT can be used in big retail shops for real-time pricing mechanism to provide some kind of offer to the consumer. Application of RFID and near field communication (NFC) with trollies can help in auto-checkout which will provide extra consumer satisfaction as customers will not be waiting in long queues to checkout (**Nukala et al., 2016**).

Application of AI and IoT has led to emergence of cloud kitchen. Cloud kitchen are implemented concept of AI in food industry where consumer's food habit is analysed to reduce food loss. Based on consumer's food habit and demand, food is prepared in a central kitchen and transported to different outlets to meet the consumer demand. These data are first gathered over a period of time to track the trend and demand of food by the consumer. Along with food processing, the food handling sector is also significant, and AI plays a significant role in managing the workload of the entire processing unit in this sector. The figure illustrates some significant applications drawn from the food handling and processing sector (Kumar *et al.*, 2021).

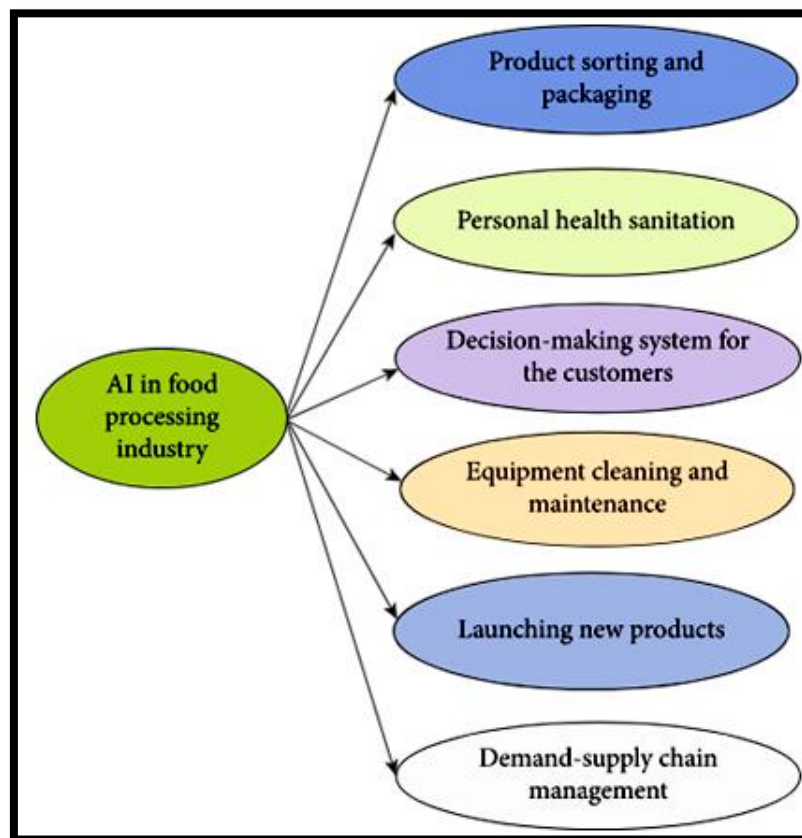


Figure 2: Data Analysis at Food Industry

- 1. Food market analysis:** Being one step ahead of the competition is even more crucial because consumer and market expectations are changing quickly. By segmenting customers into various demographic groups and simulating consumer preference behaviour or anticipating what they will need — even before they do — AI/Machine Learning understands the human sense of preferences and taste.
- 2. Production optimization:** AI has enormous potential to increase output and identify the optimal operating conditions for manufacturing facilities to meet and even surpass KPIs. A few of its uses may be quicker production changeovers, a reduction in the time needed to move from one product to another, and the identification of production bottlenecks before they become an issue.

3. **Waste reduction:** AI based methodologies to monitoring and measurement can have a massive influence on waste reduction. Rather than waiting until the end of a batch or cycle to check the quality of product, AI that uses real-time monitoring can detect glitches as soon as they happen.
4. **Supply chain management:** Artificial Neural Networks based algorithms on can check and monitor the process of AI food delivery and products tracing at every stage, making it secure and providing transparency. Likewise, it makes pricing and catalogue predictions, which avoids additional costs.
5. **Hygiene:** The use of AI offers enormous potential for improving the hygiene and cleaning tasks that are so important for beverage and food facilities. In order to establish the appropriate cleaning duration, an AI-powered multi-sensor system can detect food residue and microbiological debris on equipment.
6. **Developing new products:** Predictive algorithms and machine learning are used by AI technology to develop a model for consumer taste preferences and predict how well they will respond to new flavours. The records can be segmented into demographic groups to help corporations develop new foodstuffs that match the preferences of their target consumers. With these, producers could know what products will thrive before the hit the tables.
7. **Anticipating consumer preferences:** Food producers use artificial intelligence-based solutions that let them model and predict the flavour preferences of their target audience as well as how they will react to novel flavours. Predictive analytics powered by artificial intelligence will assist food producers in creating new food items that are closely matched to consumer tastes and preferences. The Kellogg Company introduced an AI-enabled technology in 2017 to assist consumers in selecting the 50 ingredients for granola that should be used to create a specific custom-made manufactured commodity. The AI also plays a significant part in suggesting which ingredients to include in granola and determining whether or not certain combinations of ingredients will taste nice.
8. **Sorting fresh produce:** One of the main tasks faced by food processing plants relates to the unbalanced accessibility of feedstock. Food processing plants depend on labour-intensive sorting to sift and sort vegetables, leading to loss of productivity and increased expenses.

III. SCOPE OF ARTIFICIAL INTELLIGENCE IN THE FOOD PROCESSING SECTOR

1. **Selecting raw produce:** One of the most serious problems that food manufacturing facilities face is the volatility of feedstock sources. In food processing facilities, manual sorting is employed to separate and filter vegetables, which results in lower efficiency and greater expenses. AI can assist food manufacturing firms increase efficiency in food classification by combining scanners, cameras, and machine learning to enable more efficient food sorting (Nosratabadi *et al.*, 2020). By merging AI with sensor-based visual sorting techniques, for example, time-consuming activities for sorting local food can be

minimised, leading to better yields, better quality, and less garbage. (Marr, B., 2017). AI is being used to better adapt robots to manage a variety of item forms while lowering waste and costs (Kakani *et al.*, 202).

2. **Efficient supply chain management:** Given the rising need for transparency, supply chain control is a crucial duty for all food businesses. To guarantee supply chains are developed in accordance with consumer and industry needs, the food company tracks and analyses products for food safety at every stage of the supply chain. A more accurate forecasting system is required to manage price and supplies (Jayashankar *et al.*, 2020). Product sourcing is made easier and more efficient by AI-based picture recognition technologies. AI also helps with efficient and effective product monitoring from producer to consumer, boosting consumer confidence. (Rawat *et al.*, 2021).
3. **Observance of food safety:** AI-enabled sensors are employed in food establishments to make sure that food employees obey safety regulations, and technologies like face recognition and object identification are utilised to check whether personnel are following the Food Safety Act's requirements for excellent personal hygiene.
4. **Equipment for food processing cleaning:** Current cleaning procedures are set up to clean devices at regular intervals. By reducing human interaction, the risk of food-borne virus cross-infection is reduced. On the contrary, this technology operates in the dark and is built for worst-case scenarios. Using AI-enabled technology (SOCIP), which analyses food waste and microbiological material in a piece of equipment using infrared waves and optical fluorescence scanning, to better the removal process (Tsakanikas *et al.*, 2020). The amount of energy, time, and water used decreases as a result (Garton, K., 2020).
5. **Anticipating consumer preferences:** Food producers use artificial intelligence-based solutions to study and predict the flavour preferences of their target customers and to predict how they will respond to new flavours. Data analytics powered by artificial intelligence will help food manufacturers create new foods that are closely correlated with consumer tastes and preferences.

IV. POTENTIAL PROSPECTIVE

Growing population has a significant impact on things like government initiatives and international business. Finding a balance between food production and consumption in emerging countries with expanding populations is the most urgent issue related to this topic. To address specific problems and preserve efficiency, private and public investors are attempting to integrate AI and image processing advances into sectors like food, agriculture, and industrial. This element serves as the foundation for the country's improved financial situation, which is made possible by the moderate increase in technological improvement. Government efforts to improve the effectiveness of the food supply are being implemented, especially in nations like China and India, by using technologies like deep learning and information analysis. For instance, Google and Microsoft are donating their technologies to these countries and helping to build a sustainable global economy. For instance, utilising deep learning techniques, Microsoft and the ICRISAT organisation of the Indian government implemented Microsoft Cortana Smart Suite for agricultural information gathering and analysis.

V. CHALLENGES TO THE ADOPTION OF AI TECHNOLOGY IN FOOD BUSINESS

The previous ten years have seen numerous changes in the food and beverage business as a result of the quickly shifting consumer behaviour, technology advancements, and stringent rules and regulations. Such issues have overwhelmed the food and beverage manufacturing industries with a series of hurdles. In food and beverages marketplace the development of the global AI is driven by factors such as dynamic changes in purchasing pattern of clients who are choosing to prefer for food that can be provided fast, including food that can be accessible simply and at economical costs. The adoption of AI technology contains obstructions like:

- 1. AI deployment cost:** Which means that only giant companies in the food industry come up with the money for it. The instruments and technologies used in artificial intelligence are very expensive and requires huge amount to established as well as also high cost maintenance. It also high skill person team to manage and controlled it.
- 2. Cultural challenges:** The use of AI is accompanied by dread, as is the case with any technological developments. The fear that humans will lose their employment to computers as computers take over, the concern that such technology could be used negatively in the future and the fear that power will be concentrated in the hands of a small number of people. These could make businesses less inclined to adopt AI.
- 3. AI technology is still in infancy stage:** Specialized skill sets in data gathering and analysis are becoming more and more important. Many organisations are hesitant to invest in artificial intelligence (AI) as a new technology until it is clear how effective or valuable it will be. Increased openness and greater customer involvement in decision-making are requirements of AI technology. This presents a dilemma because businesses in the food and beverage industries are renowned for jealously guarding their top-secret secrets.
- 4. One track minds:** The vast mainstreams of AI implementation in use are extremely specialised. They perform a single activity and practise it until they get better and better at it. In order to provide the most effective output, it simulates what would occur given every configuration of input value and measures the result.

Food processing businesses may significantly automate the food categorization process by utilising artificial intelligence. They can do this by combining lasers, cameras, and machine learning to sort food more effectively. For instance, by deploying AI involving sensor-based optical sorting solutions, the delayed time-consuming processes for sorting fresh food can be removed, leading to higher yield with better quality and lesser wastage. AI is utilised to standardise machines more effectively so they can handle a variety of produce sizes, reduce waste, and save money.

In order to estimate sales results for a given period of time, artificial intelligence takes data from historical a record that has been processed using AI-enabled algorithms. AI mostly helps food producers and merchants by enabling them to comprehend their

customers more fully. The ability of businesses to identify client tastes and preferences will enable them to forecast potential sales patterns for their goods. Due to the fact that controlling the supply chain is still a significant challenge for many F&B businesses, AI can contribute to more transparency in how businesses operate.

VI. CONCLUSION

In order to meet the food demand, the food industry is converting from older ICT technologies to more modern ones like the IoT and AI. The food business is now using artificial intelligence at its most basic level. Because AI can improve sanitation, food safety, and waste management systems, its role is expanding daily. AI will change the food processing sector in the future since it has the ability to produce productivity that is reasonable and healthy for both clients and staff. By reducing human error in manufacturing and, to a lesser extent, surplus goods, the use of AI and IoT in food production and restaurant enterprises is already elevating the industry. It offers inexpensive shipping and packing costs, increased customer satisfaction, quick services, voice searching, and more individualised orders. Large food factories can also profit from these business advantages, which will ultimately result in clear benefits. The food sector is becoming better and more efficient thanks to artificial intelligence, and additional improvements are on the horizon. Due to its capacity to decrease waste, forecast product markets, enable round-the-clock efficient and effective monitoring, improve cleanliness, manage costs, and boost income, AI is playing an increasingly significant role in the food sector. Future leaders in the agricultural and food industries will be those who make the most use of this technology's potential. The Internet of Things and artificial intelligence are the way to produce food sustainably in the future.

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