Artificial intelligence and its uses in the modern food industry

The concept of food safety is to ensure that the food does not contain any microbial, chemical, or physical contaminants during preparation, transportation, and storage and should not cause any disease or illness to the consumers. With the increasing population growth, consumers' expectations and awareness havebeen raised more than ever.

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To satisfy the present demand, the food industry needs fast and accurate analysis and monitoring techniques to ensure food safety throughout the supply chain. Some modern approaches to ensure food safety are the usage of automated analysis techniques (AATs) along with artificial intelligence (AI), like computer vision (CV).

Artificial intelligence (AI) is defined as a field of computer science that imitates human thinking processes, learning ability, and storage of knowledge. The use of artificial intelligence is being increased by leaps and bounds and its use has spread across all industries including food. Landing and use of AI are profoundly aiding food producers and manufacturers in different ways.

The AI technique addresses the problems of limitation and non-availability of the human workforce. It further aids in terms of the vision and application of traditional machines utilising machine learning for better evaluation of issues seen concerning food safety. Other than that the food hazards which often take place due to various causes can also be alleviated with the profound and right application of AI.

Applicability of artificial intelligence in the food industry is growing day by day due to various reasons, which include appropriate management of the supply chain, application of AI in food sorting, production development, classification and prediction of the quality parameters, quality control, food safety and proper industrial hygiene.

AI has a variety of algorithms to choose from such as expert system (ES), fuzzy logic (FL), Turing test, cognitive science, artificial neural network (ANN), adaptive neuro-fuzzy inference system (ANFIS), machine learning and logic programming. These various algorithms are often used in different sectors of food processing, handling, and marketing systems efficiently. Some important uses of those algorithms are as follows:

Role of expert system (ES)

Knowledge-based ES is a computer program capable of simulating human expert-like reasoning and decision-making within a special domain of expertise. This system is based on the knowledge of the experts. The main components of the expert system (ES) are the human expert, knowledge engineer, knowledge base, inference engine, user interface, and user.

The knowledge-based expert system applies to the fermentation process of white wine production through supervision, intelligent control, and data recovery. ES is used to calculate the nutritional value of the food essential for the users. Process design, safety management, quality of food, and risk assessment are the issues about food safety that can easily be handled and controlled by the use of ES.

Fuzzy logic (FL) in food application

This was first introduced by Zadeh in 1965 based on the impeccable capability of human intellect in decision-making and unravelling imprecise, uncertain, and ambiguous data while solving problems. The simplicity and ability to solve problems very fast and accurately means that this system is popular.

FL has been employed in the food industry in food modelling, control, and classification and in addressing food-related problems by managing human reasoning in linguistic terms.

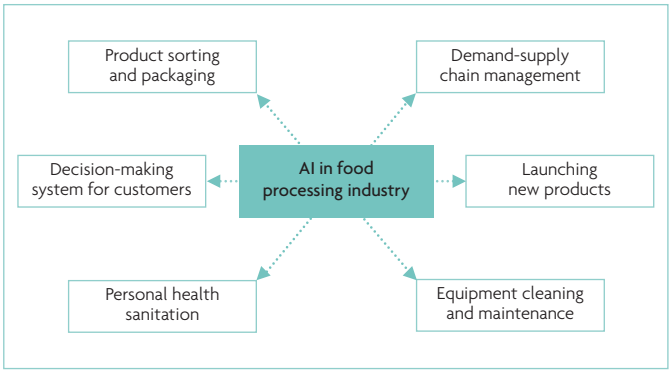

Fig. 1. Opportunities of AI in Food processing industry (Di et al., 2020).

Artificial neural network (ANN)

ANNs correspond to computational systems that aim to imitate some properties of biological neurons. Owing to its adaptability, ANN methods have been successfully employed by numerous researchers to model and predict many different processes in the food industry, food processing, food engineering, food properties, and quality control.

Adaptive neural fuzzy inference system (ANFIS)

This is a synergic hybrid system that combines the advantages of artificial neural networks (ANNs) and fuzzy inference systems (FIS). This system can be used in food drying, in modelling various food properties, for example antibacterial activities in vegetable soup, antioxidant activity and anthocyanin content in different ripening stages of sweet cherry, migrants in food packages, fatty acid composition in vegetable oils, and thermal conductivity of various fruits and vegetables. The system can also be used for modelling microbial growth and thermal processing.

Food safety assurance by AI

The role of artificial intelligence in the food industry incorporated food security management and food quality management. Food security management can be enhanced by recognition technologies and image processing. Apart from that, fertiliser management can be improved by using AI. Smart farming and solid monitoring, robocop, and predictive analysis can be improved by using artificial intelligence. These all are linked with the aspect of food safety. For example, traditional machines tend to struggle in inspecting the contamination of sun-dried tomatoes.

However, the process is well-suited for AI. Operational and informational consistency in food safety management could be improved by the use of the application of AI. Retailers around the globe are investing in new automation technology for the collection, sharing, and storage of data used in the management of food safety.

Consistency of practices and information about food safety between the digital and physical entails the food retailers fulfill the increasing needs of both consumers and shoppers. On the other hand, the analytical tools of AI can assemble and create a new data set for inflicting insight into the data sources for issues regarding retail food.

Training for food safety is also influenced by the use of AI and its supporting complex algorithms. Fostering a culture of food safety is essential for gaining the trust of the consumers and reliable culture of food safety is dependent on the

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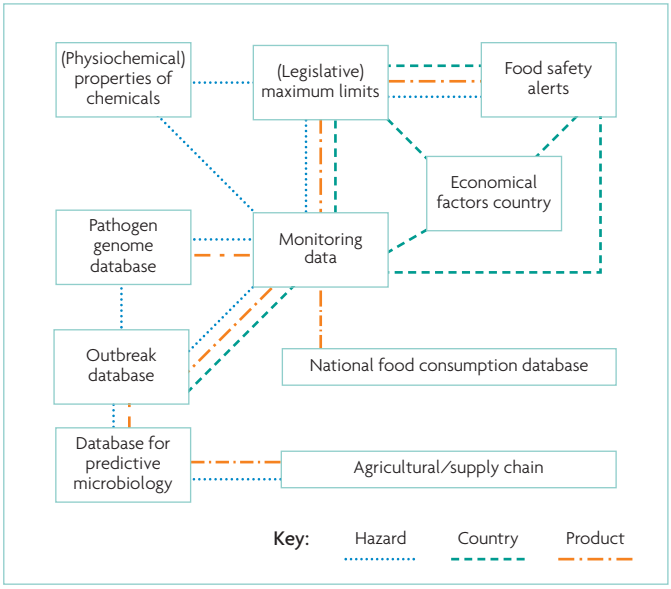

Fig. 2. Possible data linkage for food safety (Vagsholm et al., 2020).

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training programme of food safety focused on the fundamental concept of food safety and its importance.

AR and VR, a few of the Vision artificial intelligence technologies advance the food safety program for consumers and retailers.

AI and hazard assessment in the food processing chain

The HACCP is one of the greatest systems for preventing food hazards to create sustainable foods by eliminating chemical, biological and physical elements. The digital software of HACCP which is served by FoodDocs allows one to have an insight into the management of food safety. The seven principles of HACCP were created by the National Advisory Committee on the criteria regarding the microbiological factor for foods that play the role of the foundation element of the HACCP system.

Analysing hazards, recognising the critical control points (CCPs), and establishing critical limits, CCP monitoring needs, corrective auctions, efficient record-keeping processes, and processes for verifying are the seven principles that play a significant role in eliminating hazardous elements from foods. Conducting a hazard analysis is done for identifying the potential hazards that can be present in the foods. On the contrary, recognising the CCPs in the middle of the process where the hazards could be present and could be prevented or controlled too. In the stage establishing critical limits is the preventive measure that is related to the very critical point.

For instance, a limit that is critical must be satisfied with each CCP whereas suitable critical limits can reflect the regulations of the FDA and FSIS. However, establishing requirements of CCP monitoring is done to ensure the CCP must stay within the limit. A substantial material and measure could be required for the monitoring. The monitoring of CCPs is vital to the process as the next stage, according to the HACCP, needs the establishment of corrective actions.

Establishing corrective actions will be needed if it is found by the substantial monitoring that the CCP is exceeding the prerequisite limit. In the case of any problem regarding the contamination, corrective actions need to be presented in place for preventing further contamination.

In the later stage, establishing an efficient recordkeeping process such as data storing facility within the internal storage system is needed. The software needs these procedures to die because the document of HACCP software may not be working properly. The records should incorporate documents of CCP monitoring and verification of the activities along with the deviation records.

Establishing procedures such as the use of PPE and gloves before the packaging could be established.The verification process could incorporate the process of CCP records, HACCP plan, CCP limits along with microbial sampling.

Food production management and packaging

AI can significantly enhance food production and marketing by improving the packaging of food products with augmented shelf life and a combination of various menus with the use of algorithms of AI.

With the help of machine learning and AI, the food industry's future is wholly dependent on robotic farming, smart farming, and drones.

With the application of AI, supply chain management can be optimised by improving the tracking capabilities of products through the supply chain so that companies can improve product quality control before reaching the customers.

Customer relationships can also be optimised by the use of AI by analysing sales data that has been collected from online stores or physical stores to understand the purchasing behaviours individual of customers.

Based on consumer preferences AI can also help to optimise the product packaging design rather than simply following trends. By application of AI-driven technology customer preferences and needs can be tracked to formulate Customer Relationship Management (CRM), this is done by gathering information through surveys.

Based on the results the companies tailor their products and services according to the requirements of the individual.

Supply Chain Optimisation can be done by using artificial intelligence to streamline the packaging production process from start to finish by integrating multiple data points.

These include throughput timeframes, labour costs of each step involved in production – for example moulding – overall cost savings due the use of automation vs manpower, etc.

Artificial intelligence in post-Covid-19 pandemic

If the perception of Covid-19 is taken into consideration the effect of AI on food safety would be better understood. It is used for maximising the output whilst reducing food waste which is often contaminated with the foods.

On the contrary, the use of automation systems like robotics and automated conveyor belts and other systems enhance food safety by having the ability to screen and remove toxins.

AI sensors such as ultrasonic sensing technology and 'optical fluorescent imaging are now being used to identify the various kinds of residues of food for preventing contamination to percent food hazards.

On the other hand, AI is applied for ensuring the use of PPE, gloves for checking the temperature, and food cleanliness. There are a lot of opportunities for AI in food safety from training management for safety to the delivery of packaged food without any human intervention.

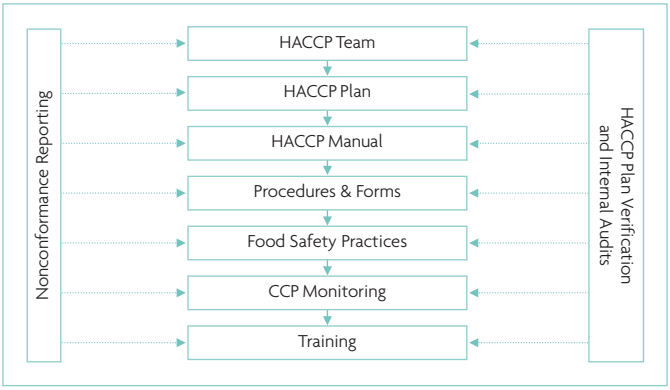


Fig. 3. HACCP system and its components (Ma et al., 2020).

Limitations of AI system application

The challenges like data quality, biased data, and the security of data could be compromised while using AI for the management of food safety. It is known that the quality of machine learning and artificial intelligence is dependent on the input data being high quality.

Biased, incomplete, and inaccurate data lead to harmful outcomes and decision-making on the management of food safety.

Unsupervised learning and its algorithms like DBSCAN and HACCP software help in food safety. Instead of manually searching the biological, physical and chemical, and radiological hazards this HACCP can extract data from HACCP plans.

Inconsistency in high-quality input in data projection can lead to the ineffective decision-making of the algorithms resulting in the need for human intervention for better safety management of food.

Like any other sector, the food industry is also associated with risk due to the overuse of artificial intelligence. Food processing and safety management of foods could be attacked by ransomware.

On the other hand, instead of the physical data and data risk, facilities that are AI-powered could be completely shut down if cybercrimes take place and a cybercriminal infiltrates the password-protected system.

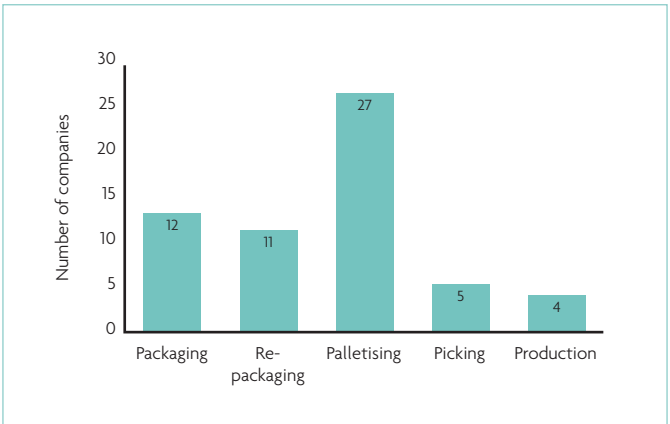
For instance, JBS, the largest meat processor in the world, experienced a large ransomware attack resulting in the shutting down of its monster of outlets across the US. This attack caused food safety management as the safety management could not use the HACCP software to prevent microbial contamination.

Reducing risk whilst maximising the available benefits in the context of AI in food safety begins with the resilience of various organisations assessing both the external and internal threats to the safety management of goods and serving an operational management. This would help in establishing the protection of the food and prevent any kind of microbial contamination.

On the other hand, the most remarkable component regarding the management of food safety is being altered by the use of AI including the sorting procedures of foods.

For the sorting procedure, many companies use robots, automated segregation facilities, and conveyor belts which often aid in the prevention of microbial contamination both in terms of the physical, biological and chemical micro-organisms.

Fig. 4. Prospect of robotics in different segments of food processing industry (Camarena, 2020).



Application of AI by food and beverage processors

Companies such as Coca-Cola, Monginis, JBS, Mars, Danone, Tyson Foods, Cargill, Archer Daniels 'Midland', Anheuser-Busch, PepsiCo, and Nestle are some of the companies that substantially have incorporated artificial intelligence in the safety management of food.

Few of them have incorporated HACCP software for food safety. In the present world, safety management becomes the priority of every food company as it is directly related to the health of the people.

Units of food processing of many companies such as Coca-Cola, Pepsi, and Monginis use AI-powered cameras for ensuring the employees of the company are adhering to the safety protocol and rules of the company.

It entails the unit managers of the companies monitoring their employees whether they are adhering to the safety protocol or wearing safety-appropriate protection gear according to the food safety regulations.

Conclusion

This discussion of artificial intelligence in food safety has established the connection between artificial intelligence and the management of food safety.

It has been found that AI plays a pivotal role in the safety management of all kinds of foods and beverages in the present world. An algorithm such as DBSCAN of unsupervised learning extracts certified data regarding safety management.

On the contrary, the HACCP software establishes a monitoring system for limiting the control points that should not be exceeded. Amidst the pandemic, the world population tends to approach a health consciousness where food safety is foremost important to them.

The popularity of human-operated systems of food safety is on the wane whereas the importance of AI and its applications on food safety is increasing by leaps and bounds.

The beverage industry is no exception.

The water quality measurement tool DO is operated by humans but there is a chance of occurrence of wrong monitoring which could be hazardous in the context of chemical, biological or physical contamination. This paper has also introduced a discussion about the threats and importance of AI in food safety. ■

References are available from the author on request