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Artificial intelligence and its applications in the food

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Abstract
Artificial intelligence (AI) has represented the newest technology in the food industry for decades, with increasing demand for food due to a growing world population. Artificial intelligence refers to development of human-like intelligence in a machine that can learn, plan, recognize and process natural language. Artificial intelligence is helpful in performing difficult tasks like classification, quality determination, large samples for sensory evaluations etc. Fuzzy logic, Artificial Neural Networks, Adaptive Neuro fuzzy Inference System, Machine Learning, etc. are common techniques used in the food industry. The main step in the selection process is for the user to define and finalize the goals of using her AI in research or implementation. Prediction, classification, quality control, contamination detection and estimation are among the common goals of AI applications in the food industry. It is necessary to identify the type of sensors required to the determine the sample. AI is widely recognized in the food industry due to its simplicity, accuracy and cost-saving techniques. AI has applications such as sorting perishables, managing supply chains, monitoring food safety compliance, effective field cleaning systems, predicting consumer preferences, and developing new products by streamlining and saving time and resources. Well utilized. However, deploying AI technology comes with challenges such as cost, cultural change, demand for expertise, transparency issues, and biased thinking. Despite these challenges, research continues into using AI to optimize production processes. However, it is important to note that the benefits of applying AI to the food industry far outweigh the challenges.

Keywords: Fuzzy logic, deploying AI, production processes

1. Introduction
Artificial intelligence is a branch of computer science and vigorous datasets which enable critical thinking. It also includes the sub-branches of machine learning (ML) and deep learning (Deep learning), which are often associated with AI. Artificial intelligence deals in development of machines that are developed in order to mimic human intelligence. In food industries, where the design of standard reliable procedures to control the quality of products is a major objective and as with other companies, the search for new ways to reach and serve the customers while keeping the costs low have necessitated the deployment of AI to achieve better customer experience, efficient supply chain management, improve operational efficiency, reduction in material movements and vehicle activity and to achieve the best results in the business(Iqbal *et al*.,2017) [9]. Artificial intelligence has the capacity to process large volumes of unstructured and structured data, which can be subject to continuous alteration. It enables reasoning power to draw inferences based on situation. It generates context driven awareness. The learning in Artificial intelligence is based on past patterns, input and feedback. It has the capacity of analytical thinking and problem solving. The advantage of using Artificial intelligence in food processing sectors is that it involves the standardization of the food, its ingredients, and its physical and chemical parameters.

2. Importance of Artificial intelligence
It is important for the classification, quality control, sensory ranking, for estimation and as a control tool. For any research the objective of the research includes one of the above mentioned. Classification involves the classification of milk, classification of modified starches, and classification of intact and cracked eggs. Similarly for quality control, smart cameras and associated AI-enabled software, manufacturers can enhance quality inspections at speeds, delays, and costs beyond the capabilities of human inspectors. Sensory evaluation feeds the food industry and food Scientists who provide useful and important information about sensory perception. Food quality used to estimate total value and Consumer acceptance of products. Artificial intelligence is capable of estimating bioactive components present in the

food. The AI controller can rapidly and precisely identify transient inconsistency of equipment and response back to control in real time.

3. Selection of Appropriate Alogrithm

3.1 Artificial Neural Networks

Neural networks are used to solve complex problems such as pattern recognition, rapid information processing, and adaptation. The architecture of an artificial neural network (ANN) is a simplification of the structure of the human brain. The structure of ANN consisted of an input layer, hidden layer, and output layer, either single or many layers (Trafialek *et al*., 2015) [20]. Artificial neural networks are used in mathematical modelling to create mappings between system inputs and outputs. They are especially useful in classical statistical modelling based on linear model structure and parameter estimation. ANN application in food includes the assessment and classification of the samples, complex calculation such as heat and mass transfer, analysis of the existing data for control purposes as well as for prediction purposes.

3.2 Fuzzy logics

Fuzzy logic provides degrees of truthfulness and falseness of experiments is accomplished by giving experimental ambiguous value compared to other. Fuzzy rules are also known as If-Then. Recently, technology and fuzzy concepts have been applied to sensory evaluation**.** There are two types of function approximation models based on fuzzy rules: additive rule models and non-additive rule models rule model. Additive rule models include Mamdani Models and Nonadditive Laws Models include the TSK model, the standard additive model, and the Tsukamoto model. The most commonly used fuzzy inference methods are: Mamdani model and TSK model (Routray *et al*., 2020) [15] To compute the output of the Mamdani fuzzy model, we follow several steps in Fuzzy Logic Analysis (FLA) or Fuzzy Logic Control Systems. For instance, Fuzzy member functions, Normalized member functions, Normalised member matrix, Rating member function matrix, rating subsets and quality - ranked subsets and sample ranking theory. (Ruan and Zeng, 2013) [16].

3.3 Adaptive Neuro fuzzy inference system

The adaptive neuro fuzzy inference system ``ANFIS" is a kind of artificial intelligence that combines the strengths of neural networks and fuzzy logic systems. Like a neural network, ANFIS can learn and make decisions based on data, but like a fuzzy logic system, it can also handle inaccurate or incomplete data. ANFIS is therefore well-suited for use cases where data is constantly evolving or is not always accurate. The structure of ANFIS is made up of five layers which are fuzzy layer, product layer, normalized layer, defuzzifcation layer, and total output layer (Rahman *et al*., 2012)[13]. The first level of ANFIS has customizable nodes. It is called the premise parameter. Second Layers in ANFIS have fixed nodes and the output is the product of all received signals. Each output node represents thickness of the edge of the rule. The third layer consists of fixed a node labelled as N. The third layer exits are called: Normalized edge thickness. Each node in the 4th layer is an adaptive node with a node function and parameters. In this layer it will be called as a subsequent parameter. The final layer in the ANFIS layer calculates the overall output as the summation of all the incoming signals. Its application in Food processing includes his five main categories: Food property prediction, food drying, heat treatment, Food modelling, microbial growth and quality control and food rheology (Al-Mahasneh *et al*., 2016) [2].

3.4 Machine learning

Machine learning is an emerging field of artificial intelligence that allows computers to process and interpret past data in an automated manner. Machine learning is a subset of Artificial intelligence. Machine learning uses various algorithms to build mathematical models and use historical data and information to make predictions. It is currently used for various tasks such as image recognition, speech recognition, and email filtering and recommendation systems. The models in machine learning are ANN, decision trees (DT), support vector machines (SVM), regression analysis, Bayesian networks, genetic algorithm, kernel machines, and federated learning(Mullainathan and Speis, 2017) [12] Machine learning can be supervised, unsupervised, and reinforcement learning.

1. **Supervised learning -** Supervised learning is a type of machine learning technique that trains a machine learning system by providing data labelled with sample data and predicts an output based on it. It is based on supervision by humans.
2. **Unsupervised Learning-**Training is provided to the machine using labelled, classified or unclassified datasets, and the algorithm must work without missing that data. The goal of unsupervised learning is to reconstruct the input data into a set of objects with new features or similar patterns. In unsupervised learning there are no predetermined outcomes. Machines seek useful insights from vast amounts of data.
3. **Reinforcement learning-** Reinforcement learning is a feedback-based learning method in which the learning agent receives a reward for each correct action and a penalty for each incorrect action. Agents automatically learn this feedback and improve their performance. For e.g. Robots used to perform particular task in food industry

3.5 Natural Language processing

Natural language processing is broadly defined as the automated manipulation of natural language such as speech and text via software. The branch of computer science that deals with the interaction between computers and humans. A language for programming computers to process and analyse large amounts of natural language data (Goldberg, 2016) [5]. Its application includes language translation, smart assistant, document analysis, automatic summarization, predictive text, chat bots etc.

3.6 Computer Vision System

It is a combination of computer vision system "CVS" image processing and pattern recognition technology. Machine vision is the scientific field that allows machines to see. Visual information is captured and analysed by a camera, converted from analogue to digital, and processed by digital signal processing. It seeks to automate tasks that the human visual system can do (Milan, 2008) [11]. It primarily comprises of digital camera and computer software like MATLAB.

3.7 Robotics

The engineering and science of designing, building, operating, and using robots. A computer system for control, sensory

feedback, and information processing. These technologies are well known they are developing machines that can mimic human behaviour on behalf of humans (Tondu, 2012) [19]. Robots are helpful in performing tasks that are repetitive or labour intensive. The application of Robotics comprises of cartooning, product development by Robots such as biscuits or other bakery products, Labelling and coding, and filling robots. It has wide application in meat industry where it involves the removal of hair or hide, deboning, splitting, primal cutting and evisceration and dressing.

4. Computerized food evaluation

Computerized food quality evaluation systems can consistently detect deviations from standards. Such computerized systems can be built to mimic human senses, but if there are no mental and physical problems, human appraiser. One digital camera can be connected PC with image processing software for adjustment build an image processing system. The acoustic sensor works as an electronic ear. Set of gas sensors when combined with pattern recognition algorithms can work as electronic nose. A series of electrochemical electrodes when combined with pattern recognition algorithms makes this possible become an electronic tongue. These systems work separately or combined with multi-sensor data fusion to improve individual performance.

4.1 Electronic Nose

It detects odours and Flavours. It consists of an array of electronic chemical sensors which can recognize both simple and complex odours (Yan *et al*., 2015) [21]. The E-nose's main software components are the feature extraction and pattern recognition algorithms where responses are processed called and selected. In general, E-Nose is divided into three main parts: sample delivery system, detection system and computer system (Szulczynski *et al*., 2018) [18]. Cyranose 320 is a handheld “electronic nose” developed by Cyrano Sciences of Pasadena, California in 2000. Its application includes mostly quality control or contamination detection.

4.2 Electronic tongue

An electronic tongue (e-tongue) is a device that can determine and analyze taste. Several less selective sensors are available for electronic tongues, also known as 'multisensory systems'. Signal processing uses advanced mathematical techniques based on pattern recognition and multivariate data analysis (Ha *et al*., 2015) [6]. The electronic tongues used in laboratories, is the Astree Liquid and Taste Analyzer of Alfa MOS (France). E tongue is made up of three main components: the sample delivery chamber (or automatic sample dispenser), a bunch of different sensors with different sensitivity levels, and an image-recognition system to process the data. For example, electronic tongues can be used to separate different types of chemicals in liquid phase samples. Sensors enables discrimination between organic and inorganic compounds. All sensors combined create a unique fingerprint that shows a spectrum of different responses. E-tongue's statistical software enables taste recognition and perception (Mavani *et al*., 2022) [10].

4.3 Artificial mouth

An artificial mouth is constructed by combining information corresponding to the three senses: "auditory" from a microphone, "tactile" from a force sensor, and "olfactory" from a gas sensor array. A piston inside a chamber containing a crunchy food sample was moved at a constant speed by the action of a stepper motor connected to a lever. A force sensor was utilized to record the force exerted on the piston, while a microphone was positioned at the base of the chamber.

4.4 Multi-sensor data fusion

A computerized sensing system which will act similarly to human appreciation of food with the combination or fusion of five senses.

For example: Artificial mouth

4.5 Near infrared spectroscopy (NIRS)

Infrared spectroscopy measures infrared radiation from materials using specific wavelengths. Materials have IR bandwidths, which exhibit peaks and dips where electrons in the molecule emit or absorb photons. The NIR region of the electromagnetic spectrum is approximately 700 to 2500 nanometres. NIR spectroscopy measures the light scattered by and through the sample material, allowing rapid determination of material properties. This process does not affect the material itself. Recently, NIRS is of an interest in food industries as it is helpful in determining the quality of product and control the objective of study (Cortes *et al.*,2019) [3].

5. Applications of Artificial intelligence

5.1 Trend Analysis

The first use of AI in the food industry is to help companies to analyze common customer requirements and wishes. Based on big data analytics and machine learning models, AI can generate useful insights about customer needs and desires that lead to product development. This stage is very important as the company needs to select the products that are most likely to succeed in the consumer market. AI is the force of change that gives companies the confidence to launch specific products with different characteristics. By utilizing trend analysis techniques, food companies can efficiently meet customer needs and appropriately target the right customers in the market.

5.2 Effective speed

Accelerating manufacturing is one further benefit of Artificial Intelligence in the food business. However, with the development of Artificial Intelligence and automated machinery, machines can now make more things simultaneously and more swiftly attain superior outcomes. In turn, this helps the business and increases income.

5.3 Quality control

Inspection of food quality is a challenging operation that demands accuracy. However, when food and other items are produced in large quantities, quality is rarely sacrificed or ignored. However, if the production process is managed by AI-supported robots, this is not a drawback. However, AI tools and algorithms may be taught and modified to examine several criteria to guarantee quality. Because only specific traits are accepted by machines, this particular work can also be done with less errors.

5.4 Sensors

Intelligent sensors continuously monitor the manufacture and packing of the finished product from start to finish and alert the user if anything is amiss or out of the norm. This might be anything from poor product quality to power disruptions. All

food businesses, in particular, will benefit from the application of AI in smart sensors since it can both help detect aberrant activity and do away with the idea of quality inspectors across the whole production chain.

5.5 Research and exploration
The food sector may look into such incidents and look into the hidden causes of mishaps with the use of AI. Applications using artificial intelligence (AI) may conduct in-depth research and deliver quick answers by analysing and interpreting historical records.

5.6 Segregation
One of the most important steps in starting food production is food separation. An efficient and organized production process requires separation and sorting of ingredients. Previously, this separation required a human to do this work manually. Instead, custom-built machines powered by AI algorithms are now used to separate food ingredients, which are then blended to produce products. (Rawat, 2022) [14].

5.7 Cleaning of Food processing equipment's
Using an AI-enabled technology (self-optimizing cleaning-in-place system "SOCIP") that uses ultrasonic sensors and fluorescence imaging, food residue and microbial build-up are measured in one device and afterward optimize the cleaning process (Agbai, 2020) [1].

5.8 Anticipation of consumer preferences
Artificial intelligence in the grocery sector can track customers, their preferences and purchases. These are all important variables in predicting sales. For example, retailers can use repeat purchases to better understand their key customers and increase inventory levels. Artificial intelligence takes historical data and processes it with AI-powered algorithms to provide insights that can predict long-term sales cycles (Soni, 2022) [17].

5.9 Development of new product
AI technology uses machine learning and predictive algorithms to model consumer taste preferences and predict how consumers will respond to new flavours. Data can be broken down into demographic groups so companies can develop new products that match the tastes of their target users.

5.10 Track of Supply Chain
Food manufacturers can now track the food supply chain with custom AI applications and portals, from packaging materials to production ingredients. Artificial intelligence also facilitates the efficient and transparent traceability of produce from the farm to the end consumer, resulting in increased consumer trust. (Hammerkopf, 2019) [7].

6. Conclusion
For a variety of purposes, including modelling, prediction, control tools, food drying, sensory assessment, quality control, and tackling challenging issues in food processing, AI has been playing a significant role in the food business. Aside from that, AI may improve company tactics because it can perform sales predictions and enable yield increases. Due to its simplicity, precision, and cost-effectiveness in the food business, AI is well-known. The food sector is becoming more effective and superior thanks to artificial intelligence, and in the near future, many more innovative innovations are expected. Artificial intelligence has contributed significantly in waste reduction, cost management and time efficient technology. Research is still being done to determine the best ways to address artificial intelligence's problems and broaden its use.

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