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Enhancing the Food Processing in Industry 5.0 Based on Artificial Intelligence

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Abstract: The new Industry 5.0 framework should taken into account which aims to incorporate value chain collaboration, human importance, and long-term viability in an industrial setting. During the present-day business sectors, human-robot collaboration is considered to be one of the best aspects. This demonstrates that contrasted to the previous edition, there will be a decreased risk of accuracy and that humans will conserve both labor and time. Machine learning encompasses artificial intelligence, which remains to be a crucial and encouraging factor in many different types of industries 5.0. Food, health, medication, and other firms continually produce positive results and continue to benefit consumers. This paper proposes artificial intelligence which offers data in a format that is accessible to individuals to access. Thus, the food industry 5.0, which is clearly explained in this paper, follows the convergence of artificial intelligence and human intelligence. As an outcome, industries will gain knowledge about latest developments in the food sector, particularly improved production, time savings, and economic growth. The production process is a flexible and personalized one as both human and AI are engaging in act. Therefore the preparation of foods in the promotive, hygienic, and healthiest manner is possible which will give good revenue for the food industries.

Keywords: *Artificial intelligence; machine learning; food industry 5.0; flexible food production*

1. Introduction

Food, frequently referred to as supplies, has been accepted as a human need and as the highest point of farming, having been grown through the delivery of farmers' ranged products. Food industrial goods are crucial to the fulfillment of each nation. Along with that, it plays an important part in how the global and national economies are progressing. As a consequence, there is an immense need for the security of food sector solutions and their efficacy when delivered adequately. Artificial intelligence (AI) alongside other recently invented technologies has demonstrated interest in accomplishing goals in the past few decades. As a consequence, it is important to investigate the sophisticated food sector and AI-based innovative farming. These strategies meet social demands and generate premium products on a timetable. The food sector will produce a lot more nutritious goods instantly by employing these modern innovations, which will dramatically increase the business's revenue. In Figure 1.1, the zone under every category is highlighted. This investigation presents an overview of the research of machine learning and AI in the food industry by encompassing every facet of modern technology. AI is not just employed in these types of operations. Furthermore, it may help with food preparation, storage, and supply. Robotics and smart drones are manifestations of intelligent machines that can be extremely beneficial in decreasing the expense of wrapping. Furthermore, it will encourage the shipment of food supplies, labor completion in hazardous conditions, and very high-quality goods provision. AI's major improvements to the food industry can be generally classified into two primary groups: food security management and food quality governance [1].

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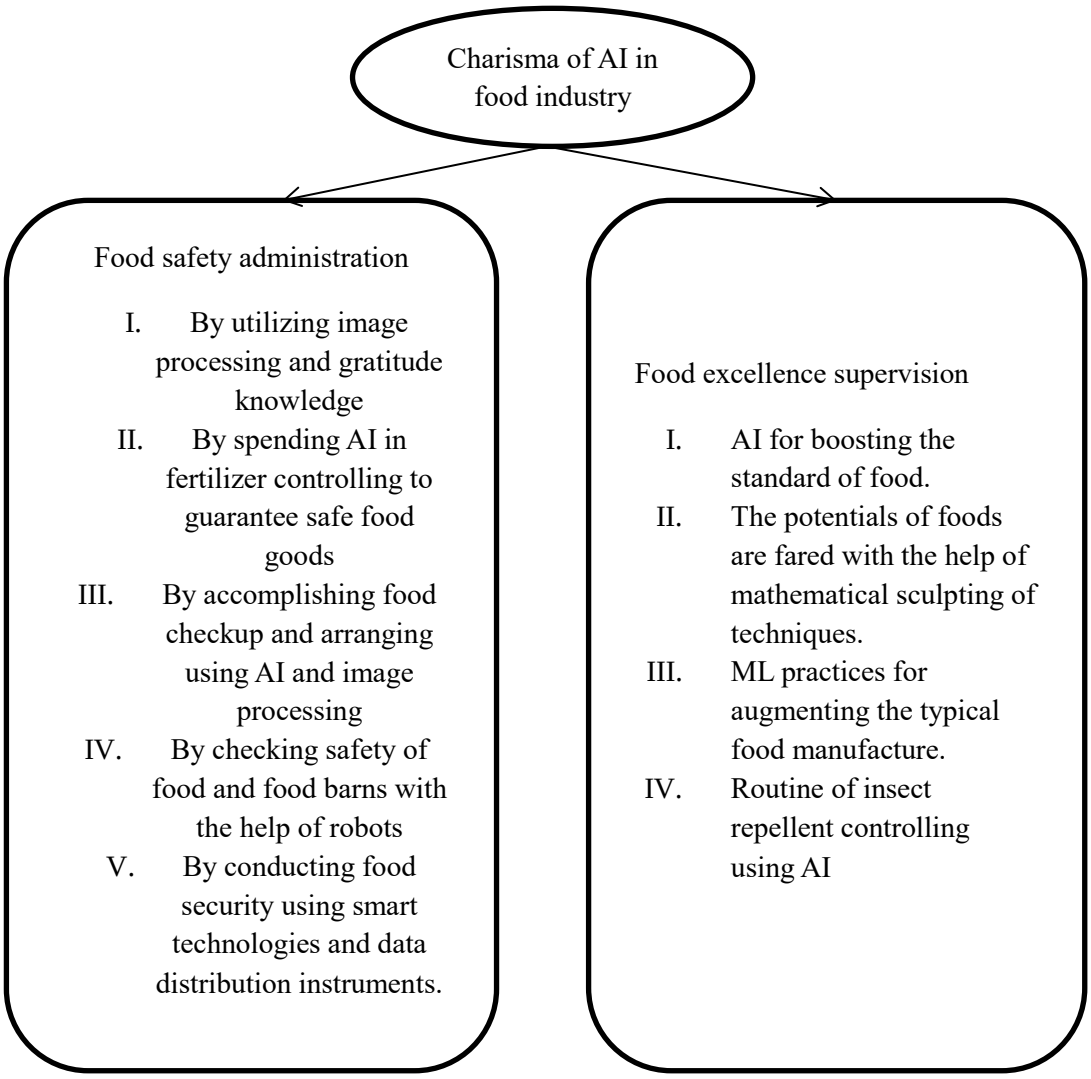

Fig.1.1. AI's role in food industry

To the best of our ability, very few previous works have focused on the implementation of Industry 5.0 technologies in terms of food security, given the increasing interest in utilizing such technologies for an assortment of potential categories. This conclusion encourages us to develop an evaluation of Industry 5.0 gadgets and how they can be implemented in every step of the chain of food supply, with projected advantages for consumers by making use of these technologies' potential as well as possibilities in each component of the food system. Industry 5.0 will implement robots to work together with people. The objective of the current piece was to deliver an overview of the hypothetical benefits of Industry 5.0 technologies in the food supply chain, spanning the stages of farming, manufacturing, shipment, and sales. It illustrated the benefits of harnessing these important technologies—AI, massive data analysis, the Internet of Everything (IoE), etc.—in a human-centric fashion in order to work collaboratively to integrate them into the food system and accomplish longevity of the supply chain, quality, integrity, and privacy. To the greatest degree of our comprehension, this topic has not yet been studied by another work [2].

Despite this, this field has a varied and non-linear course of action that is repaired by a computerized and genuine method like AI and reproducibility. AI applies computational methods that symbolize cognitive skills and brainy solutions to various kinds of food business challenges, which boost the visibility of food security. The food manufacturing lines get the advantage of automation, and an enormous quantity of data is obtained, preserved, investigated for conceivable supply chain enhancements, and employed for risk analyses. However, applying those innovations into practice lures hackers and adds a level of vulnerability to the sector [3].

The subsequent paper includes a general overview of each part of this professional work. The primary focus of the inquiry on applicable prior studies has been stated clearly in Section 2. The unique features of the AI in food industry are discussed in Section 3, with particular relevance to the aspects of the system program, statistical investigation, intuitive theoretical framework, and graph-based technique. This third section examines AI and ML procedures for guaranteeing the drilling process's lasting viability. Section 4 presents a variety of distinct images and charts proposing AI in Industry 5.0. Section 5 retains the ultimate power when it deals with the beneficial effects of AI and the savvy innovations that modern enterprises are adopting.

2. Related works

Wang, L. et. al [4] Utilizing augmented reality equipment to construct a dynamic bridge between goods and consumers is exceptional. This digital media technology is frequently discovered in food wrapping, most notably in packages of dairy goods. It is crucial that the amalgamation of food visual effect factors that emphasize the attractiveness of food wrapping. Customers can access AR-enabled material, such as a 3D depiction of the food's history, via their smartphones or other electronic devices to scan the AR verification control mechanism encountered on food containers. Travelers can see the food's origination in a 720° widescreen perspective to get distinct visual effects from the traveling procedure.

Ben Ayed, R. et. al [5] At this point, there is an increasing emphasis on the usage of machine learning strategies in the four basic supply chain groups for the farming sector: initial production, manufacturing, packaging, and shipping. Additionally, the utilization and installation of AI offer numerous benefits that can transform the food industry and its corresponding organizations. Subsequently, innovations in AI technology have made it achievable for food-based firms to function more efficiently by improving management techniques. This has supported many hotel companies in making investments in formulas that are discovering applications across the restaurant and food industries. The intelligent operating hallmark and higher profit margin that this AI offers are beneficial.

Han, J., Li, T. et. al [6] This work suggested a system for tracking food developed around the supply chain which enables for real-time exchange of data and quality analysis in conjunction with tracking quality. Also, it leveraged big data produced by the Internet of Things to promptly eradicate poor-quality meals from the supply chain while minimizing food waste and enhancing shipping efficiency. Due to the strengthened consumer need for fresh fruit, by adopting the Internet of Things, fresh fruits can be observed to lower waste during shipment.

UmaMaheswaran, S. K., Kaur et. al [7] AI technologies offer multiple advantages to the food and refreshment firm, consisting of manufacturing, warehouse convenience, safety, and close surveillance. These advantages are also beneficial to other healthcare industries. Multiple researchers have maintained that AI innovations hold tremendous potential for the health and food sector. They may improve automation in the food industry in turn boost effectiveness and cut down on trash.

Luo, X et. al [8] Nevertheless, several Industry 5.0-centered backbone technologies may assist to enhance performance and assure food security. Additionally, the Internet of Things is essential for the survival of humans, with possibilities for applications in the arenas of environmental issues, agriculture, and other fields. But contrasted to the pioneering seed area, there aren't numerous studies that focus on food sovereignty and address current problems. It is important that the creativeness of the seed sector promotes food security and is not a weak link in the agricultural value chain. As a result, it certainly makes a lot of relevance to check out issues regarding food security employing the lens of crop advancement.

Goyache, F., Bahamonde, A. et. al [9] It is fascinating to bring the spotlight on the fact that AI has numerous uses in the food sector than just establishing trained systems to facilitate and manage food quality administration. To identify the subjective characteristics of food goods and the primary food features that inspire their categorization dependent upon consumer and market requirements, we would like to highlight the various ways in which ML techniques might help scholars and experts.

Sikder, M. R., Saif et. al [10] An extra investigation focuses on how I5.0 could promote the economy of circularity. Based on the authors, I5.0 innovations can be applied to monitoring an item's ecological impact throughout its lifecycle, which might help detect potential sustainability. The application of cutting-edge technology that includes cloud computing, AI, and the Internet of Things distinguishes the present-day industrial revolution, nicknamed "I5.0".

Fosso Wamba, S., Queiroz et. al [11] This research issue delivers a fascinating inquiry using a design-science procedure, which includes scrutiny of drone swarm cognition in agricultural technology (AgriTech) instances. The investigation points out that intelligent agri-food activities, solidified by drone swarm scenarios, suffer from the potential to enhance agriculture functioning and efficiency in isolated regions and tackle concerns about food security.

Manning, L., Brewer, S. et. al [12] Laying the framework for comprehension of the other phrases in this paper demands us to first take "morality" as an entire concept. It seems tricky to adequately assess the moral consequences of any choices made to incorporate AI into agri-food chain programs without fully investigating each of the already mentioned ethical considerations. When adopting multiple meanings to characterize the usage of AI, actors such as food technologists, engineers, farmers, and others must properly examine about the human-technology interaction.

3. Methods and Materials

A feed-forward artificial neural network that derives a set of outcomes from an amalgamation of inputs is referred to as a Multilayer Perceptron (MLP). Numerous levels of input nodes linked together in a directed graph (DG) spanning the layers of input and output characterize MLP. MLP is frequently utilized to solve challenges that require supervised training. It accomplishes this by employing backpropagation (BP) to simulate the network. Machine translation, speech recognition, and image recognition are just a few of its applications. About its simplicity of use and performance, the MLP has gradually gained popularity in the food processing industry. The input of specific characteristics drawn from fruit features and the outcome of the MLP network is necessary to create an MLP for FP (Eq. (1)). Furthermore, the alteration of network characteristics necessitates the usage of learning computations like gradient descent and backpropagation. "P" is the final value at each node's output layer in Equation (1). "W" corresponds to the input, while "x" for the weight vector. "g(.)" is the ignition function, while "c" signifies the bias.

$$P = g\left(\sum_{j=1}^{o} x_j w_j + c\right) \quad (1)$$

3.1 MLP in food processing with backpropagation

The Back Propagation Neural Network (BPNN) is a technique of estimating the mean weights of the network which integrates the gradient descent method with the chain rule. The network may categorize the data with excellent precision and a low degree of error if it catches the right input attributes. When analyzing the gradient of the loss function on its connection to the ANN parameters, BPNN is significant. Each nodes at every single level

has its slopes estimated as an outcome of the gradient being backpropagated from the output layer to the subsequent stages. Backpropagation happens in the following ways. The outcome can be determined using Eq. (2) for the contents of each neuron 'O'. (2).

$$P_O = g(net_O) = g\left(c_O + \sum_{j=1}^{0} x_{jO} p_j\right) \quad (2)$$

The net emission of the terminals on the input stratum is designated here by "netO." "o" is the total amount of input parts, "x_{jO}" is the weight coefficient that occur between nodes "j" and "O," and g(.) is the function that triggers. A common method to evaluate the error at the output layer is by employing Equation (3).

$$F = U - P \quad (3)$$

In this case, the goal output is denoted by "U," the estimated output by "P," and the error by "F." To set the new input to the OO, one must propagate backward to the earlier levels, such as the input and hidden layer, after receiving the mistake. The formula for the new weight is found in Equation (4).

$$x_O = x_p - ms \times \frac{\partial Ftotal}{\partial x} \quad (4)$$

The new weight (x_O), the old weight $\left(x_p\right)$, the gradient $\frac{\partial Ftotal}{\partial x}$, and the learning rate (ms) are all expressed in Eq. (4). The delta rule is used to update the weight in the BPNN network.

3.2 RNN in food processing

In FP, recurrent neural networks (RNNs) have also been proven to be successful. A directed graph and series are formed by the interactions among nodes in an RNN, which is an accumulation of ANN. This permits it to represent a time sequence's temporal active progress. RNNs, in comparison with feedforward neural networks, can extend a range of inputs by leveraging their internal state, or memory. RNN word is utilized flexibly to pass into two vast communities of entities with similar general construction, where one is the hindering want and the other is unrestricted goals. RNN is utilized to be allowed to retain the results generated and employed as a parameter associated with every computation utilizing storage. A sequence of calculations at the input, buried Eq. (5), and the final layers are carried out by RNN to derive the final result.

$$i_j = f\left(i_{j-1}, y_j\right) \quad (5)$$

In this case, the input state is "y_j," the previous state is "i_{j-1}," and the current state is "i_j." Equation (6) is used to compute the final outcome.

$$P_j = X_{iP} i_k \quad (6)$$

"P_j" is the end result in Eq. (6), "X_{iP}" marks the output layer weight, and "i_k" is the outcome subsequently the usage of the activating function (Eq. (7)). "X_{ii}" is the repeating neuron's weight factor and "X_{yi}" is the weight factor of the input neurons in Eq. (7). Contingent on the final result, the network's internal configuration may improve or reduce with regard to the "tanh" function.

$$i_k = \tanh\left(X_{ii} i_{j-1} + X_{yi} y_j\right) \quad (7)$$

Over decades, RNNs have been employed in FP at, the adoption level. A renowned author established an assessment framework for the bread-kneading technique. RNN has been utilized by the researchers as an example model to accurately represent the technique's dynamism. They took voltage and warmth into consideration when examining the recommended method's functionality. To learn their ANN structure, they merged the Bayesian regularization and Levenberg-Marquardt approaches. The final results of the testing have revealed that RNN functioned better when it encountered kneading bread. The MLP strategy with back propagation network is shown in Figure 3.1 clearly.

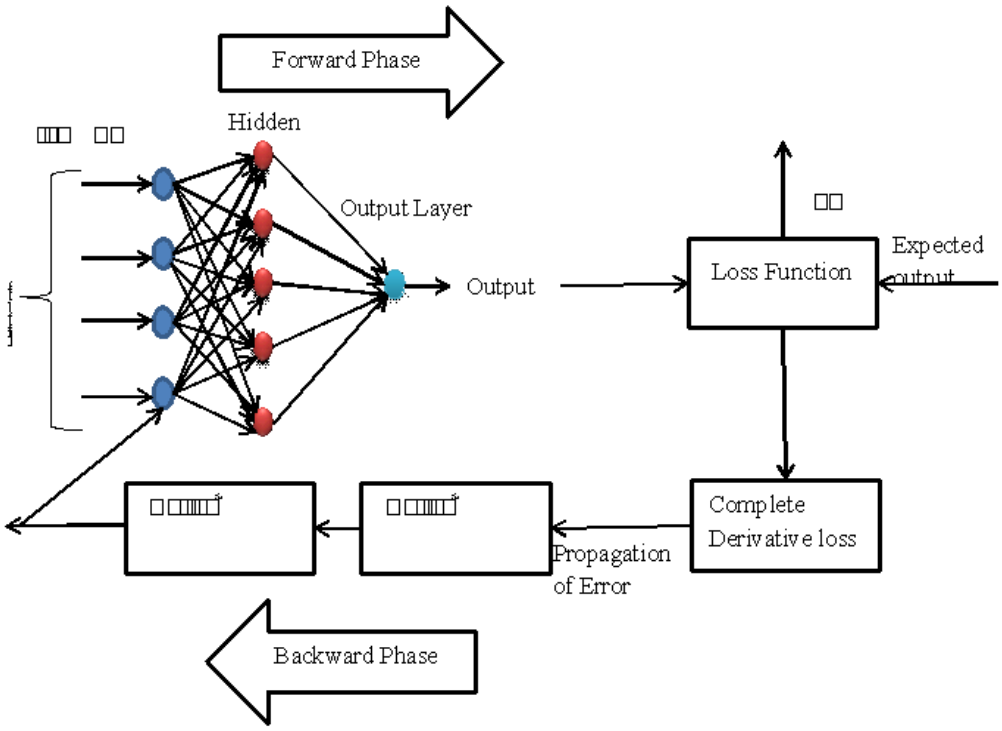

Fig. 3.1. MLP Strategy with back Propagation Network

3.3 DL in food processing

The ultimate advancement in machine learning, termed as deep learning (DL), permits data to be expressed systematically. The robust capabilities of DL to retrieve elements effortlessly from uncooked data are a plus. DL can raise categorization accuracy while limiting error rates. It involves numerous components such as grouping, blurring, encoding, and decoding methods, etc. immediately following the beginning of DL, there has been a quick advancement of consumption levels of DL and it has been successfully utilized to deal with multiple difficulties of different academics as well as additional application sectors such as image processing, data analysis, etc. However, there also have been serious gigs of DL in the field of FP. For FP, significant upgrades and DL innovations have originated. A brief illustration of certain of the major contributions has been presented. A famous researcher has designed an up-to-date method for sorting food photos into multiple groups using convolutional neural networks (CNNs). The research team's suggested techniques are based on a benchmark framework referred to as "Deep Food." They performed a three-fold cross-validation methodology while reviewing the MLC-41 sample to measure the impact of their advised procedure. After using the SMO classifier to categorize the food images, researchers matched it to a few other common predictive models, notably Bayes Net and the Random Forest classifier.

Table 1. Various food processing DL methods

DL performance used	Distinguished scheme	Issue nature	Outcome
GooglENet	-	Grouping thai food pictures	Enhanced categorization accuracy
CNN	TB-CNN	Arranging crisscrossing eggs	Improved performance with the accuracy of 99.5%
CNN	-	Crucial selection for detecting of food type	Operative extraction rate
NutriNet	AlexNet, Google Net	Diet as well as beverage image determination	Complex cataloguing rate
DCNN	-	Valuation of food calorie	Heightened acknowledgment rate
DCNN	CNN, DCNN-FOOD	Food images detection	Upgraded spotting rate
DCNN	-	Consideration of food images	Superior recognition rate as well as high sorting accuracy
CNN	Baseline Process	Food detection as well as recognition	Greater efficacy, uncovering as well as recognition rate
CNN	etc	Recognition of food pictures	Good subdivision exactness

They argued that their recommended procedure functions well and that simulated trials confirm the deep net framework's competence for multi-class segmentation. The scholars donated an advanced technique for employing CNN to foresee meal calorie and determine the prevalence of multifood. The academics browsed into a set of info that consisted of thirty unique meal types, of which one was utilized for training and several were implemented to test their approach. Their indicated procedure operates well in terms of memorizing rate, dependability, and responsiveness, as indicated by the displayed investigations [13].

4. Implementation and Results

In the present research, a systematic strategy is employed concerning gathering information and evaluation. The first step includes collecting data. In the subsequent stage, a pilot inquiry is carried out to have greater knowledge of the circumstances at present in the area. Relevant search terms, titles, and abstracts were put in place to collect these results of the study from an extensive spectrum of sources at an accurate point in time. This data will be investigated to find correlations and growth chances in the direction of a sector that is more durable. Furthermore, we will offer proposals according to the outcome of an in-depth investigation and probable justifications according to the situation of the food industry at the moment. We separated the food industry into four distinct groups, as indicated in Figure 4.1, depending on information collection and examinations. The initial category is smart farming, in which AI is utilized in numerous ways, including soil surveillance, robocropping, and statistical analysis. The second group is smart transportation, where AI is completely transforming the logistics sector. It is currently utilized throughout many kinds of industries, supporting automobiles like as motor vehicles, trains, ships, and airplanes, as well as optimizing traffic flows. AI has the capability to enhance every method of transportation more secure, more sustainable, intelligent, and effective. For example, AI-assisted self-driving automobiles may assist in avoiding human errors that lead to so many automobile crashes. However, those possibilities also pose real hazards like unexpected results and fraud, like digital assaults and distorted decisions regarding transportation. Furthermore, there are possibilities for job and ethical concerns about AI's transparency for selections made when individuals are not around.

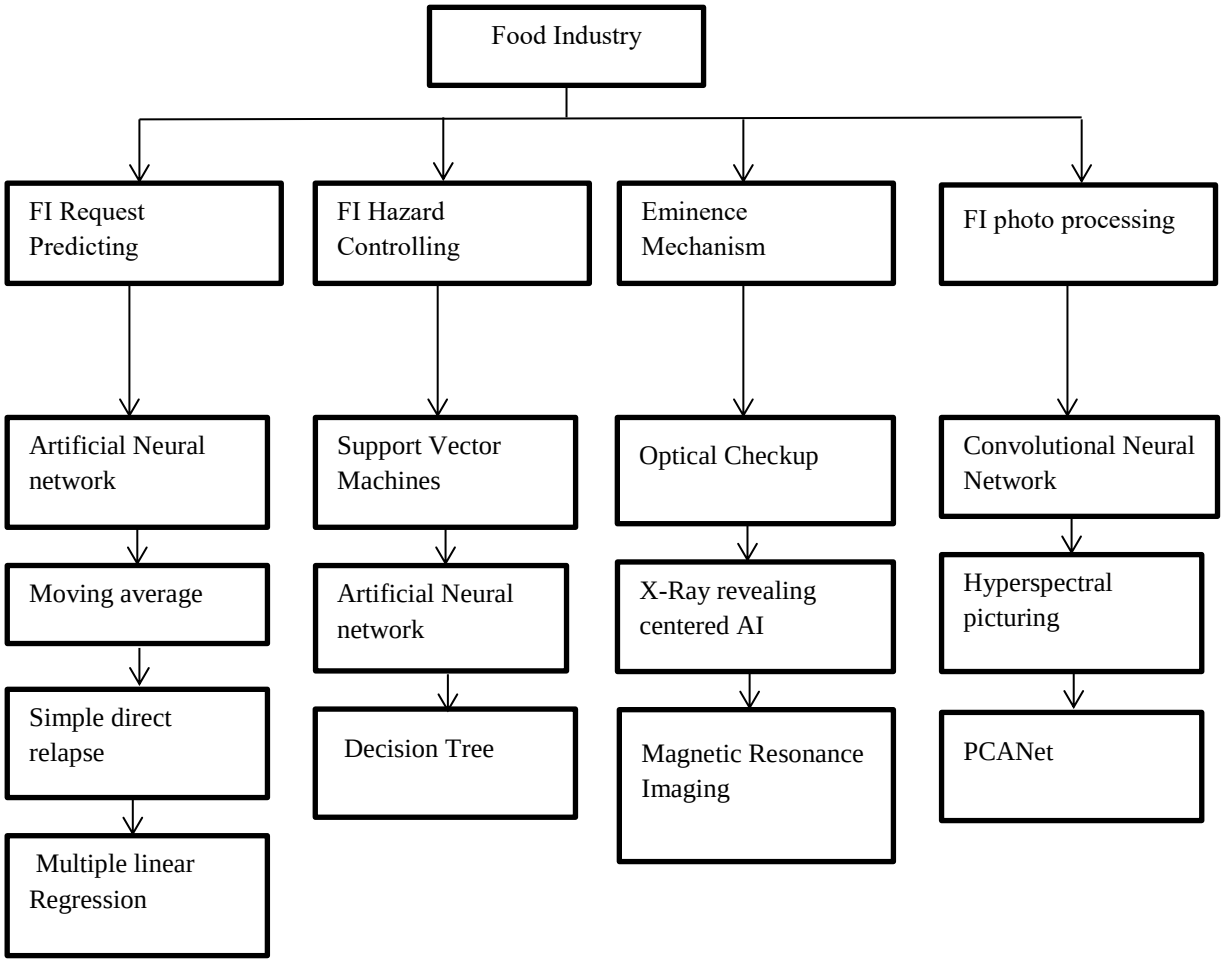

Fig. 4.1. Mapping of different AI and ML techniques

The third division contains smart processing. AI is pulling the attention of enterprises across a vast range of professions and sectors encompassing food processing and handling. AI has a direct and indirect impact on the FP and H enterprises. Indirectly, it assists landowners with weather estimation, which in change aids farmers in yielding superior raw materials for food processing business sectors, which enables them to save income on item arranging. AI facilitates logistics firms to minimize their expenses, which decreases transport expenses for food production companies. It contributes to helping FP and H organizations lower revenue in any circumstance. The ultimate area of concentration for FI is clever distribution and consumption. The label itself indicates how the farming manufacturer will be employed in FI. Challenges like mapping delivery routes, collecting raw materials, projecting demand for certain foods, and logistics preparation can all be supported by machine learning (ML). By enhancing the delivery agent's spot about present or planned traffic instances and dynamically informing them of the perfect path, ML can resolve distribution route obstacles. In the modern era, there are a huge number of apps available in the food service industry that help estimate the amount and kind of food served or ordered as well as the associated inventory. The predictions for smart farming investments, which will show the USD growth year over year, are indicated in Table 2.

Table 2. Illustration of Smart Farming Investment Predictions (2020-2025)

Years	Smart Farming Investment Predictions (USD Billion)
2020	2.1
2021	2.9
2022	4.1
2023	5.2
2024	6.1
2025	10.1

Statistical examinations of crowding and the food items that will be requested in the probable future can be carried out with these data. These data points are generated by mixing data from earlier consumer contacts, especially meal options, practices, and disagreements, with the offering of fundamental products all along that time frame. Depending on the collected and investigated data, we believe that demand for smart farming is increasing every day. Huge amounts of capital are being placed by investors to boost the efficiency of farming. The expected growth of innovative agriculture in the coming decades is depicted in Figure 4.2. The funds invested in the remaining three categories are highlighted correspondingly in Table 3.

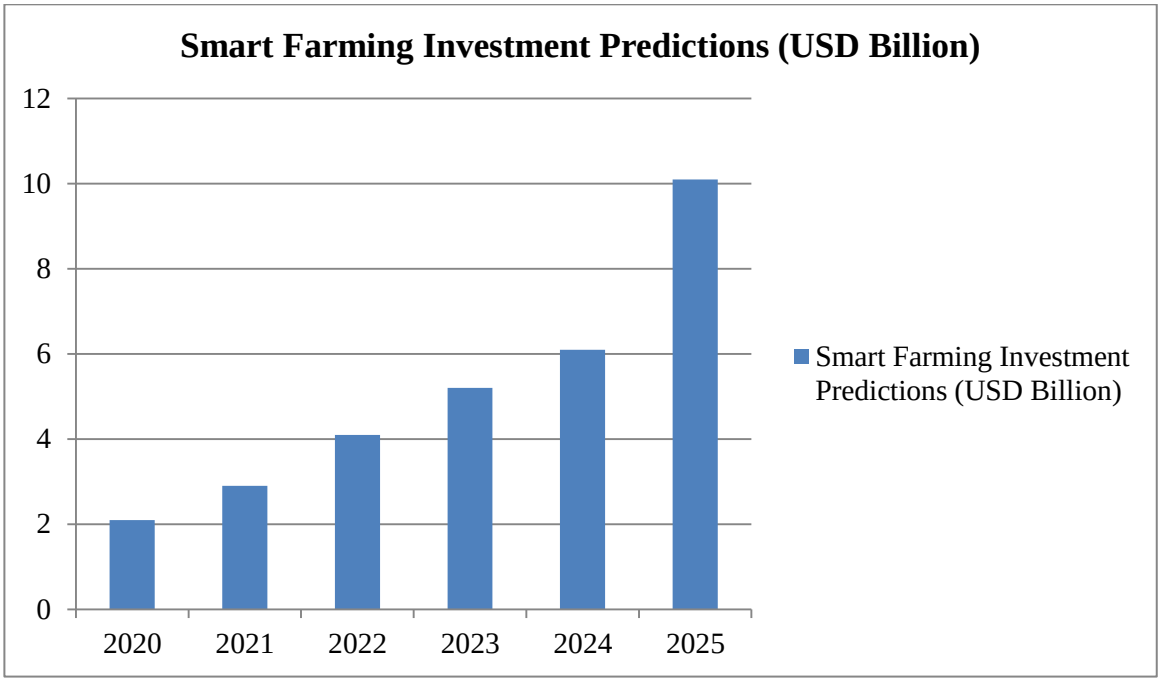

Fig. 4.2. Forecasting smart farming investments

Table 3. Prediction of Farming Investments

Investment methods	2025	2023	2022
Smart Distribution & Consumption	9.9	6.1	4.2
Smart Processing	7.7	5.1	3.9
Smart Transportation	6.9	3.8	2

The subsequent graph, which is illustrated in Figure 4.3, the same way leverages a similar Table for expressing the bar chart. This will provide an easily understood justification for the insightful comprehension of the investment prognosis in the intelligent business.

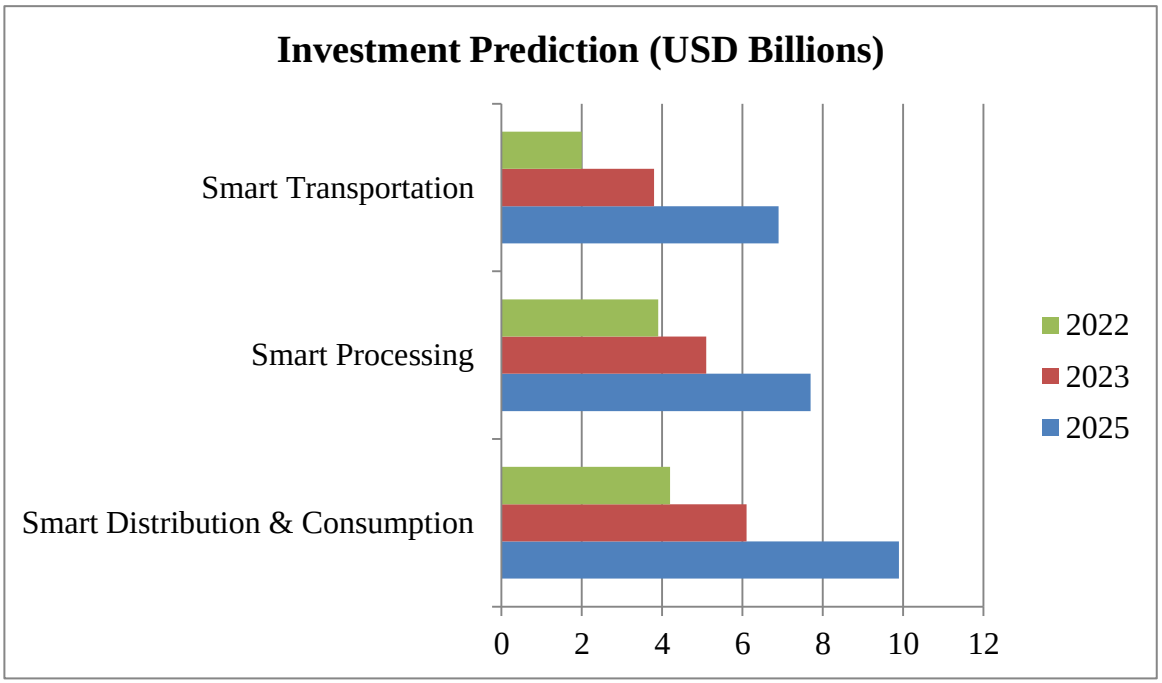

Fig. 4.3. Future Investment Forecasting in FI

It is visible that the food processing and production industry requires a massive quantity of expenditure. System-based AI can more quickly find numerous imperfections in food manufacturing than human-based approaches. Added to that, it has been witnessed that this field is extremely research-intensive. The worldwide spread generates hurdles for the food manufacturing chains, which generates several barriers because computerization isn't there, with hygiene and security representing the primary concerns. Once detectors are combined with the microcontroller, output spikes are established by the microcontroller, leading to a reasonably priced and user-friendly framework for a spectrum of artificial neural robotics projects. It might turn out to be highly beneficial for the food industry. In the agro-based business, AI-based gadgets that target agricultural results, yield estimates, surveillance of sickness, and obtainable features have amalgamated machine learning and enormous amounts of data to deliver upgraded information for making decisions and movements. AI and machine learning methodologies deliver multiple opportunities for multiple sectors to enhance and mechanize treatments, save expenditures, and abolish human error. AI and machine learning might assist food makers in bars, cafes, and restaurants. Both of these departments furnish several regular examples of AI applications in the food field. It's more essential than ever to maintain one step in front of opponents because clients and marketplace demands are fluctuating quickly [14].

To safeguard food standards in the food industry, automated technology will be an essential element to effectively boost industrial efficiency. AI will be vital to the generation of food in the coming years. An additional section of AI is robotics. Firms that offer food and beverages are progressing swiftly by using creativity for tasks and organizational reductions before emphasizing on how to fulfill customer needs. As the globe advances beyond COVID, AI is being employed in increasing quantities to enhance food production, and as the human population grows faster than before, so are requirements for speed, effectiveness, and durability. Food arranging requires paying close consideration to the finer aspects of the item, such as size or pigment. These characteristics enable food suppliers to execute reliable choices on how to prepare various food items, which will eventually improve consumer buy rates. These modern systems perceive foodstuffs with human perception by using sensor capabilities like cameras and near-infrared sensors. The food industry has numerous CCTV cameras positioned; this is just a single depiction of AI's sophisticated characteristics. Deploying this AI function, it is feasible to assess whether individuals are fully committed to conforming to food hygiene standards by employing dedicated cameras that are outfitted with facial recognition and object detection functions [15].

5. Conclusion

Scholars are now concentrating on futuristic implications of AI in the food business. Many distinct kinds of research have been done on numerous applications up to this point, most of them are yet in the development stage. When it comes to food processing—which includes grading, classifying, predicting, evaluating quality, etc.—both AI and DL prove to be effective tools. These strategies have proved to be successful methods for imitating complex tasks connected to food hygiene and safety. Although numerous approaches have been designed to solve the issues that have manifested in the food industry, AI and machine learning have given individuals access to cutting-edge technology in the actual world. AI handles a range of heterogeneous systems that measure numerous parameters that signify quality, looks, texture, common consumer popularity, and other qualities. The unique strategy involved evaluating data patterns and refinement of the technique to yield result that is precise, trustworthy, competent, demands fewer human resources, and supports in the operator's long-range forecasting of future events. As a consequence, food industries uses the idea of AI, which reduces and successfully accomplishes each task.

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