Current Journal of Applied Science and Technology

40(18): 1-9, 2021; Article no.CJAST.70223
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Advancements in Food Technology Using Artificial Intelligence- Deep Learning

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2021/v40i1831439
Editor(s):
(1) Dr. Teresa De Pilli, University of Foggia, Italy.
Reviewers:
(1) Shahzad Faisal, SKUAST-K, India.
(2) Gajanan P. Deshmukh, Maharashtra Animal & Fishery Sciences University, India.
Complete Peer review History: https://www.sdiarticle4.com/review-history/70223

Original Research Article

Received 01 May 2021
Accepted 05 July 2021
Published 27 July 2021

ABSTRACT

The food industry has continued to evolve in terms of technologies employed in food processing. These advancements are because of increasing demand of food. Many industries are beginning to explore new technologies to enhance maximum efficiency and productivity across the food value chain. Artificial Intelligence (AI) is one of the emerging technologies that have found great relevance in the food sector. AI is simply the creation of smart machines capable of exhibiting human intelligence. This technology uses algorithms like machine learning and deep learning to mimic

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human behavior. AI has continued to find relevance in food processing and has proven to be an added advantage to the industry. In this article, we considered the relevance of AI to the food industry, its various applications in food processing, benefits, and setbacks to its adoption in the food industry.

Keywords: Food industry; artificial intelligence; emerging technologies; food processing; machine learning; deep learning.

1. INTRODUCTION

With the promotion of healthy foods and increase in population growth, the demand for safe and quality food in the world has increased over the years. According to food and Agricultural Organization, the rise in growing population can reach around 9.1 billion by 2050 [1]. In order to meet the market demand of this increasing population in terms of healthier food, the food industry has continued to adopt newer food processing technologies.

Throughout history, different technologies have been employed in food sector to ensure the safety and quality of food. In early 1800s, Frenchman Nicholas Appert who is the father of food technology developed a method of preserving food called **canning**. In the 1860s, French scientist Lious Pasteur discovered in a research that thermal processing would deactivate unwanted microorganism which he referred to as **pasteurization**. Subsequently, the demand in food supplies invoked equivalent production value and novel food processing technologies. Novel food technologies are new trends in food processing as a result of consumers demand for health promoting foods with high nutritional value [2].

The idea of machines replacing human efforts in handling tasks at greater precision has always been a hope of the future. This hope is gradually becoming a reality with the introduction of Artificial Intelligence (AI). Nowadays, Smart machines that possess the ability to perform sophisticated tasks are gradually replacing human efforts. These machines are trained to intelligently see with visual perception, hear with speech recognition, and make useful decisions among others [3]. AI comprises of different fields which enables such advancements. These fields include Machine Learning, Natural language Processing, Visions, Robotics and Autonomous vehicles. The two major algorithms in the field of AI that enables such advancement are Neural Networks (NN) and Deep Learning (DL) [4].

Artificial intelligence has been employed as a data analysis tool to solve most challenges in the food sectors such as food sorting and grading, calories estimation, quality detection in fruits and cleaning of process equipment. AI not only reduces human labour and error but also ensure maximum efficiency and productivity across the food sector. However, the main purpose of AI in the food system is not to fully replace human effort but to develop intelligent systems capable of carrying out human task accurately and speedily.

These advances in food technology have led to innovations and improvement in producing safer and high nutritious foods for the increasing population.

2. CONCEPT OF ARTIFICIAL INTELLIGENCE IN RELATION TO FOOD INDUSTRY

Artificial Intelligence refers to designing machines (robots) with the ability to exhibit human intelligence. AI can mainly be described as either weak or strong. Weak AI can carry out one specific task while the strong is designed to carry out a series of operations considered to be human, Fig 1.

The use of AI in the food industry cannot be over-emphasized. Artificial Intelligence in food industry gives rise to larger possibilities to optimize and automate food processes and make less human error. It plays a vital role in ensuring food safety across the production line of a food plant using AI enabled camera which can smartly recognize objects and faces. Some food manufacturing companies have used this technique in ensuring workers are complying with food safety laws and regulations. AI can be employed in the various stages of the food industry from sorting fresh produce which when done manually can lead to inefficiency and time wastage.

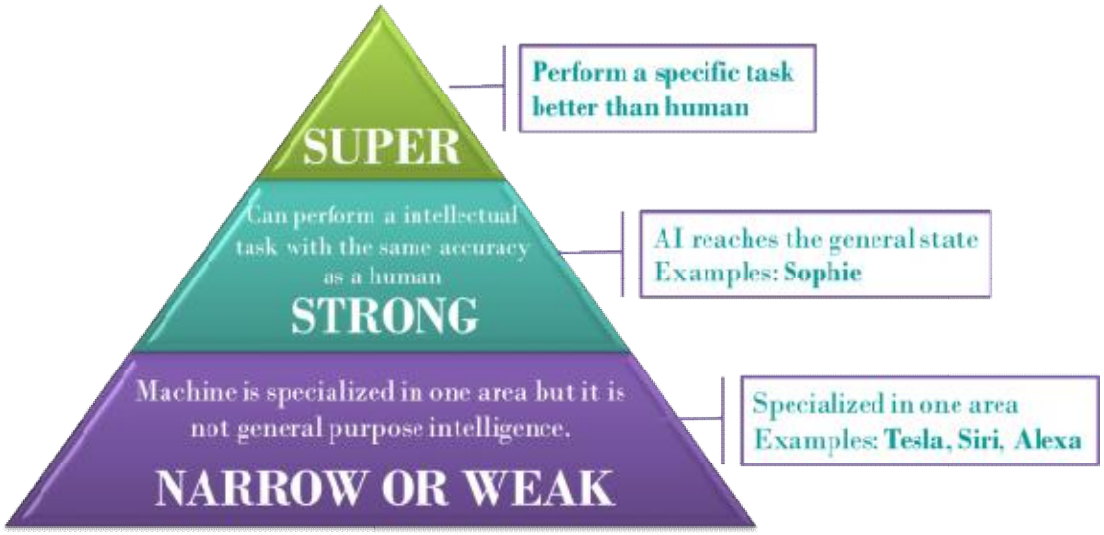

Fig. 1. Categories of artificial intelligence [5]

AI has successfully helped in reducing losses that occur during food processing. With AI, machines can be calibrated and trained to measure materials with high precision in order to manage product size, reduce waste and cost [6].

AI can also be deployed in cleaning food processing equipment. It uses a system called Self –Optimizing-clean-in-place system in place of the conventional CIP systems. The self-optimizing CIP systems are also trained to reduce food contamination with ultrasonic sensing and optical fluorescence. The efficiency of the supply chain management and development of new products according to consumer's choice can also be carried out with AI systems.

This emerging technology has not only made food processing easier and convenient but has increased productivity across the food sector.

2.1 Application of Artificial Intelligence in Food Processing

The food processing industry is one of the fastest growing industries in the world. As the demand of quality food is on the rise, many industries tend to employ more advanced technologies like Artificial Intelligence into the food system in order to improve the activities involved in food processing. AI not only allows automation of food processes but also helps in managing the food supply chain and reduces human error. There are different applications of AI in food processing some of which are; sorting raw materials and packaging, ascertaining food safety and standards, maintaining good manufacturing practices, product development, quality evaluation and establishing smart standard operating procedures using adaptive vision, consumer acceptability and decision making.

2.1.1 Sorting raw materials and product packaging

Among many others, TOMRA Sorting solutions developed artificial intelligence applications that utilize machine learning in sorting foods with sensor-based optical sorting technologies and near infrared sensors. These processes save time, money, and improve products quality. For example, TADD (Trainable Anomaly detection and Diagnosis) uses a type of robotics to sort and detect diseases of potatoes, Fig. 2.

AI has also been extensively used in the food packaging sector. These machines are trained with certain data algorithms to enable them collect products, arrange them and box them carefully. With this facility in food processing plants, human direct contact with food and hence, food contamination are greatly reduced.

2.1.2 Ascertaining food safety and standards

Food safety is the greatest concern of every food industry. Food safety ensures that the health of a consumer is protected from food borne diseases which can be caused by food contamination

either by bacteria, fungi or pathogens. Technological advancements in the food sector have granted food industries better tools to control and improve food safety. AI can be employed in food processing to monitor personal hygiene of workers using facial and object recognition. It can be used to prevent manual food cross contamination caused by handling and packaging by human workers.

Fig. 2. Sorting potato with an optical sorting machine [7]

Fig. 3. IBM AI-assisted tongue app, Hypertaste [8]

The use of electronic nose or tongue (electronic chemical sensors) which imitates the human sensory organs can be useful to recognize odor in raw materials thereby preventing cross contamination and improving the quality of foods during processing, Fig. 3. AI can also be applied in the field of food safety risks assessments which includes chemical and microbial risks assessments.

2.1.3 Maintaining good manufacturing practices

Compliance to good manufacturing practices can be significantly improved in the food industry with the application of AI. For instance, the use of facial and object recognition-enabled sensor-based cameras can monitor workers, ensuring the use of proper clothing and proper handling of equipment and materials within the production premises as required by safety laws.

2.1.4 Product development

Machine learning trained with predictive algorithm has been used in different stages of developing new products. Such systems are trained to detect flavour, model consumer choice product, reaction and acceptance of the new product.

Data can be segmented into demographic groups to help companies develop new products that match the preferences of their target audience. According to Cassa-Rosal *et al*. [9], data can be used to determine consumer preference by segmenting it into demographic groups. Coca cola's self service beverage fountain is an example of this innovation. It allows consumers to formulate different flavoured-drinks as preferred [10]. There are three areas that new product development requires success, which are:

1. Reduction in product development cycle time: This determines how quick a food industry begins to recover its investment in a new product. The ability to seize both market dominance and share of its competitor, i.e. the first- mover advantage most times gives significant profit margins for the life of product.

2. Increase in product development innovation: These helps to build product image and create a franchise through successive product innovation and enhancement. The extent to which the consumers like the product is determined mostly by new innovations added to that product.

3. Repeated use of company's knowledge assets: Reusing existing company's knowledge is good, but it is important to avoid those costly rework and repetitive mistakes. Research that has greatly generated insightful knowledge and consumers' advantage choices should be considered and new innovations should be done on it to improve it.

To achieve maximum success in the food industry, in this twenty- first century, innovation of new products is the key. The food industry is becoming highly competitive, consumers no longer want products that are of low- prices but they want products that are of low-prices and of high quality. As a result of that the practice of product lifecycle management (PLM) is becoming a master player of innovations.

2.1.5 Quality evaluation and establishing smart standard operating procedures using machine vision

The issue of quality and consumer acceptance is of utmost importance in the food industry. To consistently ensure safe and wholesome food, standard operating procedures and quality control guidelines must be established and followed during production and through the food supply chain. Since the first industrial revolution, standard procedures of food production and processing as well as quality evaluation have been evolving. Initially, maintaining standard operating procedures and quality assurance guidelines were quite arduous and required intensive human labour which is often slow and prone to bias and inconsistencies. Technological advances led to the emergence of artificial intelligence in most modern industries. The application of artificial intelligence such as machine vision systems in ensuring food safety and quality is a game changer in the food production and manufacturing sector. A machine vision-based solution provider, TOMRA, has been developing sensor-based machines for executing standard operating procedures in most food manufacturing companies [11]. Sorting, grading, peeling, and packaging of foods can be carried out with these sensor-based machine vision systems. Fig. 4.

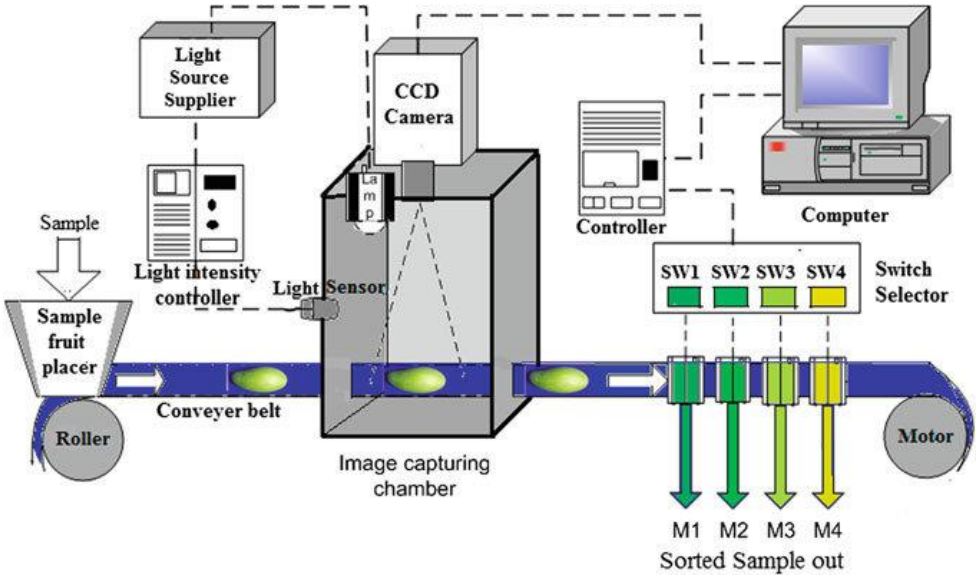

Fig. 4. An automated machine-vision based mango sorter model [12]

Adaptive Vision, another Machine vision solution provider, launched a data-based software, typically for industrial quality evaluation. The software can be trained with algorithms that can detect foreign materials in food, classify fruits according to ripeness, identify defects on food material and plants, ensure completion of food packages and count objects [13]. Machine vision systems are trained with deep learning algorithms that inspect images while collecting data and providing meaningful information from the images. Machine vision has been successfully used in detecting eternal defects in colours, shapes and sizes of food as well as evaluating internal quality of food with high degree of accuracy [14]. Momin *et al*.[15], reported 98% accuracy in identifying defects in soybeans and stem pods using HIS (hue, intensity, saturation) based machine vision system trained with median blur filters, morphological dilation and erosion, watershed and connected-component labeling algorithms. Faridi and Aboonajmi [16] provided a comprehensive review that cited evidence on application of AI from studies on fruits, vegetables, meat and cheese that used either the HIS (hue, intensity, saturation) or RGB (red, green, blue) colour based machine vision system algorithms.

2.1.6 Consumer acceptability and decision making

Consumer acceptability and decision making with respect to wholesome food products are always uncertain and changing. According to Koster [17], there is a consensus that consumer choices are greatly influenced by both physiological and psychological components. Prior to the launching a novel food product, a consumer studies must be carried out to develop a deeper understanding for a guaranteed product success [18]. Hedonic assessment tests and qualitative surveys are the most common methods to deduce consumer acceptance and purchasing decisions. These tests often require a large population of consumer panelists to achieve accurate results. The process of screening panelists, preparing tests location and analysis of data obtained are both costly and time consuming [19]. There has been a growing attention on the use of artificial intelligence algorithms in determining consumer acceptance recently. Alvarez-Pato et al.[18]used a galvanic skin response (GSR) device and facial emotion recognition (FER) software in deducing consumer acceptance through emotional reactions. Fuentes et al. [20] assessed the aroma flavour of pinot noir with an accuracy of 99% using artificial neural network (ANN) models. Machine learning models with predictive accuracy of 99% were proposed by Gunaratneet et al. [21] as an alternative to sensory evaluation panels which were costly and prone to bias. In the study, the physicochemical parameters of chocolate were used to train machine learning models to predict consumer acceptance. AI in the food industry has helped to efficiently determine consumer choice, reduce waste during production, reduce food contamination and make

useful decisions. Most food industries are leveraging on AI technology and Machine Learning to help consumers with day-to-day food choices. For example, Edaman, a New York based company compiles a 50,000-item food database with a recipe analysis which allows consumers to get nutrition information for any recipe or ingredient list. This technology gives consumers the privilege to customize their desire recipe. Also, in 2018, the Kellog Company launched an AI technology Bear Naked Custom which allows consumer to create their own personalized granola from more than 50 ingredients. This technology not only allows customer to make their choice but also help industry save cost from inefficient process because of trial and error in meeting customers' expectation.

2.2 Benefits of Artificial intelligence to Food Industry

The benefits of artificial intelligence cannot be undermined. It is becoming increasingly popular due to its ability to reduce waste, improve good manufacturing practices, and safe packaging of foods. In a few seconds, automated systems can collect hundreds of data on a single food product and quickly assess it [22]. An automated system for example, can collect and process data from hundreds of individual ingredients as they move quickly on a conveyor belt. This automated system can significantly reduce labour cost and waste [23].

Benefits of Artificial intelligence to the four core areas of operations in the food industry are:

- **Food science:** Artificial intelligence carries out market analysis, construct recipe of new product ideas, identify possible consumer flavor and choice, predict yields on raw food products, and ensure safety measures. These have greatly impacted the food industry and made production easy, fast and safe.

- **Supply chain management:** The supply chain management and the distribution of the food products is major priority of every food companies. The safety of the food at every points of the food supply system is to ensure compliance to industry. Additionally, consumer specifications can be monitored accurately through the application of robots and automations. Along the distribution links, Artificial intelligence can also be used to track products effectively when transporting them from location to location.

All of these applications will efficiently track produces from manufacturer to consumers leading to increased brand trust and confidence amongst consumers [24].

- **Consumer experience:** Artificial intelligence is used to monitor and gain insights on consumers' responses on products use and also facilitates the use of self - service point - of - sale system. This process gives consumers a better trading experience.

- **Manufacturing:** Good manufacturing practices in food process enterprises have been greatly maintained since the advent of Artificial Intelligence. This has greatly reduced the risk of downtime with asset health and predictive maintenance. With the development of suitable technology, such as Artificial intelligence to the food industry, reduction of waste food products, practice good hygiene and time management can be practiced effortlessly.

2.3 Challenges of Artificial Intelligence in the Food sector

Despite the numerous benefits of artificial intelligence, there are several constraints on the adoption of this novel technology in the food industry, most especially for the small and medium sized food businesses. A major drawback is that AI systems are expensive to build due to the shortage of AI engineers. In addition, AI systems consumes time in completing the process of data mining, algorithm building, machine training and trial experiments before its application in real time [25].

Secondly, there is the fear of unemployment and wealth inequality. Su et al.[26] reported that repetitive, tedious, and dangerous human tasks are all gradually being automated with artificial intelligence systems. This will inadvertently lead to decline in demand of human labour, particularly unskilled. A review by Ernst et al. [27] described this phenomenon as the displacement effect.

Not only are AI systems expensive and time-consuming to establish, they also require constant upgrading or complete change of their

algorithm to meet up with improving industry trends. At the beginning of the protest, Shahin*et* al. [28] achieved 88% accuracy in sorting apples using the neural classifier. Recently, a convolutional neural network classifier was used in sorting 200 apples with an accuracy of 92% under 72 milliseconds in a study by Fan et al. [29].

On the bright side, Ernst et al. [27] mentioned the skill-complementarily effect, which means the emergence of AI will give rise to novel jobs that do not exist today. The World Economic Forum (WEF) [30] predicted that 97 million AI-related jobs will be created across 26 countries. Wilson et al. [31] opined that most of these jobs will involve the creation and management of machines as well as capacity building of AI engineers. Currently, AI engineers are highly in demand and according to Forbes [32], top AI engineers are paid over $350,000 US per annum.

3. CONCLUSION

The introduction of AI technology into the food industry is gradually reshaping the activities that go on in the food industry. AI in food processing not only helps improve and increase efficiency and productivity but also ensure consistency is maintained in the food system. Its role in the food industry cannot be overemphasized. However, the cost of implementing this technology seems to be a limiting factor to most food industries.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/70223