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Role of Artificial Intelligence in Smart Food Manufacturing

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ABSTRACT

Artificial intelligence is a branch of computer science that can perform tasks that require human intelligence. It helps the food industry to deal with problems of human errors and also in sustainability management. There are different Artificial Intelligence techniques like computer vision, expert system, Artificial Neural Networks, machine learning, deep learning, fuzzy logic. The application of these techniques in all the fields of Agriculture, medicine, IT, and food sectors have been rapidly increasing these days. Especially in food industry this can be applied in any processing step right from farm to fork. These have their application in different food processing techniques like raw material selection, processing, maintaining food quality, eliminating food wastage and marketing. AI can effectively reduce food waste through the optimization of supply chain management, demand prediction, and spoilage reduction. Though these measures can only sustain a part of the food. In order to reach the Sustainable development goals *i.e.*, Zero wastage and good quality can be maintained with advanced techniques. AI tools like Deep learning and Artificial Neural Networks can be used to regulate the amount of logistics for both raw material and final product, Expert system, computer vision in product development and process control, Fuzzy logic, Machine Learning and deep learning in quality control methods, Natural Language processing, Big Data, IOT, data science etc., can be used in marketing by calculating the need for the product in the market and Robotics can be used in the form of collaborative robots or articulate and packaging robots. These AI tools generally use models like linear regression model to analyze data and provide insights on how to reduce food waste. The model is trained using data that includes information about menu items, portion sizes, and ingredients.

Keywords: Artificial Intelligence, Expert systems, Food processing, Food safety, Marketing

INTRODUCTION

With rapid growth in industry artificial intelligence also had its rise in almost all the fields like medicine, agriculture, food, business and have become a part of life. In food processing it can be utilized in all the areas like raw material selection, processing, quality and food safety. AI techniques like machine learning, deep learning, IoT and Big Data etc. The main aim of these artificial intelligence techniques is to assist the human in all the possible ways to give more result in less time. Artificial intelligence tries to mimic the human intelligence using training and data embedded in it. Initially the machine is trained to perform the task from the data stored from the previous results or actions performed by the machine.

Artificial intelligence (AI) is defined as a field in computer science that imitates human thinking processing, learning and storage of knowledge. It can generally be classified into two types namely strong AI and weak AI. The weak AI principle is to construct the machine to act as an intelligent unit where it mimics the human judgments, while the strong AI principle states that the machine can actually represent the human mind (Bandyopadhyay *et al.,* 2021). However, strong AI does not exist yet but the studies on this category of AI is still in progress. It is a creative tool that mimics the human intelligence and ability processes by machines, principally computers, robots, and digital and analog equipment. Several applications of the

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AI include natural language processing (NLP) to comprehend human verbal communication as it is spoken, computer vision to see analog-to-digital conversion such as video, and speech recognition and expert systems to simulate the judgment (Mavani *et al.,* 2022). Machine learning and deep learning tools are labelled and unlabeled models that helps the user to classify the data embedded in it. These AI tools can be a generative or discriminative type that helps in creating or classifying the data. This is mainly based on coding and encoding the data. AI encoding is based on learning/acquiring data and then create algorithms to turn them into actionable information, reasoning, and self-correction as cognitive skills (Day1oglu and Turker, 2021). Artificial intelligence can also be referred to as the simulation of human intelligence through machines that are programed to think like humans and mimic their actions (Misra *et al.,* 2020) from the simplest to more complex tasks. The goals of AI include learning, reasoning, and perception (Debska and Guzowska-Swider, 2011). This term can also be applied to any equipment that exhibit characters associated with a human mind such as learning and problem solving, rationalize and take actions that have the best chance of achieving a specific goal. The continuous evolution of technology benefits different industries to scrutinize its positive and negative consequences. Today, due to the rise of big data and improvements in computing power, AI has entered the agriculture and allied fields as well (Copeland and Proudfoot, 2004).

The Fig 1 details about different AI components like Machine Learning and deep learning, Natural Language Processing, Computer Vision and Robotics in the food industry. As technology continues to progress, the food industry is undergoing through a lot of digital transformation. These mainly require the data transformation and signal processing. Automated production and intelligent manufacturing technologies have improved production efficiency, while big data analytics and block chain technology provide better insight into consumer needs. In addition, blockchain technology enhances the transparency and traceability of the supply chain, providing security for food safety (Day1oglu and Turker, 2021). At the same time, emerging technologies such as 3D-printing food and virtual reality like computer vision also open up new possibilities for future food innovation. These digital trends provide a solid foundation for the application of artificial intelligence and big data, and this article will further explore big data, blockchain, and artificial intelligence and their key roles and advantages in the food industry (Ben Ayed and Hanana, 2021).

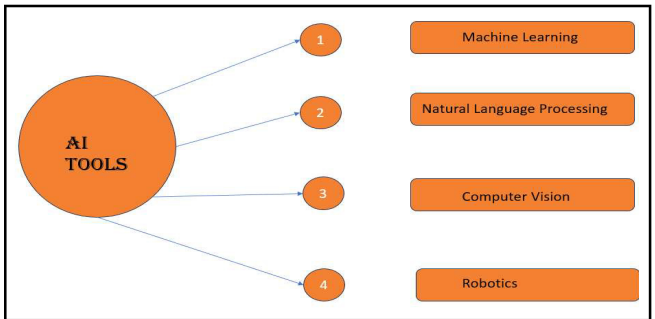

Fig. 1 : Different AI components in food

The Table 1 describe the role of different AI methods in organizational working of food industry can be categorized into different departments as food processing, food safety and quality, marketing.

Table 1: Applications of different AI methods in food industry

Different methods of AI	Application in Food Industry
Machine Learning	Food Quality
Deep learning/Artificial Neural Network	Food quality, supply chain management
Computer vision	Grading and sorting
Fuzzy logic	Sensory characteristics
Expert systems	Process development, process control
Robotics	Feeding, Milking, sorting etc.
Natural Language Processing	Menu analysis

Application of AI tools in Food Processing:

Food processing can be defined as the use of different methods and techniques that involve equipment, energy, and tools which transform agricultural and animal products into food ingredients or processed food products to make it safe for consumption for consumers. In this context, food is majorly prone to contamination at any stage of the farm-to-fork food chain via either chemical, biological, or physical entities. Food processing generally includes the steps from post-harvest handling to the preparation of final product. Post harvest handling includes cleaning, grading, sorting and many other separation techniques where robotic arms, sensor cameras, photogenic sensors can be used to grade the raw material and remove the defective products. The main reason behind using these AI techniques in processing is to improve production efficiency, creating

sustainable solutions, reduce wastage and optimize logistics.

Computer Vision in food industry works on the basis of camera, sensors, and AI based image analysis which can be used to capture, process and interpretvisual information from the production line that records visual information for quality, safety and process automation. The working of a computer vision system follows a series of steps like image acquisition, image pre- processing, feature extraction, analysis and decision making, action and automation. This is mainly used in sorting, grading and inspection areas (Nychas *et al.,* 2021).

Knowledge based expert system is a computer system that collects information from different sources to solve complicated problems. This expert system can be categorized into 3 types they are expert systems, knowledge-based artificial intelligence, and knowledge-based engineering that is classified based on its working and collection of data. Normally these problems are solved using IF-Then rule that resolve complicated issues using aid of human expertise. Generally, knowledge based expert system is mostly used in process control where the process parameters are monitored and deviations can be corrected using the past data.

Food safety:

In food industries there are many collective actions that are to be monitored like raw material procurement, product development, quality control, waste management and marketing. Not only it assists in the production and distribution of food to consumer but also it helps in sustainable development of food eco system. To reach the sustainable development goals set by FAO like Zero hunger, promoting food security and nutrition along with monitoring the link between food security and natural resources. Traditionally, reducing food waste has mainly focused on reducing food losses during production and supply chain management. For example, many food companies have implemented "just in time" inventory systems to reduce food waste. This method is based on producing and delivering the goods only when needed, which helps minimize the amount of food that goes to waste. Additionally, many food companies have also implemented "first-in, first-out" (FIFO) systems to ensure that the oldest products are used first and are less likely to spoil.

In a food industry, at each and every step the food undergoes through a sensitive path where it can be prone to any kind of hazard that makes it unfit for consumption making it a food safety issue. So utmost care and hygienic practices should be carried out to make it healthier and more harmless to the consumer. The challenge faced in any food firm is to find out to the faulty product and root cause for fault in the product. Here traceability of the product plays a major role in finding the deviation in production line. Traceability or product tracing is defined as "the ability to follow the movement of a food through specified stage(s) of production, processing and distribution". The main objectives of traceability are to ensure public health, protecting consumer interests, promote fair trade practices, risk identification and management, ensuring product safety through supply chain.

Quality control:

Apart from traceability, food safety traditionally can be done by many labs check assessments and manual check points were installed by the food company. With technology upgradation these check points came to be upgraded with AI tools in the form of sensors, spectrometers, e-Nose etc., are involved for food safety hazard detection, such as high-performance liquid chromatography (HPLC), gas chromatography (GC), high-performance liquid chromatography–mass spectrometry (HPLC-MS), gas chromatography–mass spectrometry (GC-MS) and other spectrometry techniques. There are other alternative sensor spectroscopy approaches that have also been used, including sensors with spectra in the ultraviolet (UV), near-infrared (NIR), mid-infrared, and visual (VIS) ranges. More recently multi- and hyperspectral imaging sensors have been emphasized as tools to simultaneously assessment of spectral and spatial information from food samples. The interesting thing about both these spectroscopy and imaging sensors is that they have showed results that are efficient enough, when worked with appropriate data analysis methods.

Advances in next-generation sequencing (NGS) technologies over the period has given a novel opportunity to enhance the understanding of metagenomics.

Additionally, metagenomics provides an excellent framework for studying the microbial ecosystem through monitoring the interactions among different species to identify the impact of some naturally occurring or spoiling species on the presence, growth or activation of pathogens (Misra *et al.,* 2020). Furthermore, the interactions

between the food and ambient conditions during food storage, their impact on the microbial growth can be studied across several products.

When data mining techniques like machine learning, deep learning, neural networks are combined with above mentioned techniques like sensors, spectrometry and e-Nose the data can be compiled the results can be obtained and data can be stored in data interface. The data analysis consists of workflow that follows data acquisition, preprocessing, normalizing and data handling. It has the feature to extract/select or feature engineering, and classify which may be either supervised or unsupervised regarding the problem to be solved. More recently, deep neural networks and convolutional neural networks (CNNs) provide results in more traditional Machine Learning approaches like support vector machines and genetic algorithms. These have been used for identifying and classifying food types (Kakani *et al.,* 2020). While this technology is still in an early stage, it has thus far provided promising results with food type identification using image databases. The main drawback in next step of using deep learning image-based ML algorithms is the scarcity of reference images in the libraries for all food types in varying data of quality, adulteration, and contamination. Briefly, CNNs can mimic the human visual system to gain information from computer vision.

The quality control also includes sensory attributes. These sensory attributes canbe checked using ranking the foods which can be done easily by using the Fuzzy Logic as it takes the individual perception of each person into consideration. It can also be used for classification, control, acceptance and non-linear modeling in the food industry. Expert Systems (ES) can be broadly used in the food industry for decision-making process where the consumers can decide whether the product can be accepted or rejected. On the other hand, Artificial Neural Networks model is widely applied in the food industry for prediction, classification, and controlling the task that has the ability to learn from examples which allows for the prediction process to be done accurately. Moreover, the unsupervised method of ANN is found to be very common for the classification of problem task. The other methods that can been utilized for the prediction and classification of the food samples is by using the machine learning (ML) method in which solving complicated tasks involves a massive amount of data and variables but doesn't have any pre-existing equations or formula. This method is known to be useful when the rules are complex and constantly change when the data keep changing and require adaptation and also makes it flexible and user friendly.

Since human thinking and reasoning are naturally fuzzy, the fuzzy set concept (Leka, 2024) has been applied by a number of researchers in conducting and analyzing human sensory evaluations. Copeland and Proudfoot (2004) used fuzzy logic inferences in classifying a fat spread product. A fuzzy questionnaire on the basis of a truth scale was used in which trained panelist will be asked to indicate whether a statement about a sample was considered to be "true", "borderline", or "false". The panelist responses to the statement were evaluated in the form of fractions and used as membership grades to classify a sample by fuzzy logic inferences.

Marketing:

Market research is the most important section of marketing where the consumer interests and demands are identified that help way in which the producers study the market place which studies the demand forecasting of the product along with personalized recommendation for the products.

Applications of Forecasting Models and Machine Learning Algorithms in Market Demand Forecasting:

Market demand forecasting is a critical component of decision-making in introducing a new product in any food industry. By forecasting changes and trends in consumer demand, companies can plan production and supply rationally and avoid overstock or out-of-stock situations (Hofmann and Rutschmann, 2018). These forecasting models and ML algorithms can use previous sales data, market trends, and other relevant factors to build accurate design for demand forecasting models. By learning and analyzing the existing and current data models and algorithms can be designed to identify demand patterns, conduct a forecast procedure, and provide ultimate recommendations and decision support that helps in demand forecasting which can be achieved through the application of big data analytics in supply chain management and predictive models, machine learning algorithms in demand forecasting. Food companies can more easily understand the supply chain situation and consumer demand by matching of supply and demand that in turn helps in improving operational efficacy and consumer satisfaction. This will help in optimizing supply chain management and production planning and enhance

the competitiveness of companies along with regularized productivity.

Application of Individualized Marketing and Recommendation System:

Individualized or Personalized marketing is a customized marketing strategy that mainly focus on consumers' interests, preferences, and behavior. For example, Liao *et al.* explored how marketing advertisements in social media can be analyzed with big data to understand consumers' behavior. The application of personalized marketing and a recommendation system can be realized through big data analysis and artificial intelligence algorithms (Bronson and Knezevic, 2016). With the help of big data analytics, companies can understand consumers' purchase history, preferences, and behaviors to provide personalized product recommendations, pricing strategies, and promotions that enhance consumers' buying experience and loyalty (Liao and Yang, 2021).

A recommendation system uses algorithms and models to recommend food products that suit consumers' tastes and needs based on their preferences and similar consumer behaviors, increasing purchase conversion rates and sales (Mariani and Wamba, 2020).

Consumer Behavior and Forecasting Analysis:

Big data analytics can help food companies understand consumer behavior, decision-making processes, and purchase motivations in a better way and, thus, predict trends and changes in consumer behavior and preferences. Through behavior analysis, companies can not only identify the characteristics but also helps in fulfilling the needs of different consumer groups, optimize product positioning, marketing, and design new strategies. Forecasting the consumer behavior can help companies in making more accurate inventory management, production planning, and supply chain decisions that improve operational management and the ability to meet customer demand. Through the application of personalized marketing and recommendation systems and consumer behavior analysis and prediction, food companies can better understand consumers, provide personalized products and services, enhance consumer satisfaction and loyalty, and, thus, gain an advantage in the market competition (Verma *et al.*, 2015).

Conclusion:

The study can be summed up as artificial intelligence plays a major role in the overall development of food industry in terms of production, quality assessment, storage conditions and improving the food safety. Many AI tools like Deep learning, machine learning, fuzzy logic, Big Data and many other Large Language Models that help to complete the task in less time with reduced number of errors.

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