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Applications of Artificial Intelligence in the Food and Beverage Industry

[1]Prefa, C.A., [2]Omoregie, L.C., & *[3]Eze, P.
[1]Department of Biology, Ignatius Ajuru University of Education, Port Harcourt, Nigeria
[2]Department of Biology Education, Federal College of Education Technical Omoku Rivers State, Nigeria
[3]Department of Home Economics, Ignatius Ajuru University of Education, Port Harcourt, Nigeria

***Corresponding author email**: prexyeze@gmail.com

Abstract
For us to survive and be healthy, food safety is essential. In order to protect consumers from food-borne illness and reduce the likelihood that food companies will incur millions of dollars in recall costs and possible harm to their brand, the complexity and sophistication of today's food systems require adhering to the strictest food safety regulations and utilizing cutting-edge technologies. The theory and development of computer systems capable of carrying out tasks that typically require human intelligence is known as artificial intelligence (AI). In an effort to increase profits and find new ways to reach and serve customers, the food industry has started to adopt AI technologies due to intense competition and rising demand. Applications like fresh produce sorting, supply chain management, food safety compliance monitoring, efficient cleaning in place systems, predicting consumer preferences, and new product development with increased efficiency and time and resource savings have all been successfully implemented with AI. Adoption of AI technologies is hampered by a number of factors, such as cost, cultural shifts, the need for specialized knowledge, problems with transparency, and one-track minds. Research on AI-optimized production processes is still ongoing despite these obstacles, but it's crucial to remember that the advantages of using AI in the food industry far outweigh the drawbacks.

Keywords: Robotics, Beverage Industry, Machine Learning, Deep Learning, Food Quality.

Introduction
The conventional definition of artificial intelligence, according to Addanki et al. (2022), is a synthetic version of human-like intelligence that can learn, reason, plan, perceive, or process natural language. It is the theory and development of computer systems that can perform tasks that normally require human intelligence, such as speech recognition, visual perception, decision-making, and language translation (Kumar, 2019). Artificial intelligence is a branch of computer science that focuses on creating machines that mimic human behavior. "The science and engineering of making intelligent machines, especially intelligent computer programs," is how John McCarthy, the father of artificial intelligence, defined the field (Sadiku et Al., 2020). Two

of the most popular algorithms in the field of artificial intelligence are machine learning and deep learning. People, businesses, and governmental organizations use these data-driven models to forecast future events. In order to handle the complexity and diversity of data in the food industry, machine learning models are currently being developed (Karanth et Al., 2023). In the beverage industry, artificial intelligence (AI) is becoming more and more important, changing everything from production to marketing and customer interaction.

Human health depends on eating a balanced diet. Although natural products have long been used as food, they are now being processed to satisfy consumer demand (Zhou et al., 2019). Food safety is crucial for human health as well as the food industries. As a result, the food industry needs a quick and accurate detection technique. These conventional techniques, like polymerase chain reaction (PCR), high-performance liquid chromatography (HPLC), and gas chromatography (GC), are expensive, time-consuming, and labor-intensive. To satisfy the demand for high-quality food, we must create accurate, fast, reliable, and nondestructive methods for evaluating food and quality. Despite the many benefits of these noninvasive methods, there are still some risks (Lin et al., 2023).

A healthy diet requires careful consideration of food type, composition, nutrients, and processing techniques. People's eating habits vary depending on where they live. Examining the quality and safety of food for consumers around the world requires an understanding of food attributes, such as type, composition, nutrients, and processing techniques (Zhou et al., 2019). Food industries adjust to new technologies for improvement as living standards rise and the significance of food quality increases due to technological advancements. The food industry now needs fast and precise analytical methods to satisfy consumer demand due to the expanding population, rising consumer expectations, and increased awareness of food quality. Food safety is related to food hygiene and health.

Food safety is the provision of high-quality food to prevent food-borne illness or making sure that food is free of physical, chemical, or microbiological contaminants during storage, preparation, and transportation. Although food safety and security are sometimes used interchangeably, they have different meanings. Food safety refers to the availability and health of food that does not make a person sick (Chen & Yu, 2022). According to Mohd et al. (2020), the food industry places a high priority on developing reliable, consistent processes to control product quality. As is the case with other businesses searching for new ways to reach and serve customers while keeping costs low, the use of AI has become essential to improve customer experience, supply chain management, and operational efficiency; reduce material movements and vehicle activity; and achieve the best results in the business.

AI Applications in the Food Industry

i AI in Dairy Products

Protein, fat, carbs, minerals, and vitamins are all abundant in milk. It is in high demand because it is nutrient-dense and widely consumed by kids, especially vegetarians. However, due to rising demand, the vendors adulterate milk in order to maximize profits rather than people's health. According to Anwar et al. (2023), this adulterant may result in serious health problems..The microbial load of raw milk will determine its acceptance in dairy processing facilities. According to Jeong et al. (2015), various adulterants reduce the number of microorganisms. Adulterants such

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as formalin, sodium hypochlorite, and hydrogen peroxide are detected by E-Nose. Adulterants can be found using a variety of equipment. In one experiment, they tested eight levels of formalin, seven levels of sodium hypochlorite, and eight levels of hydrogen peroxide (Tohidi et al., 2018). For every adulterant, the accuracy approaches 92% (Tohidi et al., 2018). An E-nose was used in a 2018 study to identify different concentrations of different oils and fats combined with pure ghee. First, it was heated between 40 and 500 degrees Celsius (Ayari et al., 2018). With the aid of AI and ML, electric noses can locate pollution and infections by accessing a database of harmful scents. It contributes positively to food safety and quality (Mohd Ali et al., 2020). Because milk is perishable, high-quality equipment is required to meet high-quality standards, and the cost of maintaining such equipment is higher. However, due to certain advancements in dairy products, the level of hygiene has improved, and these perishable food items' shelf lives and maintenance expenses have dropped (Sharma et al., 2021). If milk is not properly refrigerated, it spoils quickly. AI requires a system with wireless sensors in order to prevent spoiling.

One of the labor-intensive and labor-intensive tasks is milking cows. The automatic milking machine was created in Europe in 1999. The United States later introduced it (Aderssen et al., 2020). The cow's electronic tag makes it simple for the robot to recognize them. Once the milking cups are disconnected, they are fastened to the teats. The cow was later sprayed with the disinfectant prior to leaving (Lusigman, 2021). According to one of the findings, one of the causes of the decline in milk production is heat stress. A back propagation neural network was used to gather this data. By dousing cattle's bodies with water, we can reduce this stress (Sharma et al., 2021).

If milk is not properly refrigerated, it spoils quickly. AI requires a system with wireless sensors in order to prevent spoiling (Chen &Yu 2022). One of the most labor-intensive and time-consuming jobs is milking cows. The automatic milking machine was created in Europe in 1999. The United States later introduced it (Lin et al., 2023). The electronic tag is fitted to the cow, making it easy for the robot to identify them. The milking cups are attached to the teats after the milking cups get disconnected. The cow was later sprayed with the disinfectant prior to leaving (.Elias et al. (2002)

One of the results, which was gathered using a back propagation neural network, states that heat stress is one of the causes of the collapse of milk production. We can reduce this stress by misting cattle with water (Sharma., et al., 2021). In this case, the fluorescence image is transformed into the fluorescence intensity. The microplate reader was then used to compare the acquired values. A new tool for identifying food pathogens was created because the two results did not differ significantly (Amani et al., 2022). The shelf life of processed cheese is predicted using the linear layer design, and the multiple regression model is used to control the expiration date (Sharma., et al., 2021). The computer vision system and multispectral CVS check the products' apparent quality (Chauhan et al., 2017).

ii AI in Meat and Meat-Related Goods

Meat is well-known worldwide for both its flavor and nutritional profile because it is a recognized source of protein (Rahmati et al., 2016). Suppliers mix inexpensive and expensive meat to generate revenue. Because of these adulterations, food quality and safety are critical (Rohman, 2019). In 2022, Huang and Gu used the E-nose to collect data on adulterated meat. The beef and pork in this

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experiment are combined. After removing the fat tissues, the mixture is blended for one minute. 1DCNN-RFR is a framework that combines a random forest regressor (RFR) with a one-dimensional convolutional neural network (1DCNN) to detect meat adulteration quantitatively. When this framework's efficacy was compared to the other four models, it outperformed the other models for meat adulteration (Huang & Gu, 2022). The study used an E-nose to determine the freshness of beef cuts in conjunction with Feyzioglu and Taspinar (2023). Four classes are used to categorize the quality of the beef.

The data set's active features are identified using the analysis of variance method (ANOVA). To categorize three active features, they were chosen using ANOVA. Techniques for machine learning were applied. According to the findings, KNN accuracy is 98.8%, while LR accuracy is 98.6% (Feyzioglu & Taspinar, 2023). Both men and machines are needed to remove a sheep's carcass; the man will cut and slice the remaining parts, while the machines are used. Seafood stored under different conditions can be detected for spoilage using intelligent packaging technology. Principal components analysis (PCA), partial least squares regression analysis (PLS), and hierarchical cluster analysis (HCA) are used as experimental methods; PLS was chosen to identify spoilage markers. Meat quality and microbial estimation are solved using a fuzzy logic system with fuzzifier and fuzzified components. Meat's visual appearance will be more accurately quantified by machine vision (Sharma et al., 2021). Perishable goods include meat and aquatic products. A quick, nondestructive quality detection technique is needed for them. Spectral sensing is used in conjunction with the TML for this purpose (Lin et al., 2022). Anderssen et al. demonstrated in 2020 that moisture loss in frozen and thawed cod can be accurately predicted by combining HSI with the PSLR model. In developed hyper-spectral models, genetic algorithms are allowed (Anderssen et al., 2020). A spectrophotometer can scan meat and meat products in a single scan. It can assess the different attributes of the product. Deep multilayered ANN predicts microbial and fungal contamination (Ellis et al., 2002). A genetic algorithm that employs artificial intelligence to detect adulteration in order to differentiate between chicken and turkey is used to analyze the spectroscopic data (Ellis et al., 2005). Yoa et al. (2019) created a portable pH monitoring system for pork meat. In this system, the hyper-spectral scanner and smartphone are linked. It also has a white LED lamp to light the sample while the photo is being taken.

The reflected spectra are then calculated by analyzing the image. A pH meter is used to measure the meat sample's pH, and support vector regression is used to create models between the pH value and the establishment of image processing data. It is a potential method for predicting pH in pork meat because of the good accuracy of the results (Yao et al., 2019). The hyper-spectral imaging system is used in the meat industry to detect contaminants in chicken and poultry, while CIS (computer imaging system) is used for quality characteristics in fresh beef, such as sensitivity to contaminants, meat color, and pH. According to Chen and Yu (2022), it can identify 140 carcasses per minute.

iii AI-Powered Fruits and Vegetables

Because they offer essential nutrients for human health, fruits and vegetables are essential to the diet. However, improper handling during storage leads to the loss of fruits and vegetables, which are subsequently attacked by various microorganisms, putting consumers' health at risk (Zhou et al., 2019). A sophisticated refrigerator with intelligent refrigeration can reveal information about the product's age and composition. Images are fed into this refrigerator, which uses a

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microprocessor to process and display the results. The shelf life of this refrigerator is also monitored. Vegetables are arranged based on maturity, weight, and size. Up to 96.55% accuracy is possible with this refrigerator. Infrared color and ultraviolet images are used in automatic visual inspection to sort the fruits. 15 fruits are sorted every second (Sharma et al., 2021).

Machine vision is a tool used in image processing to determine product quality based on consumer demand. In this fluorescence imaging, multidimensional algorithms and machine vision are used to identify the contamination on the apple surface. To identify areas of the apple that are infected, they use two red-purple linear lights. This system is used to lower the risk and prevent food-borne illnesses. Fruit pH, firmness, softness, and moisture content can all be detected by infrared imaging with a high correlation coefficient (Chen & Yu, 2022).

Zhang et al. (2020), used the CNN model and deep learning with infrared hyper-spectral imaging in to determine the total phenolic content of flavonoids and anthocyanin in black goji berries. This experiment produced positive results (Zhang et al., 2020). Because 3D structure images provide detailed information on the sample conditions, they can be used to evaluate the quality of a variety of fruits and vegetables, including their ripening defects and damage. Another benefit of this is that plants use chlorophyll for photosynthesis. It provides appropriate indicators for smartphone-based spectroscopy, which is a good suggestion made by the author to increase the technique's usability (Amani et al., 2022). Every food industry that deals with fruits and vegetables sorts its produce. It takes a lot of time and human resources. Utilizing cutting-edge technologies like AI and ML will significantly lower production costs. According to TOMRA's sorting and peeling solution, they can recover up to 5–10% of production. The system analyzes the vegetables using X-rays and near-infrared spectroscopy lasers with photographic cameras in order to minimize waste while sorting the potatoes (Blythe, 2020).

iv Artificial Intelligence in Baked Goods

The bakery industry now uses a variety of automated systems, such as food quality sensors that translate food characteristics into electrical signals. These signals are used to determine a number of quality parameters. The smart ovens are there in the bakery industry. Baking operations are now simple and take less time thanks to advancements in the bakery sector; intelligent control systems improve product performance and provide suitable baking conditions (Sharma et al., 2021). Many sophisticated control techniques that can be used in fermentation, baking, and dairy processes are covered by Kudashkina et al (2022). There are multiple steps involved in making bread. To make bread, the dough is infused with yeast. The bread's quality suffers if any of the steps are not carried out correctly (Addanki et al., 2022). The sensors regulate the dough's and sourdough's rheological characteristics. It also regulates the temperature, humidity, weight, acidity, and smell of the dough. In robotics technology, this is the automated controlled system.

It takes an hour to check the bread's quality, and it takes three hours to bake everything from beginning to packaging. In order to assess the bread's quality, we first cut it and then use a camera to examine its interior. Food characteristics are translated into electrical signals by the sensors used to detect food quality (Addanki et al., 2022). Before the bread is authorized for distribution, these signals are examined to make sure it satisfies quality and safety requirements. This painstaking procedure contributes to the final product's consistency and customer satisfaction.

AI Applications in the Beverage Industry

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1. Quality control: By evaluating data from sensors and cameras to make sure that goods fulfill stringent quality standards, artificial intelligence (AI) can enhance the beverage industry's quality control procedure. AI, for instance, can be used to spot packaging flaws, guarantee product flavor consistency, and keep an eye on production procedures to avoid contamination (Thapa et al., 2023; Tohidi et al., 2018).
2. AI can assist beverage manufacturers in predicting when equipment is likely to malfunction, enabling them to plan maintenance before a breakdown happens. This can enhance overall production process efficiency and decrease downtime (Khosravani, 2019).
3. Inventory management: AI can be used to optimize inventory levels, guaranteeing that beverage producers always have the proper quantity of raw materials and completed goods on hand. AI systems can help businesses make better inventory management decisions by analyzing supply chain data, demand projections, and historical sales data (Intaravanne et al., 2012).
4. Personalized marketing: Beverage companies can use AI to target customers with messages that are tailored to their demographics, preferences, and behavior. AI can assist businesses in developing focused advertising campaigns that connect with their target audience by evaluating data from social media, online reviews, and past purchases (Ayari et al., 2018; Aquino et al., 2018)
5. Product development: By examining market data, consumer trends, and preferences, AI can assist beverage companies in creating new products. AI systems can spot trends in consumer behavior and offer insights that can assist businesses in developing goods that have a higher chance of succeeding in the marketplace (Chen, 2019).

Artificial Intelligence Technology Adoption Difficulties in the Food Industry

The following are barriers to the application of AI technology:
Because AI is so expensive, only very large companies in the food industry can afford to use it.
Cultural challenges: As with all technological advancements, the use of AI is associated with anxiety. Fears include the fear that computers will replace humans in the workforce, the fear that a small number of people will hold all the power, and the fear that computers will eventually take over and be negatively manipulated. These could make companies that use AI hated (Dubois, 2018). While AI technology is still in its early stages, specialized skill sets related to data collection and analysis are becoming increasingly necessary (Amani et al., 2022). Since AI is a new technology, many businesses are reluctant to invest until its actual worth and potential are established. AI technology requires increased transparency and more involvement of consumers in decision-making. Food and beverage companies are known to fiercely protect their proprietary recipes, which presents a challenge (Jeong et Al., 2015).
One-track minds: the great majority of AI applications currently in use are extremely specialized. They carry out one specific task and learn to become better and better at it (Dubois, 2018). In order to achieve the most efficient output, it simulates what would occur given each possible combination of input values and measures the outcome.

Conclusion

The prominent use of AI in the food industry and its numerous applications were covered in this essay. AI is essential to the food industry's future. People have a lot of false beliefs about artificial intelligence. One of the most prevalent misconceptions is that AI will replace humans and cause them to lose their jobs. However, this is untrue; supervision is required in order to carry out operations using AI. According to various researchers in the aforementioned paper, machine

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learning, deep learning, computer vision, etc., will help to improve food quality and product safety. It reduces the frequency of food-borne illness outbreaks. The various pathogens in food are identified through image processing. Compared to other conventional methods, it requires less time. The paper discusses the various applications of machine learning, deep learning computer vision, and image processing in a variety of industries, including milk and dairy, meat and meat products, fruits and vegetables, and bakery.

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