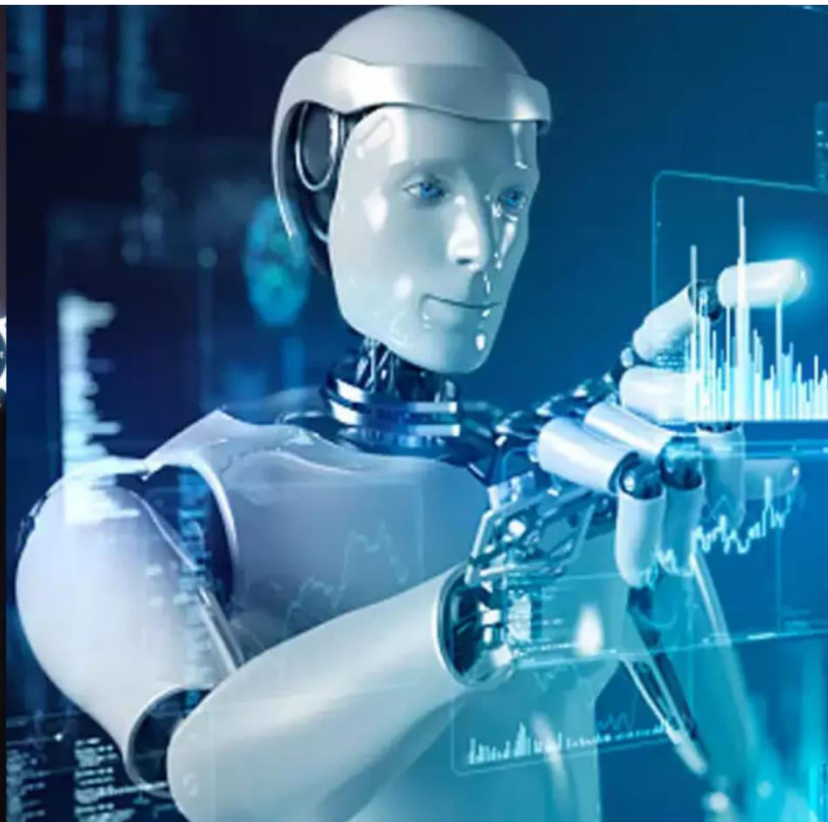




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AI in Food Industry

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ABSTRACT: Artificial Intelligence (AI) is rapidly transforming industries and day to day life, with applications spanning from online platforms, such as food delivery applications , virtual assistant and offline domains like robotics etc. AI is also used by different companies for marketing in B2B as well as B2C. In a B2B (Business-to-Business) context, companies often focus on relationship-building, personalized outreach, and content marketing. In the B2C (Business-to-Consumer) scenario, businesses emphasize emotional appeal, social media engagement, and direct consumer interactions. This proposes the study regarding the role of AI in the food industry, focusing on how artificial intelligence is transforming various aspects such as product development, supply chain management, customer engagement, and operational efficiency.

KEYWORDS: Artificial Intelligence; supply chain management; operational efficiency; product development

I. INTRODUCTION

The international food production and provision of food production is one of the most intricate and dynamic systems that involve numerous individuals such as company stakeholders, company workers, product distributors, salesman and end users .Providing efficiency, uniformity ,food product quality ,less corruption in order to fulfill the rising global demand for food. But conventional supply chain management practices are usually confronted with issues like guaranteeing high-quality food production, fighting corruption in the supply chain, and fulfilling the increasing demand for food under limited time constraints. Besides streamlining supply chain operations, AI can also be a revolutionizer of food production in its own right. With the incorporation of AI-powered automation and quality control mechanisms manufacturers are able to improve food quality and shorten production schedules. For example, in Ferrero Rocher chocolate production, AI can be used to examine and verify the quality of hazelnuts, identifying defects and inconsistencies, good quality and also hygiene while improving output.This not only enhances the quality of products but also allows for mass food production within a shorter period, meeting increasing consumer demands the food supply chain must overcome the complexities of marketing and distribution in both Business-to-Business (B2B) and Business-to-Consumer (B2C) models. B2B transactions include collaborations among producers, distributors, and retailers, and also transparent sourcing, and instant meeting of demands In contrast, B2C concentrates on direct contact with the consumers. Artificial Intelligence (AI) can be a game-changer in resolving most of these challenges. Through the application of AI in food industry we can streamline supply chain operations, enhances transparency, and can also help in Strengthening decision-making in both B2B and B2C markets.This paper explores the role of AI in revolutionizing not just the food supply chain but also food production itself, demonstrating how AI-driven solutions can improve efficiency, reduce waste, enhance quality, and create a more resilient and sustainable food ecosystem.

II. LITERATURE SURVEY

1 According to the author, digital transformation, which is essential for competitive companies, is based on converging technologies such as AI, IoT, and blockchain, along with building digital competencies.AI's capacity to considerably enhance world GDP, especially in supply chain sectors such as logistics and retail, is immense. The food and beverage sector, with a high rate of expected market growth, will highly benefit from the deployment of AI. Supply chain management is expected to highly benefit while the complete potential of AI goes untapped. Incorporating AI into the

food supply chain adds value by reducing network complexity, increasing resilience by analyzing risks, and generally making the process more efficient

2 According to the author, the agriculture and food sector, a considerable segment of world GDP, is exposed to historic threats in terms of production, demand, and safety because of man's interference. Industrial automation fueled by AI, ML, and DL is set forth as an essential answer. AI can examine data and foretell sales and thus contribute towards making processes in the entire food sector more efficient, be it restaurants or food delivery outlets. The global AI in the supply chain market is growing at a tremendous pace, with growing AI adoption, data analytics, and growing applications contributing to it. Top players such as FedEx and Amazon are embracing AI, especially machine learning, to streamline their supply chain logistics. This study seeks to examine the role of AI in the supply chain, major industry trends, and effective implementation strategies.

3 The writer explains that in this research, AI's incorporation into the food value and supply chain is analyzed in-depth, examining its vertical use and related technologies. AI's adaptability is noted by its engagement with robotics, drones, big data, and other emerging technologies, influencing different points of the food chain. Yet, the research recognizes social, technological, and economic constraints on AI uptake. To address these, it proposes improving financial and digital literacy of farmers and encouraging best practices. This study intends to bridge the gap in comprehending AI's comprehensive role in the food chain, answering central questions regarding AI types, integration, related technologies, and adoption barriers, hence mapping future research trends.

4 The author writes that marketing of agricultural products is peculiarly difficult owing to intrinsic risks and complexities in its supply chain. Artificial intelligence (AI) provides a revolutionary answer with the capability to analyze demand, optimize logistics, and pinpoint inefficiencies, resulting in enhanced responsiveness at lower costs. This paper reviews the application of AI in agricultural supply chain management (SCM) from the literature in order to fill the research gap about the impact of AI on SCM performance. The research attempts to find AI methods that improve SCM, identify areas of sub-discipline maturity that are ready to be enhanced with AI, and show how AI impacts and improves efficiency. Overall, the study aims to offer a framework for enhancing marketing efficiency and food security using AI uptake.

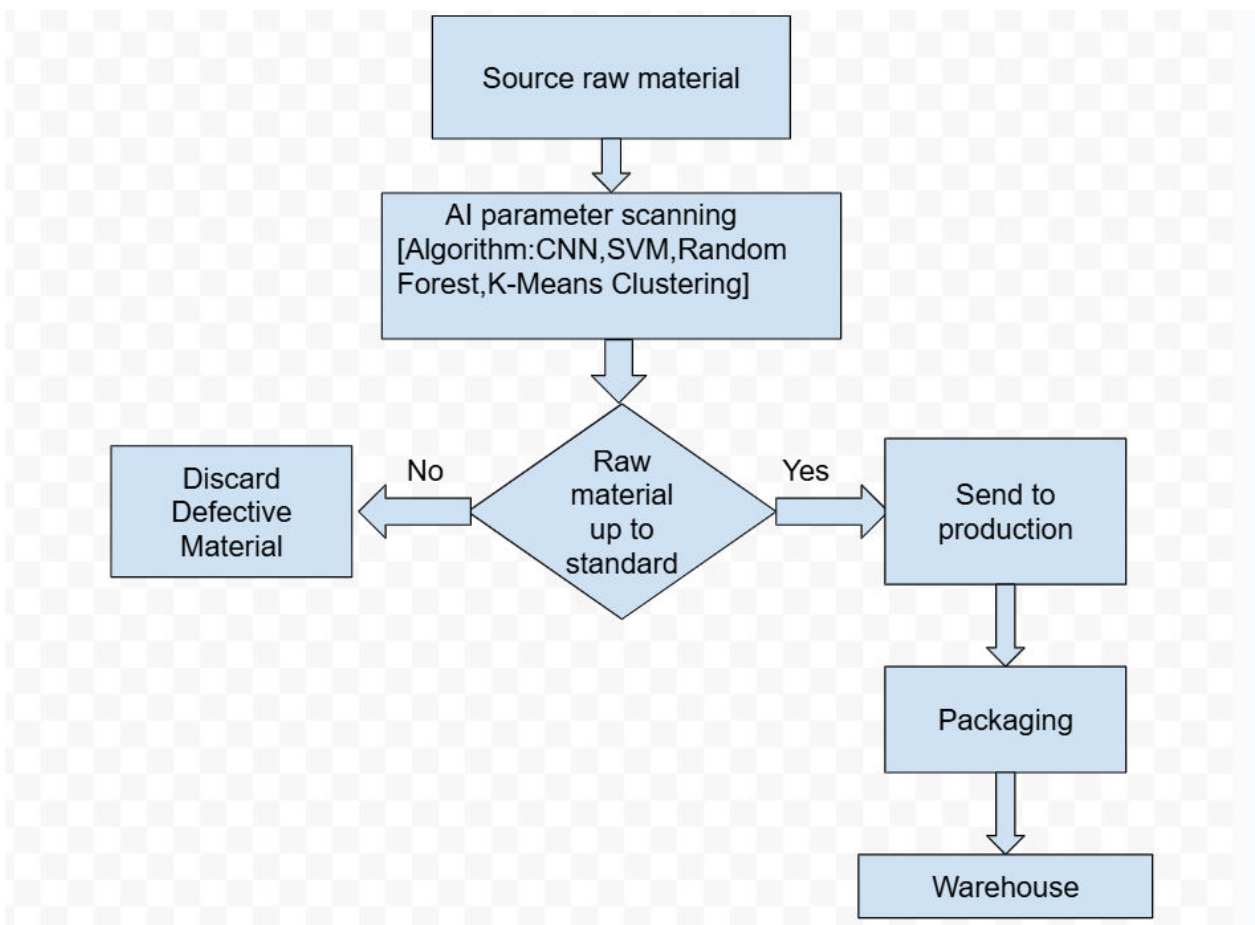
5 The author notes that the food industry has undergone huge change as a result of globalization, technology, and changing customer needs, with big data and AI being key drivers in assuring safety, manufacturing, and selling. AI, replicating human intelligence using machine learning and deep learning, and big data, defined by high-velocity, high-volume, and high-variety data, are central in demand prediction, supply chain optimization, and enhancing food safety. The integration of Industry 4.0 technologies, including smart agriculture and robot farming, brings opportunities and challenges for smart production and sustainable development. The purpose of this review is to examine the status quo of AI and big data applications in the food industry, solve problems, and present future development trends.

6 The European Commission's Farm to Fork Strategy is described by the author as focusing on having a stable, safe, and sustainable food supply, with the call for proactive measures throughout food networks. Crisis management, such as from COVID-19, calls for strong performance management to forecast failures in the food supply chain. Machine learning, nonetheless, has difficulties handling complex data, leading this study to suggest an approach of manual feature extraction through qualitative comparative analysis (QCA). This is to simplify the complexity of data, increase algorithm efficiency, and enhance interpretability for ethical and managerial advantage. The approach applies Boolean logic in identifying complex causal links, advancing beyond sole points of failure. Case studies of dairy export preparedness during the Russia-Ukraine conflict and egg supply chain sustainability during COVID-19 illustrate the framework's application. The goal is to leverage AI for early prediction of supply chain failures, enabling preventative measures.

7 According to the author, AI is essential for improving food quality and security, meeting issues such as population increase and resource limitation. This review discusses AI's potential in developing transparent supply chains and enhancing product quality using ML methods such as ANN and CNN. The aim is to minimize human intervention and maximize resources. AI's capacity to learn, reason, and correct itself is essential for automating agriculture. The research recognizes the necessity of industrial automation in applying AI effectively with emphasis on the pros and cons of various AI approaches. Eventually, the research seeks to accentuate the role of AI to achieve food security and sustainability via cutting-edge technologies.

8 The author states that artificial intelligence is revolutionizing food safety, quality, and security through advanced technologies like machine learning and computer vision. By analyzing literature from 1990 to 2024, the review highlights AI's role in real-time contamination detection, quality optimization, and resource-efficient agriculture. AI integration with advanced food processing and emerging technologies like IoT and blockchain enhances transparency and risk management. This analysis identifies research gaps and proposes strategies to address data limitations and ethical concerns. Ultimately, AI aims to create safer, higher-quality, and more secure food systems by improving efficiency and decision-making. Future innovations focus on scalable solutions for global food security and sustainability.

III. PROPOSED METHODOLOGY



Flowchart 1.1 Use of AI in factory

Stage 1: Sourcing Raw Material

Description: This is the stage where the raw food products are acquired. It may be produced from farms, meat from processing factories, or any other raw material. Logistics, transport, and first handling are all included in this stage.

Example ABC chocolate :

Hazelnuts: Good-quality hazelnuts are acquired from particular areas renowned for their quality.

Chocolate: Ferrero applies its own recipe for milk chocolate.

Wafers: Wafer is purchased or made, thin and crunchy.

Palm Oil: It is added in the filling and chocolate. (Fact: Ferrero made sustainable palm oil promises).

Sugar, Cocoa Butter, Whey Powder, etc.: The remaining ingredients are sourced through approved sources.

Stage 2: AI Parameter Scanning (Ingredient Inspection)

Description: This is the central AI-based quality control stage. Advanced sensors and cameras, connected to an AI system, take readings of the raw materials. Algorithms such as CNN, SVM, Random Forest, and K-Means Clustering process this data to detect defects or measure quality.

Example ABC chocolate:

Hazelnuts: AI vision systems examine images for bruising, blemishes, or rot. SVMs sort hazelnuts by color and size. Random Forests forecast ripeness.

Wafers: AI vision systems inspect the wafers for even size, shape, color, and crispness, rejecting broken or burnt wafers.

Chocolate: AI can be employed to inspect the quality of the chocolate at different stages, testing for viscosity, color, and texture.

Here's how the algorithms could be used:

CNN (Convolutional Neural Networks):

Application: Image recognition and feature extraction.

How it operates: CNNs are taught on a huge set of images of hazelnuts, both good and bad. The network is trained to recognize patterns and characteristics that differentiate between high-quality hazelnuts and bad ones. These characteristics may be:

Shape: Is the hazelnut spherical and symmetrical, or is it deformed?

Size: Is the hazelnut of the right size

Color: Is the hazelnut consistently hazelnuts from unacceptable ones.

Random Forest:

Aim: Combination-based prediction and classification.

How it works: A Random brown, or maybe discolorations revealing mold or rot

Shell Integrity: Is the shell unbroken, or are cracks or breaks present?

Texture (possibly by way of specialist imaging): Is the surface smooth or wrinkled or has some other texture defect

ABC chocolate Example: The CNN would scan photographs of hazelnuts running along a conveyor belt and rapidly check for, and mark, those which are too small, irregular, discolored, or have broken shells

SVM (Support Vector Machines):

Purpose: Classify according to features learned.

How it works: Once the CNN extracts the features from the images of the hazelnuts, the SVM employs the features to categorize every hazelnut.

For instance:

1 Acceptable (good quality)

2 Slightly Defective (may be used for other tasks)

Forest builds several decision trees, each of which is trained on a random subset of the hazelnut data. Each tree produces a prediction (acceptable/unacceptable), and the Random Forest makes a final, more solid classification by combining these predictions. It can also give a probability score reflecting the confidence in the classification.

ABC chocolate Example: Random Forest examines different parameters (shape, size, color, moisture level – perhaps determined by other sensors) and estimates the general quality of the hazelnut. It is able to guess at the possibility of internal faults or rancidness.

K-Means Clustering:

Purpose: Clustering similar items together.

How it works: K-Means puts clusters of hazelnuts together based on their features. It can be applied to sorting hazelnuts into various grades or classes even if they are all technically "acceptable."

ABC chocolate Example: K-Means might be applied to

1 **Wafers:** Defective, burnt, or otherwise broken wafers are rejected.

2 **Chocolate:** Lots of chocolate that does not pass quality is rejected or reworked.

3 **Unacceptable (reject)**

ABC chocolate Example: The SVM accepts the points (size, shape, color, etc.) given by the CNN classify hazelnuts by size, and trace borders to set apart acceptable, so that Ferrero can utilize the bigger, more aesthetically pleasing hazelnuts for the entire center of the hazelnut center of the Ferrero Rocher, while smaller bits could be utilized in the outer shell or other products.

Stage 3: Decision Point: Raw Material Up to Standard?

Description: The AI system comes to a "pass/fail" conclusion based on what it has analyzed. This is the key control point.

ABC chocolate Example:

Hazelnuts: Hazelnuts that pass the strict standards of Ferrero (size, shape, color, no defects) go through.

Wafers: Wafers that are ideally shaped and crunchy continue. Broken or burnt wafers are turned away.

Chocolate: The chocolate, if it passes the quality criteria, is okayed.

Stage 4: Discard Defective Material (No Branch)

Description: Products that do not pass the AI check are taken out of production. This avoids lower-quality products going further and wastes less in the end.

ABC chocolate Example

Hazelnuts: Hazelnuts that are too small, deformed, discolored, or damaged in the shell are rejected

Stage 5: Send to Production (Yes Branch)

Description: Raw materials that meet inspection are sent to the subsequent stage of processing.

ABC chocolate Example:

Hazelnuts: The high-quality hazelnuts chosen are roasted and made ready for the center.

Wafers: Ideal wafers are employed to form the crispy shell.

Chocolate: The passed chocolate is employed to enrobe the hazelnut and wafer.

Stage 6: Packaging

Description: Processed food products are packaged for sale or distribution.

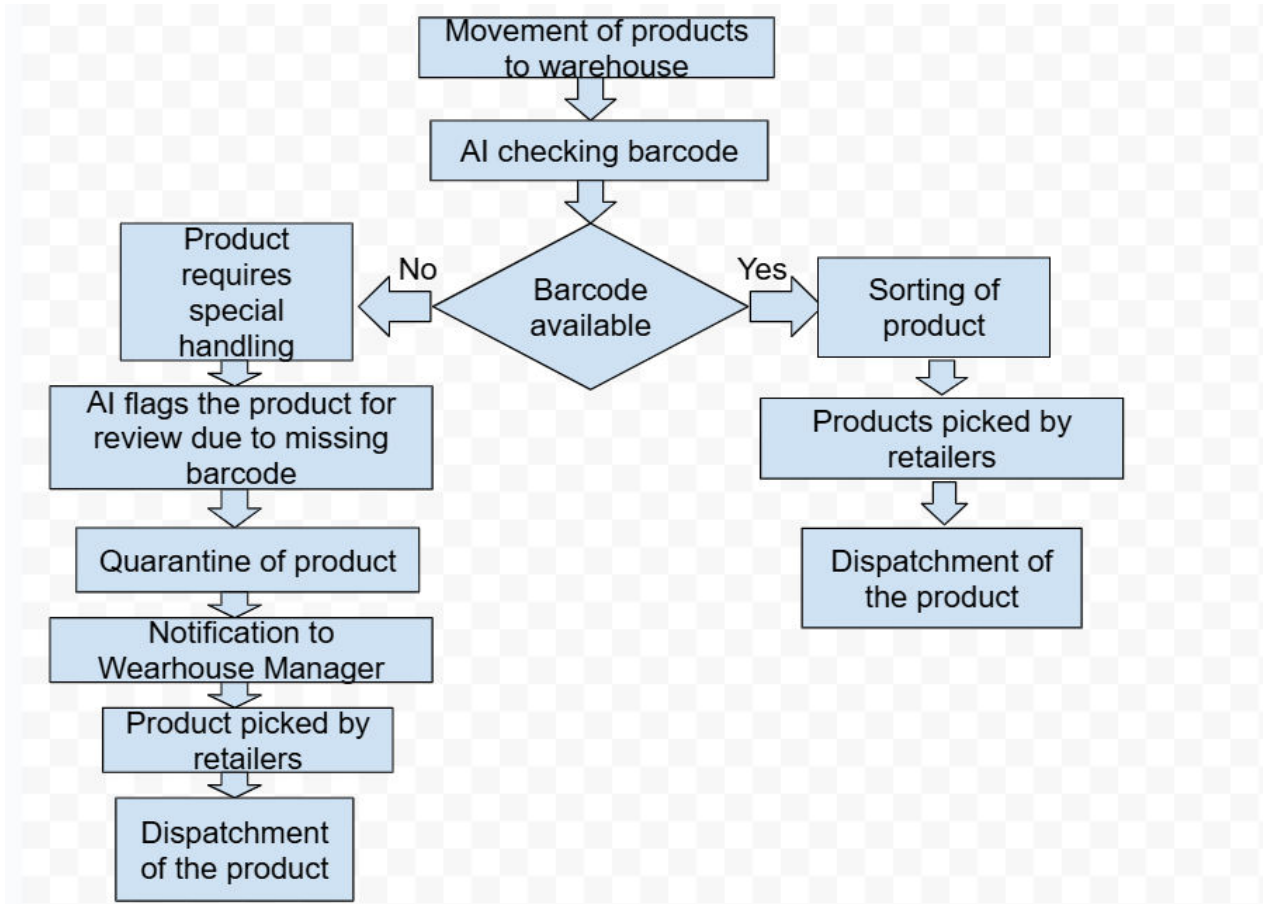
ABC chocolate Example: This encompasses the gold foil wrapping, paper cup, and box. There are automated machines that wrap every chocolate perfectly. AI vision systems could be applied to inspect the wrapping and packaging quality (e.g., labeling position).

Stage 7: Warehouse

Definition:

A warehouse is a huge building where merchandise or materials are stored. It is an essential link in the supply chain as it serves as a holding location between production and distribution. Warehouses vary from tiny local storage warehouses to giant distribution centers occupying acres. They are usually outfitted with such tools and technology to handle inventory as forklifts, pallet racks, conveyor belts, and computerized tracking systems. The main tasks of a warehouse are to receive products, store them securely and efficiently, and then distribute them to their final destination, be it a retailer, a manufacturer, or a consumer. Contemporary warehouses tend to have advanced logistics and management systems to maximize operations, reduce storage time, and facilitate on-time delivery. They are crucial to organizations of any size, allowing them to control inventory efficiently, address the needs of customers, and streamline supply chains.

ABC chocolate Example: The chocolates are kept in controlled conditions to keep them fresh and of good quality until they are shipped or another delivery method.



Flow chart 1.2 Dispatchment of Products

Explanation of flowchart 1.2

Stage 1: Movement of Products to Warehouse

Description: This is the first point of entry. Products coming into this stage simplifies the movement of goods into the warehouse storage or directly to the picking area.

Stage 2: AI Checking Barcode

Description: A system based on AI scans the barcode of every product. This is an automated process to rapidly recognize the product, pull its information from the database, and authenticate it.

Stage 3: Barcode Available? (Decision Diamond)

Description: This is the point of critical decision. The AI verifies whether the barcode is scannable and whether the data is as expected.

YES Path (Right): If the barcode is OK, the product goes to Stage 4 (Sorting).

NO Path (Left): If the barcode is missing, damaged, or contains incorrect information

Clear Labeling: A tag is placed on the product with information about the problem with the barcode, the quarantine date, and other appropriate details.

Documentation: A document is made documenting the problem, the product information (if it exists), and why it was quarantined. This document will be modified as the problem is resolved, warehouse, normally by means of truck

Stage 4: Sorting of products (Right Path)

Description: Valid barcodes products are sorted according to numerous factors (e.g., type of product, destination, order priority)

Stage 5: Product Requires Special Handling (Left Path)

Description: This is the stage activated when a barcode problem is detected. The product is marked for manual handling and transferred to a special area for handling.

Stage 6: AI Flags the Product for Review Due to Missing Barcode

Description: The AI tool marks the product automatically and identifies the exception reason (wrong, missing, or broken barcode). It builds an audit trail and encourages next step.

Stage 7: Quarantine of Product

Description: The item is physically kept separate from the normal flow of inventory. This avoids it from being inadvertently shipped or stored, so that the issue with the barcode is addressed first.

Physical Isolation: The product is relocated to a distinct holding area or cage, well labeled and sealed.

Stage 8: Notification to Warehouse Manager

Description: The supervisor or warehouse manager is immediately informed of the quarantined product. The notification must include:

Specific Details: Product identification (if available), where the quarantined product is located, and the nature of the problem with the barcode.

Urgency: Emphasizing the urgency of taking action to reduce delays.

Potential Impact: If available, an estimate of the impact on orders or inventory.

Stage 9: Product Picked by Retailers (Both Paths Converge)

Description: All items, whether processed under normal circumstances or under special handling, end up at this level. The retailers pick the items and makes the payment of the items they purchased

Stage 10: Dispatchment of the Product (Both Paths Lead to the Final Step)

Description: The final stage where products are packed, labeled, and shipped to their destinations. This applies to all products, regardless of their initial barcode status.

Table 1.1 Difference between Distributor and without distributor

Parameter	With Distributor	Without Distributor
Supply Chain Complexity	Simplifies logistics by handling distribution networks	Requires direct management of supply chain, increasing complexity
Cost Efficiency	Additional costs due to distributor margins and commission	Lower costs as middlemen are eliminated, but higher operational expenses
Speed and delivery	May delay delivery due to multiple handling points	Faster deliveries due to direct supply

IV. ACKNOWLEDGEMENT

We are deeply indebted to our Guide Vedika Patil for her guidance and helpful suggestions during the research.

V. CONCLUSION

AI is revolutionizing the food sector through supply chain optimization, enhanced food quality, and increased efficiency of operations in B2B and B2C businesses. AI streamlines operations, enhances transparency, and facilitates improved quality and faster turnaround. In the future, AI has vast scope for further application in sustainability, automation, and predictive analytics. This will make the food ecosystem more resilient, efficient, and sustainable, ultimately improving food safety and lowering environmental footprint.

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