IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES
ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 10, Iss 4, 2021

Recent Advances and Applications of Artificial Intelligence in Food Industries

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Abstract

This paper explores the growing influence of Artificial Intelligence (AI) in the food industry, examining its diverse applications. AI revolutionizes food production, quality control, supply chain management, personalized nutrition, and waste reduction. It enhances dairy farming, aids in beverage analysis, and automates fruit and vegetable sorting. While AI offers promising solutions, it also introduces challenges, including data privacy and ethical concerns. This research highlights AI's transformative role in the food sector and emphasizes the need for ethical, regulatory, and technological considerations."

Introduction

Artificial intelligence is a field of computer science that focuses on creating systems or machines that can perform tasks that typically require human intelligence. These tasks include things like understanding natural language, recognizing patterns, solving complex problems, and making decisions.AI systems can be designed to mimic human cognitive functions, such as learning from data, reasoning, problem-solving, and adapting to new information. They can range from simple rule-based systems to complex machine learning models.

There are various subfields of AI, including as shown in fig no 1 [1-3]:

- Machine Learning: This involves training algorithms to learn from data and make predictions or decisions based on that data.
- Natural Language Processing (NLP): NLP focuses on enabling machines to understand, interpret, and generate human language[4].
- Computer Vision: This field enables machines to interpret and understand visual information from the world, like images and videos.
- Robotics: AI-driven robots are designed to perform physical tasks and interact with the environment.
- Expert Systems: These are rule-based AI systems that emulate the decision-making abilities of a human expert in a specific domain.
- Neural Networks: These are computational models inspired by the structure and function of the human brain and are a key component of deep learning.

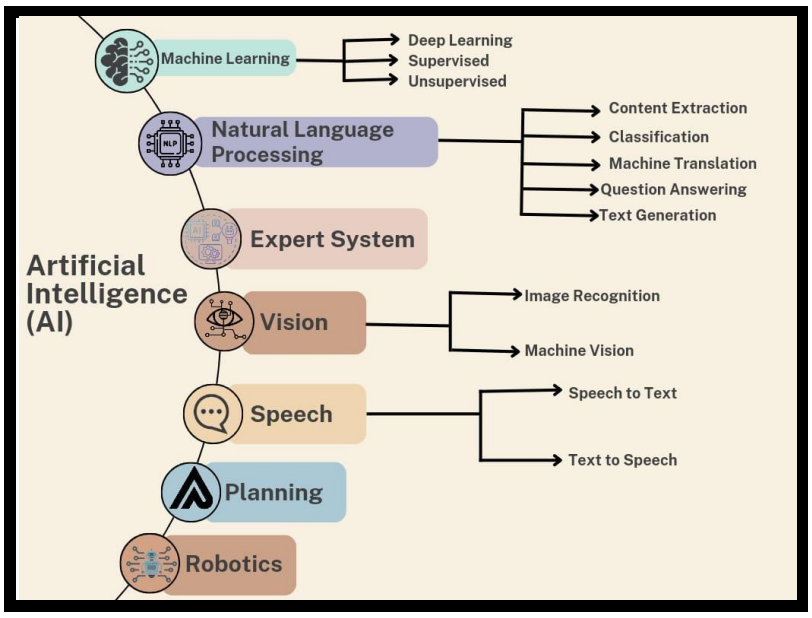

Fig no 1 (Application of artificial intelligence) [5,6]

Artificial Intelligence in Food Industry

The integration of Artificial Intelligence (AI) into the food industry is poised to bring about significant changes and innovations, from production and distribution to consumption and safety. This paper explores the promising future aspects of AI in the food sector while addressing the unique challenges it presents. It delves into the potential applications of AI in food production, supply chain management, personalized nutrition, and sustainability. Simultaneously, it critically examines the challenges, including data privacy, regulatory concerns, and ethical considerations. This paper aims to shed light on how AI is poised to revolutionize the food industry while emphasizing the need for careful ethical, regulatory, and technological considerations. However, this integration of AI also introduces a host of distinctive challenges, ranging from data privacy and ethical dilemmas to regulatory complexities. This research paper embarks on a journey to explore the exciting prospects AI offers to the food industry while dissecting the hurdles that must be navigated to unlock its full potential.

Artificial intelligence (AI) is making significant advances in the food industry, transforming various aspects of food production, distribution, and consumption. Here are some recent advances and applications of AI in the food industry [7,8,9,10]:

- Quality Control and Inspection: AI-powered systems, often using computer vision, can inspect and sort food products with high precision. They can identify defects, foreign objects, and ensure product quality. This is especially valuable in food processing plants for fruits, vegetables, and meat products.
- Supply Chain Optimization: AI algorithms are used to optimize supply chains, helping food companies reduce waste, improve inventory management, and predict demand more accurately. This ensures fresher products and less food wastage.

- Predictive Maintenance: AI can predict equipment failures in food production facilities, such as refrigeration systems and conveyor belts. This helps companies schedule maintenance before a breakdown occurs, reducing downtime and preserving food quality.
- Food Safety and Traceability: AI is employed to enhance food safety by monitoring and tracing the origin of products. Block chain technology, often integrated with AI, provides end-to-end traceability, enabling quick recalls in case of contamination or other issues.
- Personalized Nutrition: AI is used to develop personalized nutrition plans based on an individual's health data, dietary preferences, and goals. Apps and platforms offer tailored meal recommendations, taking into account dietary restrictions and nutritional needs.
- Recipe Recommendations: AI-driven apps and websites can recommend recipes based on available ingredients or dietary preferences. Some AI systems even generate new recipes by analyzing flavor profiles and ingredient combinations.
- Food Delivery and Distribution: AI-driven logistics and delivery platforms optimize routes, predict delivery times, and reduce delivery costs for food delivery services. This enhances customer satisfaction and efficiency in the food delivery business.
- Smart Kitchens: AI-powered appliances and kitchen devices can assist with meal preparation. For instance, smart ovens can cook food to perfection, and smart scales can weigh ingredients and provide cooking instructions.
- Sensory Analysis: AI and machine learning are used for sensory analysis of food products, enabling companies to develop and refine flavors and textures based on consumer preferences.
- Food Safety Monitoring: AI-equipped sensors can continuously monitor food storage conditions and alert users or suppliers when parameters such as temperature or humidity deviate from safe levels, reducing food spoilage.
- Waste Reduction: AI helps reduce food waste at various stages, from production to retail. It can predict when food items are likely to expire, prompting discounts or donations to minimize waste.
- Nutrient Analysis: AI tools can analyze the nutrient content of food products, making it easier for consumers to understand the nutritional value of what they eat.

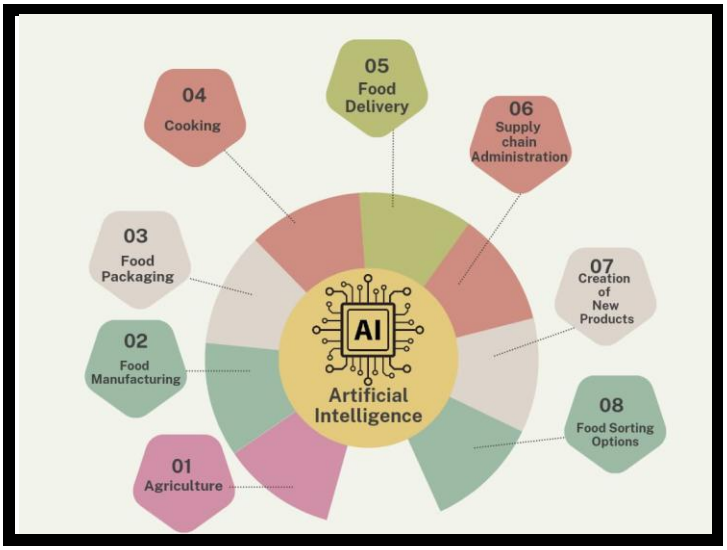

Figure no 2 Various Applications of Artificial intelligence in Food industry

Recent Advances and Applications of Artificial Intelligence in Food Industries

In processing industry, there is a strong focus on food quality, nutritional value, and processing methods in response to consumer demands. AI and ML technologies are playing a crucial role in addressing various challenges in food processing. AI is an interdisciplinary approach that is bringing improvements to different aspects of the food sector [11].various applications also shown in figure no 3

AI is essential for ensuring food safety and quality control. AI systems can detect potential contaminants, spoilage, or defects in food products, reducing the distribution of tainted food, minimizing health risks, and maintaining consumer trust. Predictive an1alytics models driven by AI can anticipate quality issues, allowing proactive measures to maintain high product standards. Moreover, AI is enhancing the development of food products by optimizing flavor, ingredient selection, and nutritional profiles.

AI is also streamlining processes in food manufacturing through automation and robotics. These technologies enable efficient and precise operations such as harvesting, sorting, and packaging with minimal human intervention. Precision agriculture, another AI application, employs sensors, drones, and data analytics to improve farming practices. This results in increased productivity, resource conservation, and environmentally sustainable farming through better yield estimation, crop health monitoring, and pest management.

AI and ML are indeed catalysts for innovation in the food processing industry, helping to meet the evolving demands of consumers and improve efficiency and quality throughout the food supply chain,

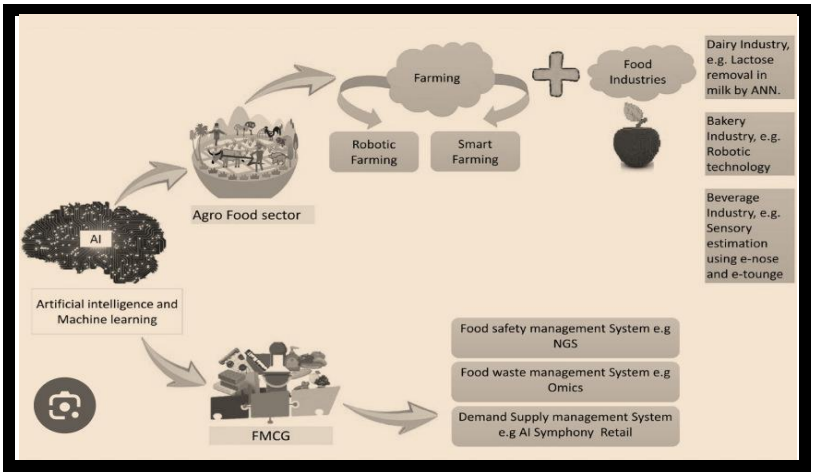

Figure 3 Applications of artificial intelligence in Food Industries

Artificial Intelligence (AI) in food safety and quality assurance in the food industry.

Artificial Intelligence (AI) plays a crucial role in ensuring food safety and quality assurance in the food industry[12, 13].

- AI systems, particularly that using computer vision, can swiftly and accurately detect contaminants like foreign objects, pathogens, and impurities in food products. This helps prevent contaminated products from reaching consumers.
- AI-powered cameras and sensors are used to inspect food products for defects, such as bruised fruits or damaged packaging. Automated quality checks improve consistency and reduce human error.
- AI, often integrated with block chain technology, is employed to create end-to-end traceability for food products. This allows for the rapid tracking of products in the event of recalls or food safety issues.
- AI helps maintain the machinery used in food production and packaging. By analyzing data from sensors, AI can predict equipment failures before they occur, reducing downtime and ensuring the safety and quality of food products.
- AI algorithms assist in optimizing supply chains. They can predict demand, reduce waste, and manage inventory efficiently, ensuring that food products are fresh and delivered on time. AI is used for sensory analysis to assess the taste, texture, and aroma of food products. This helps food manufacturers refine their recipes and create products that meet consumer preferences.
- AI tools can analyze the nutritional content of food items. This information is crucial for food labeling and helps consumers make informed choices about their diet.
- AI-equipped sensors constantly monitor storage conditions such as temperature and humidity. If these conditions deviate from safe levels, alerts are generated, reducing the risk of spoilage and contamination.:
- AI is used in precision agriculture, where drones, sensors, and data analytics are employed to monitor crop health, estimate yields, and manage pests. This ensures high-quality raw ingredients for food processing.
- AI is applied to analyze customer feedback, reviews, and social media discussions related to food products. This information is valuable for manufacturers to make improvements and ensure customer satisfaction

Artificial Intelligence (AI) in the dairy sector

Artificial Intelligence (AI) is revolutionizing the dairy sector in numerous ways, from optimizing milk production to enhancing dairy product quality and sustainability. Here are some key applications of AI in the dairy industry and also shown in figure no 4 [14,15,16].

1. Cow Health Monitoring: AI-powered systems use sensors and data analytics to monitor the health and well-being of dairy cows. They can detect early signs of diseases, monitor vital signs, and provide insights into optimal feeding and milking schedules, ultimately improving cow health and milk production.

2. Milk Yield Prediction: AI algorithms analyze data from sensors on cows to predict milk yield. This information helps dairy farmers make informed decisions about milk production and resource allocation.

3. Automated Milking Systems: AI-driven robotic milking systems can autonomously milk cows. These systems use computer vision and machine learning to identify and milk cows efficiently, resulting in increased productivity and reduced labor costs.

4. Nutrition Optimization: AI is used to create personalized nutrition plans for cows, ensuring they receive the ideal diet for milk production and health. AI algorithms consider factors such as age, breed, and milk yield to tailor feeding programs.

5. Quality Control: AI is employed to assess the quality of milk. It can identify issues like bacterial contamination, abnormal fat content, or somatic cell count deviations, allowing for early intervention to maintain milk quality.

6. Disease Detection: AI-based systems can detect diseases in cows by analyzing data such as temperature, behavior, and milk composition. Early detection of diseases helps prevent outbreaks and reduce the need for antibiotics.

Artificial intelligence is transforming the dairy sector by improving efficiency, productivity, and sustainability while also ensuring the well-being of dairy animals and the safety and quality of dairy products. These AI-driven advancements help dairy farms and producers meet the growing demands of the industry while addressing concerns related to animal welfare and environmental impact.

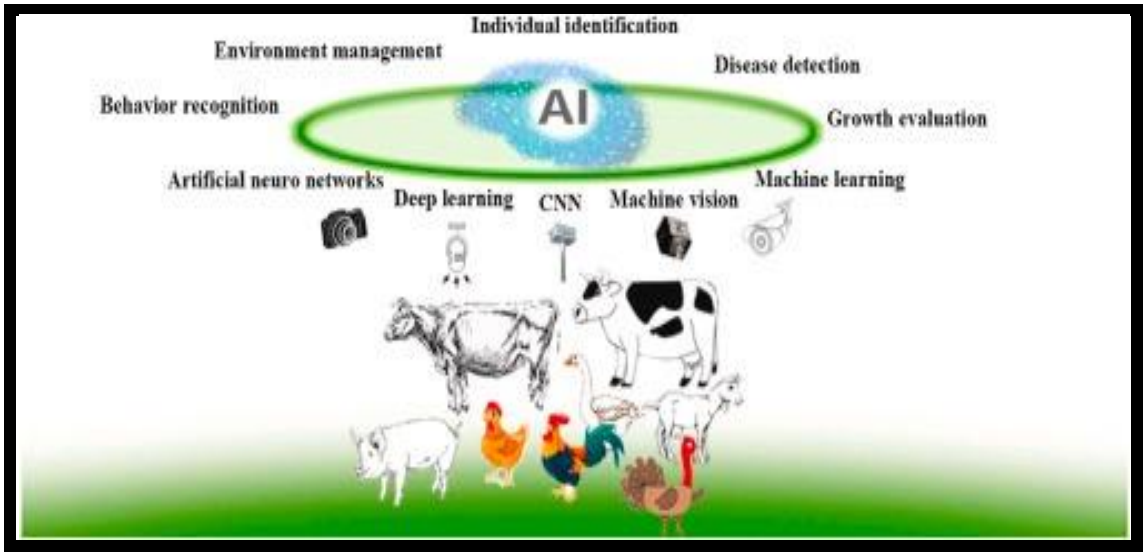

Figure 4 Applications of artificial intelligence in dairy industry

Artificial intelligence in beverages/soft drinks

Drinks are grouped into three categories (a) Alcoholic drinks (b) Non-alcoholic drinks (c) hot drinks [17, 18].

Alcoholic beverages/ drinks contain beer, wine, spirits, and Non-alcoholic beverages/drinks such as juices, carbonated water, milk, and soft drinks such as coca cola, thumbs up, Miranda etc. hot beverages such as tea, coffee, hot chocolate.

ANN in non-alcoholic beverages

A class of ANN named Deep Convolution Neural Network (DCNN) helps to get the nutrition analysis of soft drinks in order to control the weight gain or obesity. This technique can

estimate the nutritional content based on bottle size, cap ratio. It is not only for the arbonated drinks but also other fruits-based drinks. Nutritional content can be calculated using image processing as a part of CNN that helps in removal of the background part from image to get the results.

Artificial neural networks in hot beverages

An electronic nose is an innovation for the examination of smell, it works on the concept of mammalian olfactory by utilizing gas sensors that can be used in wine and coffee industries for smelling [19]. Electronic nose is utilized in food industries and beverages to control the quality of the products.

Similar to the e-nose, e-tongue is also utilized to check the quality of different types of beverages such as milk, coffee, tea, wine and beer etc. Parameters that are detected using this e-tongue are saltiness, sourness, and bitterness.

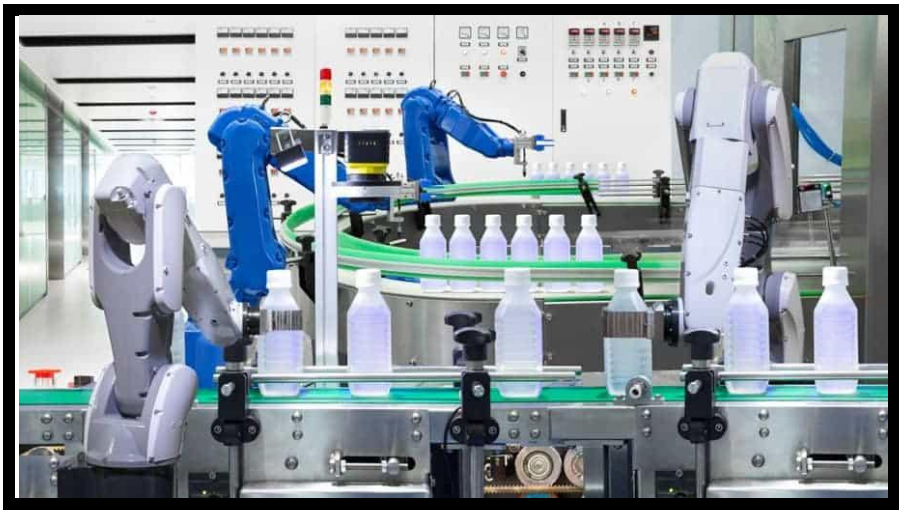

Figure no 5 Applications of artificial intelligence in beverages

Artificial intelligence in cutting and sorting of fruits and vegetables

Fruits and vegetables are major contributors to the nation, but its production is slowly decreased due to improper cultivation, lack of maintenance, losses during harvesting and post harvesting and increase in labor cost.

The automation method is used to increase efficiency and to decrease losses. This automation requires CV(computer vision), which is a part of AI, uses different software's to classify vegetables and fruits based on quality and also identification of damages in them [20].

X-ray imaging technology is one of the best non-destructive methods which help to detect diseases. For example mangoes are detected for quality by using X-ray imaging techniques and Artificial Immune Systems (AIS).

Another technique named Image processing technique was developed which analyzes, detects and segments the mangoes physical properties such as colour, shape, size and surface area from images. Some other techniques such as Principal Component Analysis (PCA) and Linear Discriminate Analysis (LDA) states that mango yield at week 7 or 8 to get the best efficiency. Competitive Learning Neural Network classifier formulated methods using fuzzy image processing to analyze and calculate the rating of mangoes. The most important step is to detect and sort the mangoes based on an accuracy rate of >80%. These techniques are not only used for mangoes but also for other fruits.

Conclusion

This paper explores the profound impact of Artificial Intelligence (AI) in the food industry, showcasing its extensive applications. AI is harnessed for quality control, supply chain optimization, food safety. It improves food production, distribution, and minimizes waste. In the dairy sector, AI is pivotal for monitoring cow health, predicting milk yields, and ensuring milk quality. In the beverage industry, AI assists with nutritional analysis and quality control. Moreover, AI-driven technologies are instrumental in the sorting of fruits and vegetables, streamlining processes and minimizing losses. While AI offers tremendous potential for the food industry, it also raises concerns regarding data privacy, regulations, and ethical considerations. In summary, AI stands as a catalyst for transforming the food industry, driving efficiency, sustainability, and consumer-centric solutions while addressing essential issues like food safety and waste reduction.

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