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The Present and Future Developments in AI Applications Within the Food Industry

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Abstract – It is important for individuals to have access to sustenance in order to sustain their existence. Enhancing food logistics, food delivery, and food safety, as well as minimizing food waste and optimizing the supply chain, are imperative. The use of machine learning and AI is crucial in attaining these objectives. The proliferation and advancement of computing networks have facilitated the emergence of state-of-the-art logistics and industrial infrastructure. The networks including sensors, machines, systems, intelligent devices, and individuals are continuously producing novel data. With the increasing computational capabilities, the analysis of Big Data may now be conducted more efficiently, comprehensively, and extensively than ever before. The aforementioned advancements have given rise to a novel epoch identified as Smart Factory or Industry 4.0, whereby there is a notable emphasis on use of AI technologies. The objective of this essay is to examine the present and prospective trajectories of artificial intelligence implementation within the food business. Before delving into the current and forthcoming advancements in food processing and manufacturing, this article will elucidate the selection principles, or criteria, for choosing an AI methodology.

Keywords – Artificial Intelligence Technologies, Machine Learning, Food Processing and Production, Food Logistics, Food and Beverage Industry.

I. INTRODUCTION

One commonly accepted conceptualization of intelligence pertains to its capacity to replicate human cognitive functions, such as acquiring knowledge, strategizing, interpreting sensory information, and comprehending linguistic expressions. Computer systems are increasingly capable of doing tasks that have traditionally relied on human intellect, such as visual perception, speech recognition, selection, and language translation. The information technology industry has made substantial expenditures in the development of robotic systems capable of doing jobs traditionally carried out by humans. According to Zhang and Lu [1], AI may be described as the use of scientific knowledge and technical expertise in the development of intelligent computer programs. Machine learning and deep learning are prevalent categories within the field of artificial intelligence. Data-driven models are used for the purpose of forecasting by many entities, including people, organizations, and governments. The food business is now using machine learning techniques to address the complex and uncertain characteristics of data. **Fig. 1** elucidates the function of AI within the food processing sector, while **Fig. 2** presents a projection of its anticipated use in the transnational beverage and food industry spanning the years 2019 to 2026.

The use of AI has become imperative for food companies due to their objectives of enhancing customer experience, optimizing supply chain management, increasing operational efficiency, and minimizing material wastage. These objectives align with the core objective of the industry, which is to provide standardized and dependable techniques for quality control in product design. Cutting-edge cognitive computing and deep learning algorithms have been developed for the aim of automated visual inspection, fault detection, and maintenance in fabrication systems. The use of reinforcement learning algorithms often proves advantageous in material processing techniques and production schedules. Industries seeking to use present data are increasingly integrating artificial intelligence techniques with conventional operational research methodologies, as well as incorporating cyber-physical systems, technologies from the IoT and concepts.

This paper is organized as follows: Section II presents the methodology for choosing the most appropriate artificial intelligence method. Section III presents a discussion of the wide-range applications of AI in the field of food production. Section IV discusses the different trends on the applications of AI in the food industry paying closer attention to its disruption in the future. Section V draws final remarks to the paper, as well as directions for future research.

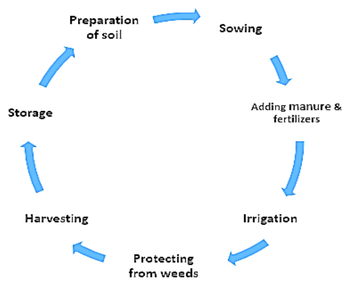

Fig 1. Artificial Intelligence in Food Processing

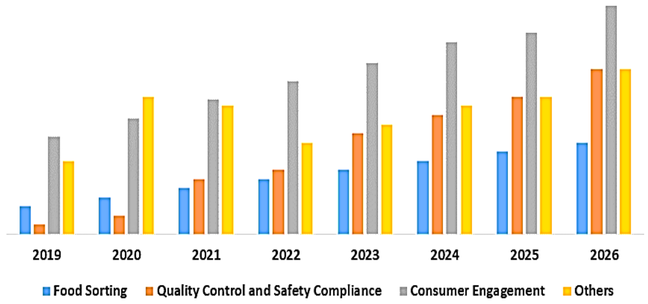

Fig 2. Global AI in the Beverage and Food Industry, By Application 2019 – 2026

II. CHOOSING THE APPROPRIATE AI METHOD

To ensure the user achieves precise, efficient, and cost-effective results, it is essential to use the appropriate algorithm throughout the development of the AI model. The primary objectives of artificial intelligence applications in the industry of food are estimation, quality control, adulterant detection, classification and prediction. The subsequent stage involves determining the need of using specialized transducers, for example computer vision system (CVS), Near Infrared Spectroscopy (NIRS), E-tongue and E-nose, for the purpose of collecting data from the samples. The acquisition of attributes and features of the samples used in AI algorithms for sample testing is often achieved by integration with sensors. After users have established the need of sensors for their study, they may proceed to evaluate and choose an appropriate algorithm.

The Artificial Neural Network (ANN), Fuzzy Logic (FL), and Machine Learning (ML) techniques are often used AI algorithms. While ANFIS (Adaptive Neuro-Fuzzy Inference System) has shown superior accuracy compared to other algorithms, its model complexity renders it less appealing. When selecting an algorithm for their research, users should consider the intricacy of the investigation. The AI algorithms are integrated with the available data upon selection of the algorithm. The performance of the created model is evaluated by testing and validation, using R^2 and MSE metrics. Upon successful validation, the AI model is formed. However, in the event of a failed validation, customers are required to choose the algorithm once again. **Fig. 3** presents a comprehensive framework delineating the process of selecting and constructing an AI model specifically tailored for use within the food industry.

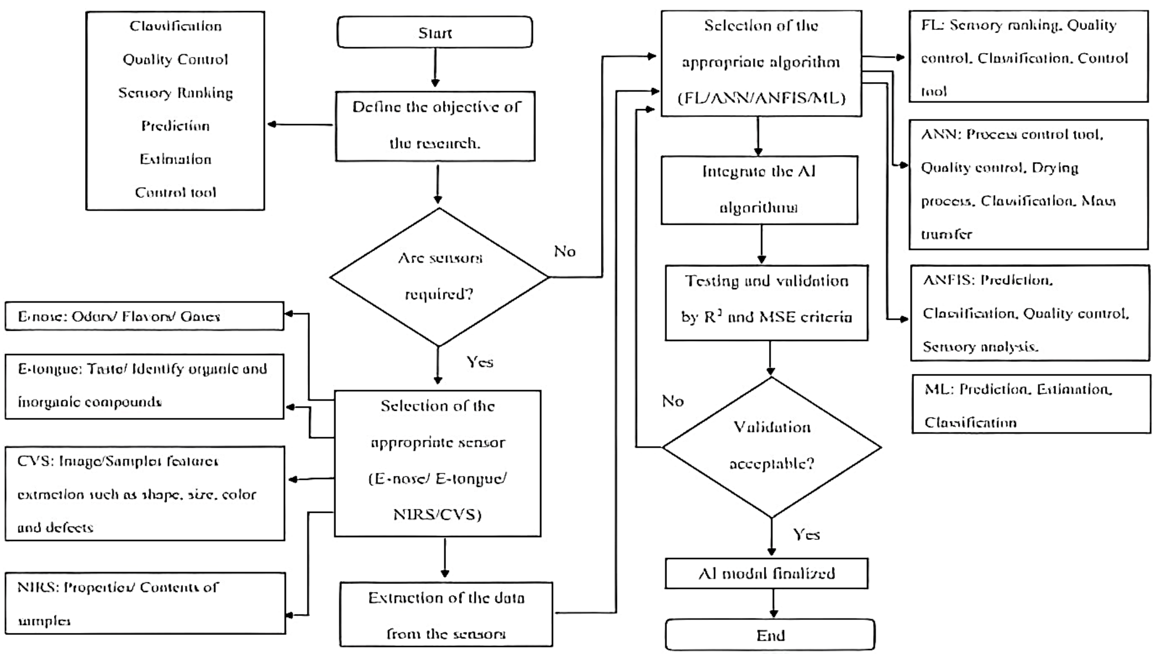

Fig 3. Flowchart for Developing AI Model

III. APPLICATIONS OF AI IN FOOD INDUSTRY

Sorting Fresh Produce

Although a certain degree of spoiling is inevitable, the primary cause of product loss during processing is mostly attributed to inefficient sorting techniques. The presence of a significant volume of garbage results in huge financial losses for businesses. The need to decrease food waste extends beyond financial concerns, as it is driven by the projected increase in food consumption of 59%-98% by the year 2050. The identification of foreign objects or fruits that fail to meet the criteria set by food safety organizations is a critical component of the supply chain, making sorting an essential process. Therefore, the exclusion of inferior products is an essential stage in this process.

The consumption of food has detrimental effects on both the economy and the environment. According to the Food and Agriculture Organization (FAO), the global emission of greenhouse gases is estimated to be 8% attributable to the loss and waste of food. The prevalence of human sorting in the process introduces a significant potential for errors. Business enterprises may have significant consequences in the event of their failure to identify and address undesirable products or faulty merchandise, including costly legal proceedings and many other challenges. Nevertheless, several agricultural establishments have found that innovative approaches, such as the use of AI-enabled sorting robots, might potentially surpass the current methods in terms of efficacy and cost-effectiveness.

The problem of inconsistent availability of feedstock is a significant challenge for food processing plants. The loss and wastage of around one-third of global yearly food production is a significant concern within the food sector. According to projections made by the United Nations, it is anticipated that by the year 2020, around 1.3 billion tons of food would be discarded on an annual basis, resulting in a financial loss amounting to $1 trillion. The concept of "food waste" pertains to the squandering of edible food as a result of faults in preparation, storage, or consumption. Food waste is intricately linked to several sectors of the food industry, spanning from agricultural production to retail, hence including the whole supply chain. The primary contributors to food waste include transportation, harvesting methods, and food waste caused by consumers.

The food industry encounters several challenges, as seen in **Fig. 4**. The answer to decreasing food waste lies in cultivating awareness. Food waste is a consequence of inadequate system design and the industrialized process of food production. Food insecurity might potentially have similar consequences, exacerbating the issues of poverty, hunger, and social isolation. The typical method of food production is associated with substantial energy inefficiency and contributes significantly to carbon emissions.

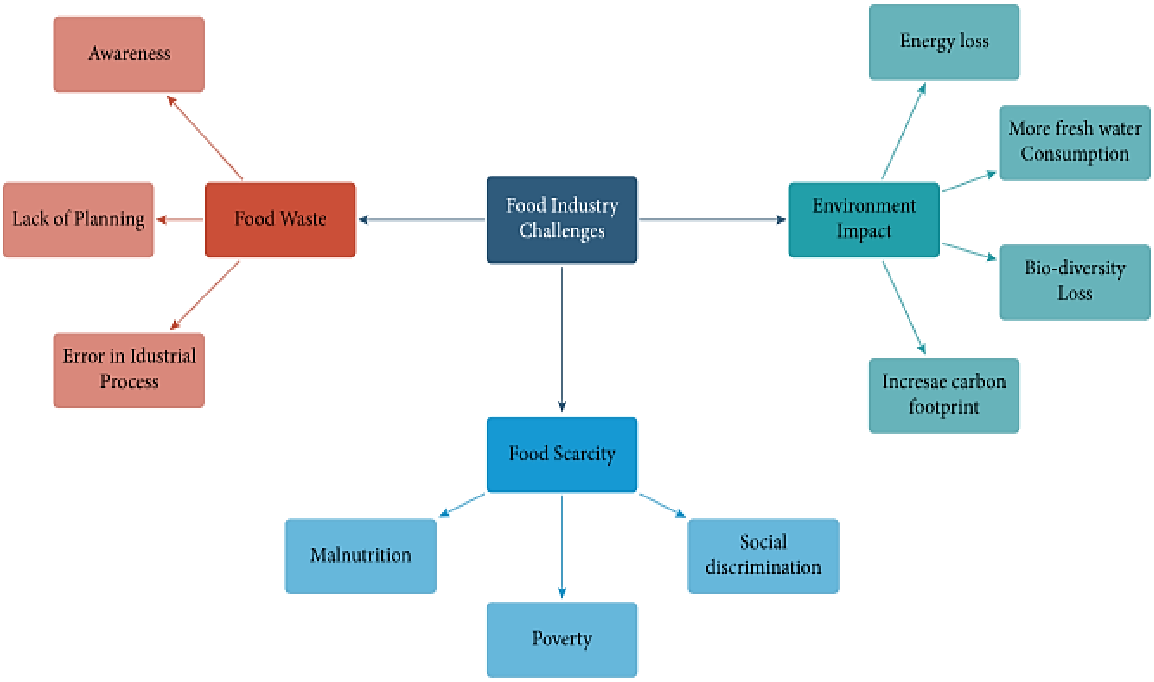

Fig 4. Food Industry Challenges

The effectiveness of vegetable processing facilities is compromised and extra expenditures are incurred as a result of their dependence on labor-intensive manual sorting. The use of AI systems including a combination of cameras, lasers, and machine learning may significantly enhance the operational efficiency of food sorting processes inside companies operating in the food business. One potential solution to address the labor-intensive and time-consuming process of sorting fresh produce is the integration of AI with sensor-based optical sorting technologies. This approach has the potential to enhance productivity, improve the quality of the output, and minimize waste. The use of AI facilitates the enhancement of machines' calibrations, hence enabling efficient management of several product sizes while minimizing both waste and expenses. In this study, we aim to explore the outcomes of climate change on diversity in tropical rain.

The accurate procurement and packaging of food products represent a significant investment of time and effort for manufacturing units within the food processing industry. Therefore, the implementation of AI-based systems may effectively handle such a complex task, therefore minimizing the probability of human error and simultaneously enhancing productivity within the sector. The diverse range of sizes, colors, and shapes shown by produce poses a significant difficulty in the development of AI systems. In order to ensure the proper training and operation of an artificial intelligence based on packing and sorting system, significant information is necessary. Multiple research facilities developed significantly different methodologies in order to achieve a same objective. TOMRA is an exemplary organization that demonstrates proficiency in executing the sorting process effectively. The outcomes of the experiment were rapid gains in productivity and a level of accuracy reaching 90%. At now, a computerized system is responsible for the bulk of product sorting and packaging operations. The use of such technology has resulted in several advantages for organizations, including enhanced production rates, improved quality yields, and decreased labor costs. **Fig. 5** provides a visual representation of significant applications derived from the industry of handling and food processing. In both the food production and retail industries, several prominent names are recognized. The increasing amount of competition within this industry is diminishing its attractiveness to potential entrepreneurs. In order to maintain a competitive edge in the food industry, it is imperative using technology, namely information science. The topic of information analysis within the meal industry is addressed in **Fig. 6**.

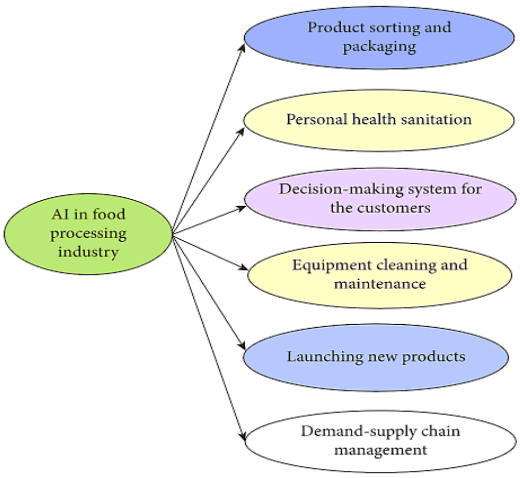

Fig 5. Important Applications Taken from Food Processing and Handling Industry

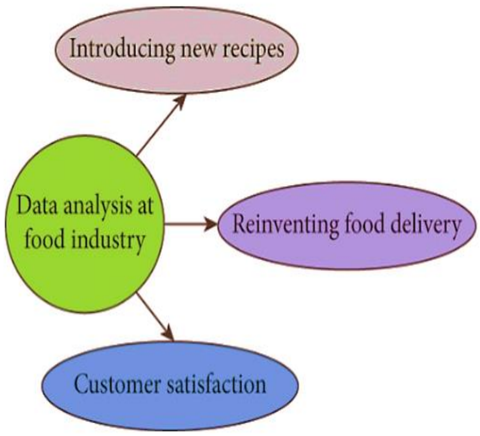

Fig 6. Data Analysis at Food Industry

Artificial Intelligence is based on decision making systems include a diverse range of equipment and plan of action, including IR spectroscopy, X-ray-based systems, high-resolution cameras and laser technology-based systems. Fruits and vegetables, along with other dietary items, may be subjected to a thorough study using input-channel methodologies and advanced technology. Traditional approaches are limited in their ability to assess the quality of objects only based on their superficial characteristics. The research findings indicate that TOMRA has shown a potential improvement in the detachment and ordering difficulties by around 5-10% specifically in the context of potatoes.

A different company, situated in Japan, used a machine learning system built on TensorFlow to address a comparable problem, yielding equally remarkable outcomes and advantageous contributions to their manufacturing division. This strategy has not only yielded significant benefits for the food processing business, but has also proven advantageous for several other sectors. Additionally, each organization verified that the solution based on artificial intelligence yielded findings of higher accuracy. The achievement in the field of potatoes serves as a driving force to explore analogous AI-driven solutions for several other domains. There is potential for expansion in order to accommodate more industries within the food processing industry.

Efficient Supply Chain Management

Our study findings indicate that although there exists a wide range of AI techniques that may be used to SCM (supply chain management), only a limited fraction of these techniques is now put into practice. One of the most prevalent and impactful techniques in the field is artificial neural networks (ANNs), which serve as a means of information processing capable of extracting valuable insights from extensive datasets and generating novel models. The correlation between input and output streams from process units is often established by mathematical regression, which serves as the fundamental principle underlying most ANNs. According to the ASCE Task Committee on Application of ANNs in Hydrology [2], a significant amount of experimental data is often necessary for such models. ANNs are often used as the predominant methodology in computational intelligence, owing to their remarkable flexibility. Predictive analytics plays a significant role in supply chain management, including several applications such as sales forecasting, marketing decision support systems (DSSs), pricing strategies, and customer segmentation. Abiodun, Jantan, Omolara, Dada, Mohamed, and Arshad [3] asserts that ANNs are becoming used in business environments. This is largely due to the fact that they may encounter situations that include a significant amount of data, for which the necessary rules or procedures are either not comprehended or not readily articulated.

In order to establish a connection between AI and non-AI approaches, the second way used is FL/modelling, as discussed by Jarrahi, Askay, Eshraghi, and Smith [4]. The fuzzy logic (FL) theory, discussed by Zadeh [5], has gained prominence in recent years as a prominent approach for developing intricate models and systems. The rapid advancement and increasing use of this approach may be credited to its ability to successfully manage qualitative data via emulating human reasoning and decision-making processes. ABSs and MASs are often used methodologies in the field of supply chain management (SCM) research. An agent-based model refers to a computational framework that replicates the actions and interactions of autonomous agents, while also including the assessment of their impacts on the overall system.

The technique described by Siegenfeld and Bar-Yam [6] integrates many disciplines, including complex systems theory, game theory, computational sociology, and evolutionary programming. In other words, agents possess the capacity to perceive their surroundings and proactively address challenges. To achieve their objectives, agents construct Multi-Agent Systems (MASs), which are networks of agents, via their interactions with each other. According to Ladyman, Lambert, and Wiesner [7], complex systems may be effectively modeled, created, and executed via their operation as a combination of code and data. Agents have been widely used in supply chain management (SCM) and several other industries since the mid-1990s in order to effectively tackle a diverse array of difficulties. The applications of supply chain encompass several areas, such as the design and modeling of supply chain systems, the examination of supply chain complexity, and the implementation of distributed supply chain planning. and collaborative structures grounded upon negotiation

The increasing need for transparency within the food sector has necessitated the adoption of supply chain management practices by all food enterprises. The meal sector is using Artificial Intelligence to optimize chains supplied by implementing food testing and monitoring measures at each step of the process. This ensures adherence to both industry and consumer standards. Enhanced pricing and inventory management via the use of more accurate forecasting techniques. The use of AI in image identification technology facilitates enhanced precision and efficacy in the process of food procurement. The use of AI in the monitoring of food items, from their origin on the farm to their consumption by consumers, has the potential to enhance confidence among consumers in the food system.

Food Safety Compliance

The increasing significance of stringent compliance standards for food safety is seen in tandem with the expansion and evolution of the meal industry. The use of artificial intelligence is becoming more prevalent among organizations as a means to automate processes and improve the accuracy of food safety evaluations. AI-enabled systems have the potential to rapidly and correctly detect potential hazards that might compromise food safety. AI-powered systems have the capability to examine data pertaining to food safety and detect trends and patterns that may elude human observers. This is made possible via the use of machine studying algorithms and other advanced technological tools. The use of AI has the prospective to be utilized in the identification of food safety concerns, including instances of adulteration or contamination. AI has the potential to assist companies in understanding the intricacies of the meal supply chain, hence mitigating any food safety issues in the future.

The automation of AI may also facilitate the implementation of food safety compliance processes. AI has the potential to enhance company efficiency by automating repetitive tasks such as record management and data acquisition, resulting in time and cost savings. Real-time monitoring of food safety data may be facilitated by the use of AI-driven solutions, enabling companies to promptly respond to developing issues. The use of artificial intelligence might potentially augment the accuracy of food inspections. In order to enhance employee compliance with food safety regulations, companies may use AI-driven technologies such as facial recognition and speech recognition. In order to mitigate the emergence of issues, enterprises may use AI-based solutions to oversee the results of food safety audits.

AI-enabled cameras are used in a food processing facility to oversee and ensure staff' compliance with safety rules. In order to maintain the prescribed levels of personal cleanliness as stipulated by the Food Safety Modernization Act, this system employs facial-recognition and object-recognition software. In the event that a violation is identified, the system promptly captures screenshots to facilitate the prompt resolution of the problem. This approach has shown a success rate above 96%.

Cleaning Food Processing Equipment

It is important to allocate enough attention towards the delineation of procedures and criteria for the cleaning and sanitization processes, as they constitute the most pivotal elements of a sanitation program. Detailed processes must be advanced for all surfaces come in tangency with food products, including utensils and equipment, as well as drained surfaces such as refrigeration units, heating, lighting devices, shields, ceilings, walls and overhead structures, ventilation, and air conditioning (HVAC) systems. It is essential that each process line be equipped with a well-defined cleaning plan, which should be adhered to on a daily basis, after production runs, or as necessary. Additionally, it is crucial to ascertain the specific kind of cleaning that is required.

It is of benefit to ensure that meal contact surfaces undergo through sanitization and cleaning processes in order to effectively eradicate any existing bacteria and eliminate any residual food substances that may serve as nutrients for bacterial growth. In order to prevent the proliferation of microorganisms, it is essential that all surfaces and equipment undergo thorough drainage followed by storage in a hermetically sealed and desiccated environment. It is important to maintain the impeccable condition and sanitary storage of all instruments, including brushes and other equipment. The implementation of protocols for the examination and assessment of cleaning and sanitation procedures is necessary in order to ascertain their adequacy. It is important to maintain continuous surveillance and documentation in order to evaluate the adherence to prescribed protocols over an extended period of time. This includes conducting inspections, swab testing, and directly observing staff members.

In the context of cleaning systems, it is possible to configure in-situ mechanisms to perform cleaning operations at certain time intervals. The use of automated systems decreases the need for human intervention, thereby mitigating the potential for transmitting food-borne illnesses. However, it is important to note that these systems are not infallible and are designed to operate on the assumption of worst-case scenarios. The AI-enabled clean in situ system (SOCIP) utilizes ultrasonic sensing and optical fluorescence imaging techniques to assess the presence of food residue and microbiological detritus inside a piece of equipment. This enables the optimization of the cleaning process. Consequently, valuable resources such as water, time, and electricity are preserved. According to Ballard, Brown, Madni, and Ozcan [8], the duration required for cleaning up is reduced by 50%.

Anticipating Consumer Preferences

In the field of behavioral research, a person's worldview greatly affects their purchasing decisions. Consumers' ingrained beliefs prohibit them from objectively weighing their options, which keeps them stuck in their ruts. Businesses that try to get people to alter their behavior by either not taking into account or directly confronting their values face an uphill struggle. Once a client associates a certain effect with a certain condition, that effect may begin to occur impetuously. Occupation can help transform into habits by determining the triggers in the habitat. Any action, period of time, or location may serve as a contextual cue. More and more people, for instance, are stocking up on cleaning wipes and hand sanitizer to keep by the door. Users are more likely to keep up the "put it by the door" habit if the product marketing and packaging continue to motivate this practice.

In order to better understand and simulate the flavor preferences of their target customers, food makers are turning to artificial intelligence-based solutions. Predictive analytics powered by AI like this will assist the meal industry in establishing new goods that are more in tune with shoppers wish. In two thousand and seventeen, the Kellogg Company introduced Artificial Intelligence enabled technology to let consumers choose which of 50 granola constitutes should be used to make a specific personalized commodity. Artificial intelligence will give ideas for what to exert in your granola and will tell you whether the impression will work well together. The AI does more than merely aid people in creating individual batches of granola. A feedback loop is created by the general information from flavor combinations, information about what choices individuals actually make, and information about what combinations they re-order. The parent business will be able to utilize this knowledge to its advantage when determining which new goods to launch under its bigger brands.

Developing New Products

According to some estimations, the duration of new product development is around 50% of the overall time needed to successfully introduce a product to the market. To enhance efficiency and cost-effectiveness, organizations may now use AI to do comprehensive digital assessments and predictions on product prototypes. In several instances, the attributes of forthcoming commodities will extend over a spectrum. Entrepreneurs possess an understanding of this phenomenon. Start-up companies exhibit a proactive approach and recognize the need of implementing cost management strategies and achieving tangible outcomes in a timely manner. The choice to use AI in order to expedite the product-market-fit stage has already been taken by the creators. Investors attentively consider the requirements of companies, so negating any grounds for complaint. In the year 2019, investments amounting to $16.5 billion were made in commodities that were propelled by AI. The presence of many internet job advertisements pertaining to artificial intelligence serves as compelling evidence that intelligent algorithms are significantly transforming the product development sector. There exists a substantial number of job opportunities for product development engineers, with over 16,000 vacancies being advertised on prominent professional networking platforms such as LinkedIn, job search engines like Monster, and career websites like Glassdoor.

The use of artificial intelligence technology plays a crucial role in the modeling of consumer flavor preferences and the prediction of their response to new tastes. Marketers often use demographic segmentation of data to effectively customize their products or services for certain customer segments. Manufacturers may use these techniques to forecast the viability of their products prior to their introduction into the retail market. Coke has implemented hands-on soft drink dispensers at several dining places, allowing patrons to customize their beverage selections. These automated systems let consumers to personalize their drinks by selecting from a diverse range of flavors and bases. Coca-Cola is using artificial intelligence technology to analyze the huge volume of data produced by several freestyle drink fountains, which distribute a multitude of drinks on a daily basis. The first output of this data was CHERRY SPRITE. The artificial intelligence system reached the determination that a standalone product consisting of cherry-flavored Sprite, only manufactured via human intervention, would likely achieve commercial success.

Front-End or Consumer Facing Applications of Artificial Intelligence

The AI ecosystem comprises three fundamental components: output systems, statistical computational methodologies, data collection and storage. These components collaborate to enable goods and services to execute tasks that were traditionally attributed to human autonomous decision-making and intelligence. These components are associated with abilities such as auditory perception, anticipation, creativity, and verbal communication. Listening devices are capable of gathering data from several sources, including goods sensors that scan the surrounding habitat and wearable gadgets that note physical activity. Prediction algorithms use the aforementioned data in order to formulate informed conjectures. For instance, Spotify leverages user preferences to build curated playlists. The last kind of system is the output system, which is tasked with facilitating communication with users or generating a response. This may be achieved, for example, via the use of vehicle guidance systems or consumer interfaces such as Baidu's Duer.

To explain the concept of Artificial Intelligence from the standpoint of its users, the emphasis is redirected from the underlying technological aspects to the tangible user experience. The concept of "consumer experience" pertains to the many encounters that occur between customers and businesses along the customer journey. It encompasses a multitude of characteristics, including the emotional, cognitive, behavioral, and sensory aspects of the customer. The technique we use consists of four distinct interactions that parallel the manner in which customers interact with the 4 artificial intelligence capabilities, as seen in **Fig. 7**.

The acquisition of firsthand knowledge has the potential to shed light not only on the practical and functional aspects of technology use, but also on the emotional and symbolic dimensions. The relationship between a person and AI may be categorized into four separate stages, namely "data capture," "classification," "delegation," and "social." The term "data capture" pertains to the process of supplying AI systems with personal information. Similarly, "classification" refers to the process of receiving personalized predictions from AI. "Delegation" denotes involving in processes of production where the consumer assigns certain duties to the AI for execution. Lastly, "social" signifies the act of interacting with an AI partner.

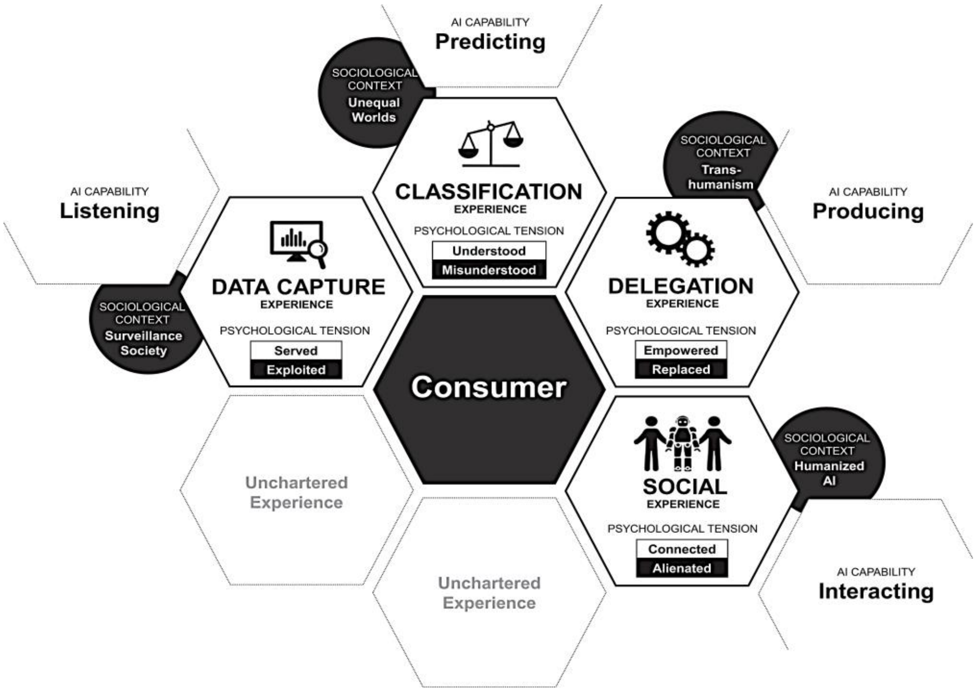

Fig 7. The Consumer AI Experience

The possible advantages and disadvantages from the consumer's perspective are enumerated for each kind of experience. It is recommended that managers consider the drawbacks alongside the benefits while directing their focus. For instance, the process of data acquisition may have both positive and negative effects on customers. Similarly, experiences related to categorization can either enhance understanding or lead to confusion among consumers. Furthermore, delegation experiences can either empower consumers by providing them with more control or render them obsolete. Lastly, social experiences can either foster a sense of togetherness among individuals or contribute to their disconnection.

Recommendation Engines
Food discovery and recommendation engines that use Artificial Intelligence have the potential to assist customers in making well-informed decisions on their dietary choices. These engines operate via programs that acquire knowledge about the food preferences and dietary needs of individuals.

Apps and Chatbots
By using Virtual Assistants driven by artificial intelligence, restaurants have the potential to reduce customer waiting times for inquiries and specific demands. The enhancement of customer service may be achieved by the simplification of the method.

Based on a recent study conducted by Følstad and Brandtzaeg [9], it was found that 34% of individuals who use chatbots have engaged in prior transactions with restaurants, while 56% of respondents are contemplating the possibility of doing so in the future. According to Leung and Wen [10], chatbots have the potential to enhance the present restaurant digital ordering system. This is because they can easily integrate with various communication systems already in place, such as point-of-sale (POS) systems, websites, and mobile apps. Chatbots provide comparable benefits to organizations in terms of revenue growth, efficiency enhancements, and cost reductions, similar to other digital ordering alternatives. According to Misischia, Poecze, and Strauss [11], chatbots possess a communication benefit over mobile app and online strategies due to the potential for consumers to bypass steps in the ordering way or place orders in a manner similar to interacting with a waitress.

The existing body of research indicates that there is considerable variation in diners' perspectives about automated ordering systems. According to Jaghbeer, Hanson, and Johansson [12], those who had a greater sense of control reported higher levels of satisfaction. Conversely, individuals who exhibited fear towards technology and had a strong need for interpersonal connections reported lower levels of satisfaction. Gaining insight into customer perceptions and behaviors about chatbots in the context of food ordering is of paramount importance for restaurant proprietors and managers, particularly in light of the promising prospects associated with incorporating chatbot technology into the current digital ordering infrastructure. Over an extended period, the field of social sciences has generated a substantial body of scholarly literature that delves into the origins and outcomes of human behavior. In recent years, researchers have devoted their attention to the study of human-robot interaction and human-computer interaction, specifically examining the social presence experienced by individuals during interactions with other agents.

However, there is a limited number of empirical research that have examined the use of chatbots in the hotel industry. The primary objective of this research is to address the existing gap in information by using the social presence theory to compare the performance of chatbots and consumer perceptions with other ordering ways for takeout of restaurant. The comparative analysis of ordering processes in full-service restaurants and quick-service restaurants has significant to importance, particularly in light of the increasing use of digital ordering systems by establishments of full-service. According to Csaszar and Ostler [13], the theory of contingency posits that the effectiveness of an organization is contingent upon the alignment between its characteristics, types, and external contingency factors.

Self-Ordering AI-Based Kiosks

Self-ordering robots powered by artificial intelligence may improve the customer service experience by lowering customers' wait times and the requirement to queue up to pay. Such devices may accept orders from customers and process payments automatically using built-in card readers. KFC is pioneering the next generation of computerized self-ordering kiosks, which are now popular at several fast-food chains. With the use of AI, KFC and Alibaba have introduced a self-ordering digital kiosk at the 2018 Computing Conference of Alibaba Cloud in Hangzhou. New self-service kiosks will speed up processes and cut down on wait times.

Robots

Robotic technology has been increasingly used within the restaurant business to enhance the efficiency and productivity of food manufacturing, resulting in expedited meal delivery. Delivery robots, equipped with technology similar to that found in autonomous cars, are deployed on public roads and walkways to transport products that have been purchased via platforms such as Amazon and Postmates. Numerous enterprises are now engaged in a competitive race to achieve the distinction of introducing completely autonomous delivery robots to the market. What are the advantages and disadvantages of implementing robot deliverymen inside residential areas? These autonomous machines already occupy valuable sidewalk space, which is already limited due to the increasing presence of dockless bicycles and electric scooters. Nevertheless, if correctly managed, these robots have the ability to mitigate several urban issues.

Despite its limited use so far, new advancements in AI have made it possible to harness the effectiveness of robots in several domains related to food. The use of drones for food distribution and the implementation of robotic arms for food processing are only a few of instances among several applications of robotics in the meal industry. Nevertheless, the adoption of food industry using these technologies has been limited due to their higher initial costs compared to the alternative of employing a sufficient workforce. The use of drones and robots for delivery at convenience stores such as "7-Eleven," as well as the implementation of 2-arm robot named "Flippy" for packaging of burger patties and cooking, exemplify notable advancements in the field of robotics.

IV. TRENDS ON THE APPLICATION OF AI IN THE FOOD INDUSTRY IN THE FUTURE

In order to ensure adherence to food safety regulations, it is essential to promote transparency throughout the supply chain, hence allowing for public inspection. The use of AI in the domain of meal production proves to be very helpful in the comprehensive monitoring of the whole supply chain. AI plays a crucial role in several domains, including cost forecasting, process optimization, stock management, and supply chain administration. Artificial intelligence (AI) has the potential to assist farmers in accurately identifying the precise location where a crop has thrived.

Fig. 8 illustrates the overall trend of artificial intelligence's increasing prominence within the agricultural producing industry. Recent research indicates a substantial increase in the use of AI methodologies between 2015 and 2020, with projections suggesting that this upward trajectory will persist in the foreseeable future. The emergence of the IR 4.0 has significantly contributed to the increasing attention towards the use of AI in the meal production industry. The term IR 4.0, sometimes referred to as smart factory, pertains to the integration of technology or intelligent systems into conventional industrial practices. The objective of AI, which falls under the umbrella of Industrial Revolution 4.0 technologies, is to develop computer systems that possess comparable intelligence to that of human beings.

The influence of IR 4.0 on recalls in the food business resulting from inspections or customer complaints is substantial. AI sensors have shown a high level of efficacy in detecting and addressing production-related concerns. In the contemporary era, individuals in the twenty-first century get knowledge pertaining to meals mostly via the use of the internet. Consequently, the fourth industrial revolution (IR 4.0) assumes a substantial influence in molding human behavior. The utilization of AI is anticipated to see an upsurge in response to the escalating concerns surrounding food safety, owing to its potential to enhance food quality and facilitate manufacturing assistance. The anticipated trajectory of AI utilization in the food business is poised to ascend in the forthcoming years due to escalating food demand and rising apprehension over the safety of food production. In 2020, there was a notable increase in the use of AI within the food business, as a growing number of academics have undertaken studies using this methodology.

Fig. 9 illustrates the use of sensors for the purpose of actual monitoring in the meal industry, whether with or without the integration of artificial intelligence. The food business exhibits a higher level of integration with external sensors compared to industries that lack such integration. AI algorithms use data acquired from samples collected by external sensors to examine various activities such as prediction, quality control, classification and others, as previously indicated. The statistics from 2017, however, revealed a greater percentage of artificial intelligence systems without external sensors in comparison to those including sensor integration. This might be attributed to the comprehensive previous research conducted in the absence of the external sensors mentioned in this study.

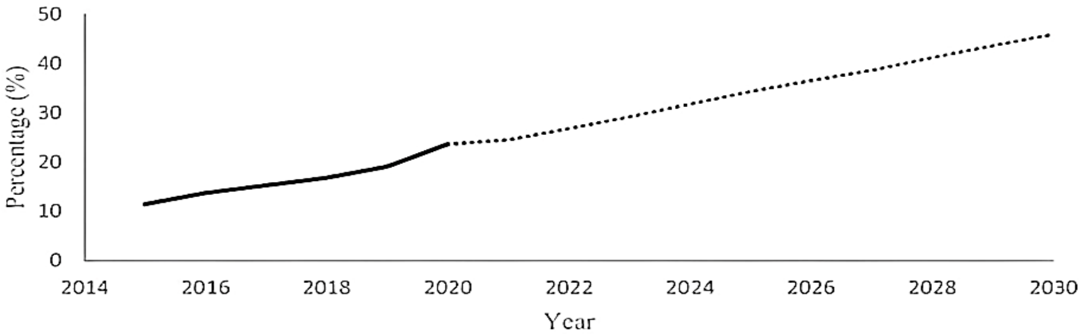

Fig 8. Application of AI in the Food Industry

The evaluation undertaken for this study revealed that a significant body of research has been dedicated to the integration of computer vision systems (CVS) sensors with artificial intelligence methodologies. This assertion is logical considering that CVS have the capability to provide essential parameters for ensuring quality control in the food industry, including characteristics such as shape, dimensions, color, and imperfections. The effectiveness of integrating the system relies heavily on the alignment of aims between the researcher and industry players, as well as the availability and ease of access to the data.

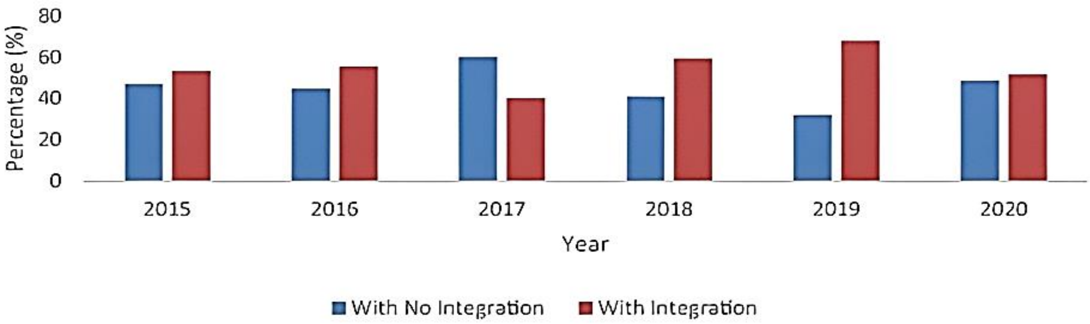

Fig 9. Comparing the use of Artificial Intelligence in The Meal Industry for Real-Time Monitoring

In summary, it is evident that the advancement of AI technology to version 2.0 will undoubtedly lead to a pronounced and unavoidable surge in AI utilization within the food industry. This trend can be attributed to the numerous advantages AI systems provide, including enhanced efficiency in time, cost, and energy management, as well as the ability to accurately forecast the primary factors influencing the food industry. Moreover, it is anticipated that a greater number of enterprises will opt to employ AI inside their respective industries, given the current global health crisis precipitated by the Covid-19 pandemic. Several small and medium-sized firms (SMEs) have experienced a decrease in their earnings, while others have indicated that they had a limited cash reserve of only one to three months. Business enterprises are anticipated to turn to artificial intelligence as a viable approach to address the difficulties arising from heightened food demand and the imperative need for tight adherence to standard operating procedures within a pandemic.

V. CONCLUSION AND FUTURE OUTLOOK

The prevalence of the artificial intelligence in the meal industry has increased in tandem with the growth of the global population and the subsequent increase in food demand in recent decades. The demand for intelligent systems in the food industry has been augmented due to their versatility. These systems are now being employed for various purposes such as assessing food quality, serving as control mechanisms, categorizing food items, and generating predictive analyses. The utilization of AI has gained significant prominence within the food industry due to its diverse applications, encompassing, control tools, quality control, sensory evaluation, food drying, prediction and addressing complex issues encountered in the food processing sector. Furthermore, the utilization of AI in sales forecasting and yield optimization enhances strategic decision-making in corporate operations. The efficiency, precision, and cost-cutting capabilities of artificial intelligence have led to its broad recognition in the meal industry. This paper gives a critical overview of the applications of Artificial Intelligence in the meal industry, along with an analysis of its benefits and drawbacks. Additionally, it explores the integration of AI algorithms with sensory technologies such as the electronic tongue and electronic nose. The aim is to present a comprehensive understanding of the potential implications and challenges associated with the use of Artificial Intelligence in the meal sector. The efficacy of the present technology has been demonstrated, and a recommended protocol has been put forth as a systematic approach for constructing the suitable algorithm prior to implementing the artificial intelligence model in the domain of meal industry. These developments are anticipated to facilitate and motivate researchers and industry participants to explore the utilization of this technology.

CRediT Author Statement

The authors confirm contribution to the paper as follows:
Conceptualization: Fengbin Sun and Qingbin Sun; **Methodology:** Fengbin Sun and Qingbin Sun; **Data Curation:** Fengbin Sun; **Writing- Original Draft Preparation:** Qingbin Sun; **Validation:** Fengbin Sun and Qingbin Sun; **Writing-Reviewing and Editing:** Fengbin Sun; All authors reviewed the results and approved the final version of the manuscript.

Data Availability

The datasets generated during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interests

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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Competing Interests

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