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AI-DRIVEN FARM-TO-TABLE SUPPLY CHAIN OPTIMIZATION: A CASE STUDY OF REDUCING FOOD WASTE

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ABSTRACT

This study explored the impact of AI-driven optimization on reducing food waste within the cassava processing supply chain in Southwestern Nigeria. Utilizing a comprehensive research methodology that included a sample of 4,200 respondents across seven states and 42 local government areas, the research was conducted between October 2023 and June 2024. Key findings indicated that the implementation of artificial intelligence technologies led to a 40% reduction in food waste and significant efficiency improvements, including a 30% decrease

Introduction

Food waste has become a huge global issue with considerable economic, environmental, and social consequences. The Food and Agricultural Products Organisation (FAO, 2021) reports that almost one-third of all food intended for human use is squandered, amounting to nearly 1.3 billion tonnes each year. This alarming statistic underscores inefficiency in the food supply chain while also leading to significant economic losses, damage to the environment, and food poverty. In underdeveloped

in processing times and a 25% reduction in transportation costs. The study highlighted the critical role of stakeholder engagement in the successful adoption of AI solutions and underscored the sustainability outcomes achieved through this integration. Comparisons with traditional processing methods revealed the transformative potential of AI, showcasing its advantages in waste reduction and operational efficiency. Challenges encountered during the implementation phase, such as data quality management and the need for robust infrastructure, provided important lessons for future applications. This research contributed to the growing body of literature on AI in agriculture, offering valuable insights for policymakers, practitioners, and researchers aimed at optimizing food supply chains in developing regions.

Keywords: Artificial Intelligence, Food Waste Reduction, Cassava Processing, Supply Chain Optimization

nations, where resources are few, the consequences of food waste are more severe, intensifying problems like poverty and malnutrition (Kumar & Singh, 2020).

The significance of minimizing food waste is paramount. This is consistent with the Sustainable Development Goals set forth by the United Nations (SDGs), specifically Goal 12, which seeks to promote environmentally friendly methods of consumption and production (United Nations, 2021). Minimizing waste enhances food security, conserves resources, and mitigates greenhouse gas emissions linked to food production, transport, and disposal (Kummu et al., 2020). Moreover, minimizing food waste is crucial in alleviating climate change consequences, as discarded food substantially contributes to carbon emissions during decomposition in landfills.

The cassava supply chain, especially in areas such as Southwestern Nigeria, exemplifies the urgent necessity for food waste mitigation. Cassava serves as a fundamental food source and an essential cash crop for millions in Nigeria.

However, a considerable amount of cassava produced disappears during its processing and distribution, mostly due to inefficiencies and the absence of contemporary technology (Ogunmola et al., 2022). In this setting, novel solutions are necessary to improve the environmental impact of the cassava processing industry. Artificial Intelligence (AI) has become a revolutionary influence across multiple sectors, including agriculture. Artificial intelligence technology can enhance supply chain processes by refining decision-making, forecasting demand, and increasing efficiency (Kamilaris & Prenafeta-Boldú, 2018). AI can significantly enhance food waste reduction by optimizing procedures, assessing crop conditions, and enabling real-time data analysis.

This study seeks to examine the efficacy of AI-driven optimization in minimizing food waste in the processed cassava supply chain in Southwestern Nigeria. It aims to identify underlying challenges and use technological advancements to offer actionable insights that improve the efficiency and sustainability of the food supply chain, thereby supporting the overarching objectives of food security and environmental conservation.

Food waste has become a huge global issue, impacting economic stability, environmental sustainability, and social equality. Approximately one-third of worldwide food production, totaling around 1.3 billion tonnes per year, is squandered (FAO, 2019). This alarming statistic not only indicates a breakdown in the food supply chain but also intensifies problems associated with resource depletion, greenhouse gas emissions, and food insecurity. The imperative to tackle food waste is emphasized by the United Nations' Sustainable Development Goals (SDGs), specifically Goal 12, which seeks to achieve sustainable consumption and production patterns by reducing per capita global food waste at retail and consumer levels by 2030 (United Nations, 2015).

The economic consequences of food waste are significant. The Food and Agriculture Organisation (FAO, 2019) estimates that food waste results in annual losses of approximately $940 billion. This amount encompasses not only the expense of the discarded food but also the resources expended in its creation, including water, energy, and labor. The economic burden disproportionately affects low-income populations, where food insecurity is already widespread. The World Bank (2020) emphasizes that minimizing food waste might rescue up to 75 million individuals from hunger, thus mitigating the fiscal burden on healthcare systems and social services linked to food insecurity.

Moreover, food waste adversely affects enterprises and the agricultural industry. Agricultural producers have economic losses when unsold crops are wasted, while enterprises bear expenses associated with trash disposal and forfeited sales possibilities (Hassan et al., 2020). The impact of food waste throughout the supply chain highlights the necessity for effective management techniques that enhance profitability and foster sustainability. From an ecological perspective, food waste has significant repercussions. The disposal of food signifies a waste of the resources utilized in its production and exacerbates greenhouse gas emissions. The United Nations Environment Programme (UNEP, 2021) indicates that food waste accounts for roughly 8-10% of worldwide greenhouse gas emissions. This statistic parallels the emissions generated by the entire aviation sector, underscoring the environmental imperative of addressing food waste.

The ecological consequences of food waste surpass mere greenhouse gas emissions. Food waste signifies the squandered water, land, and energy resources expended during the food production process. Approximately 24% of all freshwater utilized in agriculture is eventually squandered due to food loss (Hassan et al., 2020). In areas experiencing water scarcity, such as certain regions of the Middle East and North Africa, minimizing food waste could be essential in preserving these vital resources.

Social fairness constitutes a vital component of food waste mitigation. The paradox of food waste coexists with hunger, as millions experience food insecurity daily. The Global Food Security Index (2021) reveals that although

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global food production is adequate, the distribution of food could be more equitable, resulting in considerable differences in access to healthy food. The consequences of food waste are especially grave in underdeveloped nations when infrastructural deficiencies obstruct efficient food distribution. The FAO (2019) reports that 40% of food waste transpires during the post-harvest and processing phases in these regions. This scenario highlights the necessity for focused measures that improve food delivery efficiency and reduce waste, especially in areas experiencing food insecurity.

Furthermore, the social aspects of food waste encompass consumer behavior and societal norms related to food consumption. Kallbekken and Saelen (2021) emphasize the influence of consumer attitudes and awareness on food waste production, indicating that informing customers about the consequences of food waste may foster more responsible consumer behaviors. Increasing awareness of food waste can transform consumer behavior and cultivate a culture of sustainability that impacts future generations.

Mitigating food waste necessitates coordinated initiatives across several levels, encompassing policy frameworks, corporate strategies, and community involvement. Governments are crucial in formulating policies that facilitate the decrease of food waste. Recent measures, such as France's legislation banning shops from disposing of unsold food, have attracted global attention as successful techniques to mitigate food waste (Reffat et al., 2021). This act can serve as a precedent for other nations aiming to adopt comparable measures.

Moreover, collaboration among stakeholders—including producers, merchants, and consumers—is crucial for formulating efficient food waste reduction programs. Multi-stakeholder initiatives, exemplified by the Champions 12.3 coalition, seek to unite governments, companies, and civil society to expedite advancements in mitigating food waste (Champions 12.3, 2020). Collaborative initiatives can augment knowledge dissemination, optimize resource distribution, and stimulate innovation in food waste management methodologies.

The incorporation of technology into food supply chains offers a substantial possibility for enhancing food waste reduction. Recent studies illustrate that artificial intelligence (AI) and data analytics can improve supply chain efficiency, allowing stakeholders to forecast demand more accurately, optimize inventory management, and minimize waste (Garrone et al., 2020). AI-driven forecasting solutions enable merchants to optimize their ordering processes, hence reducing surplus inventory that frequently results in waste. Furthermore, technological advancements can enable the redistribution of excess food to individuals in need. Platforms linking corporations with food banks and charities are increasingly popular, facilitating the diversion of food that would otherwise be squandered to populations experiencing food poverty (Fischer et al., 2021). These technology solutions not only mitigate food waste but also advance social fairness by guaranteeing that surplus food is distributed to those in greatest need. The significance of minimizing food waste cannot be exaggerated. The economic, environmental, and social ramifications of food waste underscore the pressing necessity for intervention across all societal strata. By acknowledging the interrelation of these challenges, stakeholders may formulate holistic plans that not only reduce food waste but also foster sustainable food systems. Given the escalating challenges of population growth, climate change, and social disparities, prioritizing the reduction of food waste is essential for establishing a robust and equitable global food system.

This project aims to examine the function of Artificial Intelligence (AI) in enhancing farm-to-table supply networks, particularly in minimizing food waste. With escalating pressures on global food systems due to population growth, environmental issues, and socio-economic inequalities, the effective management of food resources has become paramount. This project seeks to conduct a comprehensive review of how AI-driven solutions may optimize supply chain operations, boost waste management practices, and eventually foster more sustainable food systems. This study aims to achieve the following primary objectives: to identify and assess the current applications of AI technologies in food supply chains, specifically those focused on waste reduction; to analyze the dynamics of food waste within the farm-to-table supply chain, pinpointing critical stages where waste arises and the contributing factors; to conduct case studies of successful AI-driven supply chain optimization initiatives that have effectively minimized food waste; and to propose actionable recommendations for stakeholders—including farmers, food producers, retailers, and policymakers—on integrating AI technologies into existing supply chain frameworks to attain waste reduction objectives.

Literature Review

The literature review provides an overview of the current state of knowledge regarding food supply chains, focusing on their definitions, structures, and dynamics. A comprehensive understanding of the food supply chain is essential for contextualizing AI's role in optimizing processes and reducing food waste.

Overview of Food Supply Chain

The food supply chain encompasses the complex network of activities, organizations, and processes involved in the production, processing, distribution, and consumption of food. It includes a series of interconnected stages, each contributing to the overall efficiency and effectiveness of food delivery from farm to consumer (Tummala et al., 2020). The main components of the food supply chain typically include:

a. **Production**: This initial stage involves agricultural activities, such as cultivating crops or raising animals for food. The efficiency of production practices is crucial for ensuring that quality food is available for subsequent stages in the supply chain.

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b. **Processing**: Once harvested, food products often undergo processing to enhance their shelf life, flavor, and nutritional value. This stage may include cleaning, cutting, cooking, and packaging processes. The processing stage significantly influences the quality and safety of food, which can impact waste levels if not managed properly (Kumar & Singh, 2021).
c. **Distribution**: This stage involves transporting food products from processing facilities to wholesalers, retailers, and ultimately consumers. Efficient logistics and transportation systems are vital to maintaining food quality and reducing spoilage during distribution. Challenges in this stage, such as inadequate transportation infrastructure or inefficient routing, can lead to increased food waste (Norrman & Jansson, 2021).
d. **Retail**: Retailers play a critical role in the food supply chain, serving as the link between producers and consumers. Their decisions, including inventory management and marketing strategies, significantly affect food waste levels. For instance, stocking practices that prioritize aesthetic standards over product quality can lead to higher levels of unsold goods being discarded (Garrone et al., 2020).
e. **Consumption**: The final stage of the food supply chain involves the consumer's purchase and consumption of food. Consumer behavior, attitudes, and awareness regarding food waste directly influence the amount of food discarded at the household level. Research has shown that educating consumers about proper food storage and meal planning can significantly reduce food waste during consumption (Kallbekken & Sælen, 2021).

Understanding the intricacies of the food supply chain is essential for identifying opportunities for optimization and waste reduction. As the demand for food continues to rise, the need for efficient supply chain

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management practices becomes increasingly evident. The integration of AI technologies within this framework presents a promising avenue for enhancing efficiency, improving forecasting accuracy, and ultimately minimizing food waste. The literature reveals that AI applications are already beginning to transform various aspects of the food supply chain. For instance, machine learning algorithms are being used to predict demand patterns, optimize inventory levels and reduce surplus (Garrone et al., 2020). Furthermore, AI-driven analytics can help identify waste hotspots within the supply chain, enabling stakeholders to implement targeted interventions (Fischer et al., 2021). However, challenges remain, including the need for data integration, stakeholder collaboration, and consumer acceptance of technology-driven solutions.

Challenges in Food Waste Management

Food waste management presents numerous challenges that complicate efforts to minimize waste at various stages of the supply chain. Understanding these challenges is crucial for developing effective strategies to combat food waste. One of the primary challenges in food waste management is the need for more awareness among consumers and stakeholders regarding the extent and consequences of food waste. Research indicates that many consumers need to be made aware of how their purchasing and consumption habits contribute to waste generation. For instance, a study by Aschemann-Witzel and Zielke (2019) found that consumers often underestimate the quantity of food they discard and fail to understand the environmental implications of their waste. This lack of awareness hinders efforts to encourage more sustainable behaviors, such as meal planning and proper food storage.

The complexity of food supply chains, characterized by multiple stakeholders and processes, poses significant challenges for waste management. Each stage of the supply chain—from production to consumption—has distinct waste drivers, and managing these interrelated components requires coordinated efforts among various actors (Duncan et al., 2020). Inefficient communication and collaboration between suppliers, processors, distributors, and retailers can exacerbate waste issues, leading to significant losses throughout the supply chain.

Regulatory frameworks often need to incentivize food waste reduction or support innovative solutions. Many countries need comprehensive policies aimed at reducing food waste, which can lead to inconsistencies in waste management practices (Bennett et al., 2020). Additionally, food safety regulations can create barriers to redistribution efforts, as food deemed unfit for sale may still be perfectly edible. The lack of standardized definitions and guidelines for food waste also complicates measurement and reporting efforts.

Economic considerations play a critical role in food waste management. Many stakeholders, particularly small-scale farmers and businesses, face financial constraints that hinder investments in waste-reduction technologies or practices. A study by FUSIONS (2019) highlights that the costs associated with food waste—including disposal fees and lost revenue—often outweigh the perceived benefits of implementing waste reduction strategies. As a result, many stakeholders may prioritize short-term profitability over long-term sustainability.

Seasonal variability and climate change further complicate food waste management efforts. Fluctuating weather patterns can lead to unpredictable harvests, resulting in surplus production in good years and shortages in bad years. These fluctuations create challenges for inventory management and increase the risk of spoilage (Kumar & Singh, 2021). Moreover, climate change can impact food quality, leading to higher waste levels if products are damaged or degraded during transport and storage.

Role of Artificial Intelligence in Supply Chain Optimization

AI technologies hold significant potential for enhancing supply chain efficiency and reducing food waste. By leveraging data-driven insights, AI can optimize various processes throughout the food supply chain.

AI algorithms can analyze historical sales data, market trends, and external factors (e.g., weather patterns) to generate accurate demand forecasts. Improved forecasting accuracy enables stakeholders to adjust production schedules, inventory levels, and distribution strategies, ultimately reducing excess supply and waste (Zhang et al., 2020). A study by Hübner et al. (2021) demonstrated that AI-driven demand forecasting can decrease food waste by up to 30% in grocery stores by minimizing overstocking.

AI can enhance inventory management through real-time monitoring and optimization. Automated systems can track inventory levels, expiration dates, and sales velocity, ensuring that products are rotated and utilized before they spoil. For example, AI-driven inventory management systems can recommend replenishment orders based on predicted demand, helping retailers avoid stockouts and reduce waste (Choudhary et al., 2020). AI can improve transportation efficiency through route optimization algorithms that consider factors such as traffic patterns, delivery windows, and vehicle capacities. By minimizing transit times and distances, AI can help maintain food quality and reduce spoilage during transportation. A study by Macharis and Melo (2019) found that AI-driven route optimization can lead to a 15% reduction in food waste during distribution.

AI technologies can also facilitate consumer engagement by providing personalized recommendations and educational resources to reduce household food waste. For instance, AI-driven apps can suggest recipes based on available ingredients or provide tips on food storage and preservation. Such initiatives can empower consumers to make more informed choices, ultimately leading to reduced waste at the household level (Stangherlin et al., 2021).

Materials and Method

This chapter outlines the research methodology employed in the study, focusing on optimizing the farm-to-table supply chain for cassava processing into garri in Southwestern Nigeria. The methodology consists of the research design, data collection methods, AI techniques utilized, and the analytical framework.

The study adopted a descriptive research design to explore the effectiveness of AI-driven strategies in reducing food waste within the cassava processing supply chain. A mixed-methods approach was implemented, combining quantitative surveys with qualitative interviews. The quantitative aspect aimed to gather extensive data from stakeholders involved in the cassava processing sector, while qualitative interviews were conducted to gain deeper insights into the challenges and practices faced by these stakeholders.

Data was collected between October 2023 and June 2024. The research focused on the Southwestern region of Nigeria, which comprises seven states and 42 local government areas (LGAs). The local governments selected were based on their prominence in cassava production and processing. The study centered on cassava processing into garri, a widely consumed staple in Nigeria. The selection of the case study was informed by the significance of cassava in the region's agricultural landscape and the potential for reducing food waste through improved supply chain practices. The seven states included in the study were Lagos, Ogun, Oyo, Osun, Ekiti, Ondo, and Delta.

Data was collected from multiple sources, including primary and secondary data. Structured questionnaires were administered to stakeholders within the cassava supply chain, including farmers, processors, distributors, and retailers. Additionally, semi-structured interviews were conducted with key informants to gather qualitative insights. Relevant literature, government reports, and existing research studies were reviewed to supplement the primary data and provide context for the findings.

The study incorporated several AI techniques to analyze the collected data and optimize the supply chain processes. Key AI techniques included Algorithms such as regression analysis and decision trees, which were employed to predict demand patterns and optimize inventory management for gari processing. NLP was used to analyze qualitative data from interviews, identifying key themes and challenges faced by stakeholders in the cassava processing sector. Data mining techniques were applied to uncover hidden patterns in the supply chain data, providing insights into waste generation points and potential areas for intervention.

The analysis framework comprised both quantitative and qualitative approaches: Statistical methods were used to analyze survey data, focusing on demographic characteristics, waste generation rates, and the impact of AI interventions on supply chain efficiency. Descriptive statistics and inferential analysis were conducted using software tools such as SPSS and R. Thematic analysis was conducted on the qualitative data obtained from interviews. Key themes were identified and categorized, providing a comprehensive understanding of the barriers to effective waste management in cassava processing. A stratified random sampling method was employed, dividing the population into strata based on the LGAs within the seven states. A total sample size of 4,200 respondents was targeted, with the distribution across the states as shown in Table 1. The sampling frame ensured that each LGA contributed equally to the overall sample size, providing a comprehensive view of the cassava processing supply chain across Southwestern Nigeria.

Table 1: table showing the sampled popultionvb

State	Local Government Area (LGA)	List of the six Local Government Areas sampled in the study	Sample Size (n)
Lagos	6	Alimosho, Ikeja, Surulere, Eti-Osa, Apapa and Ikorodu	600
Ogun	6	Abeokuta North, Ijebu Ode, Sagamu, Ado-Odo/Ota, Yewa South, Remo North	600
Oyo	6	Ibadan North, Ogbomoso North, Oyo East, Ibarapa East, Saki West, Olorunsogo	600

Osun	6	Osogbo, Ife Central, Ede North, Ilesa West, Iwo, Ejigbo	600
Ekiti	6	Ado Ekiti, Ikere, Ijero, Ekiti East, Ikole, Oye	600
Ondo	6	Akure South, Owo, Ondo West, Ilaje, Ifedore, Okitipupa	600
Delta	6	Warri South, Ughelli North, Oshimili South, Sapele, Isoko South, Aniocha North	600
Total	**42**		**4,200**

Description of the Selected Case Study

The cassava processing industry in Southwestern Nigeria is essential to the region's economy, supporting millions of livelihoods and enhancing food security. Cassava (Manihot esculenta) is a fundamental crop in Nigeria, processed into several products, with garri being particularly favored for its variety and nutritional benefits. The research concentrated on seven states in Southwestern Nigeria: Lagos, Ogun, Oyo, Osun, Ekiti, Ondo, and Delta, comprising a total of 42 local government areas (LGAs). The area is distinguished by advantageous agro-climatic conditions, rendering it appropriate for cassava cultivation. Table 1 delineates the land area allocated for cassava cultivation in each state.

Table 2: Estimated production output of cassava in Tonnes per state in the study area

State	Area under Cassava Cultivation (Hectares)	Estimated Cassava Production (Tonnes)
Lagos	8,000	120,000
Ogun	15,000	200,000
Oyo	20,000	300,000

Osun	10,000	150,000
Ekiti	12,000	180,000
Ondo	18,000	250,000
Delta	25,000	400,000
Total	**118,000**	**1,620,000**

The data reveals a considerable expanse allocated to cassava cultivation, underscoring the crop's importance in the regional agricultural framework. The conversion of cassava into gari entails multiple stages: peeling, washing, grinding, fermentation, pressing, and frying. Every phase offers prospects for minimizing food waste and enhancing efficiency via AI interventions. For example, during the grating process, much cassava may be squandered if not managed well. Utilizing AI-driven monitoring systems, processors can enhance the grating process to reduce losses. Moreover, data analytics can forecast the ideal fermentation duration, guaranteeing enhanced quality and less spoiling.

The deployment of AI solutions in the cassava processing supply chain was conducted in multiple phases, emphasizing the improvement of operational efficiency and the minimization of food waste. This section delineates the AI technologies utilized and the effects they have on the supply chain. Predictive analytics instruments were employed to project cassava supply and demand trends. This entailed the examination of historical production statistics, market prices, and consumption trends. The model was developed with machine learning technologies, including linear regression and time series analysis, to deliver precise demand estimates. AI-driven inventory management systems facilitated real-time monitoring of cassava stockpiles, hence minimizing wastage due to rotting. Sensors were deployed at processing facilities to monitor temperature and humidity, thereby ensuring appropriate storage conditions.

AI-powered image recognition technology was employed to evaluate the quality of cassava roots. This method facilitated the identification of defective roots prior to processing, hence reducing the probability of food waste during production. Artificial intelligence methods were employed to enhance the logistics of cassava shipping. This encompassed route optimization techniques to diminish fuel consumption and delivery durations, improving total efficiency.

Table 3: Results of AI implementation.

AI Solution	Impact on Food Waste Reduction	Key Performance Indicators (KPIs)
Predictive Analytics	Improved accuracy in demand forecasting, reducing overproduction	- 30% reduction in unsold garri - 25% increase in sales predictability
Inventory Management Systems	Enhanced monitoring of storage conditions, leading to reduced spoilage	- 20% decrease in waste due to spoilage; - 15% improvement in shelf life
Image Recognition	Early identification of defects in cassava roots, leading to better quality control	- 40% reduction in defective roots - 10% increase in overall quality ratings
Supply Chain Optimization	More efficient transportation routes, reducing costs and delivery times	- 15% reduction in transportation costs , - 20% improvement in delivery efficiency

Challenges and Considerations

The introduction of AI technologies showed considerable potential for minimising food waste, although various problems arose. The precision of AI

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predictions is significantly contingent upon the quality and comprehensiveness of the obtained data. In certain instances, inadequate or inconsistent data hindered the efficacy of the AI systems. Stakeholders necessitated training to proficiently employ the AI tools. Resistance to change and insufficient digital literacy among certain farmers and processors hindered comprehensive acceptance. The insufficient technological infrastructure in rural regions restricted the successful implementation of AI solutions. Investments in fundamental infrastructure were essential to facilitate these activities.

The case study emphasised the significance of incorporating AI technologies into the cassava processing supply chain to enhance efficiency and minimise food waste. The deployment of predictive analytics, inventory management systems, image recognition, and supply chain optimisation tools markedly improved efficiency and reduced waste. Nonetheless, tackling the issues of data quality, training, and infrastructure will be essential for maintaining these enhancements over the long term. As the study advances, ongoing monitoring and modifications will guarantee the complete realisation of AI intervention effects, facilitating a more sustainable cassava processing sector in Southwestern Nigeria.

Outcomes of AI-Enhanced Optimisation

The AI-driven optimisation in the cassava processing supply chain has resulted in significant enhancements in food waste reduction and operational efficiency. This section delineates the conclusions concerning the diminution of food waste and enhancements in efficiency, alongside the problems encountered and insights gained during the implementation phase. The incorporation of AI technologies has significantly influenced the reduction of food waste in the cassava processing industry. A range of indicators was examined to assess the efficacy of these interventions, as demonstrated in Table 4.

Table 4: Comparative analysis of AI implementation and the resultant effect

Indicator	Before AI Implementation	After AI Implementation	Percentage Change
Total Food Waste (Tonnes)	500	300	-40%
Waste during Grating (Tonnes)	150	90	-40%
Spoilage during Storage (Tonnes)	200	100	-50%
Defective Roots (Tonnes)	100	60	-40%

The data indicates a 40% overall decrease in total food waste subsequent to the adoption of AI solutions. A lot less waste was made during the grating process, which shows that AI-driven monitoring works to improve this important part of cassava processing. Moreover, a fifty percent reduction in deterioration during storage led to enhanced product quality and marketability. AI technologies have enhanced efficiency throughout multiple facets of the cassava supply chain. We monitored key performance indicators both before and after the deployment, as shown in Table 5.

The deployment of AI technologies led to a 30% decrease in production time per batch, allowing processors to increase output without incurring extra labor expenses. Transportation expenses decreased by 15% as a result of optimized routing algorithms, resulting in diminished fuel consumption and improved cost-efficiency. Moreover, the average delivery time diminished by 25%, markedly enhancing responsiveness to market demands. The 30% increase in product quality ratings demonstrates the beneficial effects of utilizing AI for quality control and defect management.

Table 5: Efficiency indicator of AI implementation

Efficiency Indicator	Before AI Implementation	After AI Implementation	Percentage Change
Production Time (Days per Batch)	10	7	-30%

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Transportation Costs (₦)	300,000	255,000	-15%
Average Delivery Time (Hours)	48	36	-25%
Product Quality Rating (Scale of 1-10)	6.5	8.5	+30%

Obstacles encountered and insights gained

Notwithstanding the myriad advantages gained from the AI-driven optimization of the cassava processing supply chain, various obstacles arose during its implementation. Comprehending these issues and the insights gained is essential for the effective implementation of analogous efforts in the future. Numerous players in the cassava processing industry demonstrated reluctance to embrace AI technologies. Certain processors expressed scepticism regarding the efficacy and dependability of AI solutions, firmly establishing conventional processes.

The caliber and uniformity of the collected data presented considerable difficulties. Deficient or erroneous data frequently obstructed the AI algorithms' capacity to provide dependable forecasts and insights. Implementing stringent data management standards was crucial. The current technology infrastructure in rural regions was insufficient for facilitating advanced AI technologies. In numerous instances, insufficient dependable internet access and computing capacity impeded the effective deployment of AI technologies. A pressing necessity existed for training programs to enable stakeholders to proficiently employ AI technologies. A significant number of farmers and processors were deficient in essential skills and knowledge, underscoring the necessity of capacity-building activities.

Involving stakeholders from the outset and delivering thorough education on the advantages of AI technologies were essential for mitigating resistance.

Workshops and demonstrations enhanced comprehension and adoption of AI solutions. Guaranteeing superior data quality is essential for the efficacy of AI treatments. Investing in data-gathering methodologies and conducting regular audits of data integrity improved the precision of AI-generated insights. Mitigating infrastructure constraints is crucial for the effective deployment of AI systems. Collaborations with governmental and corporate entities to augment technology infrastructure can elevate the efficacy of AI interventions. Continuous training and assistance for stakeholders are essential to remain abreast of technological changes. Implementing training programs that are accessible and customized to the distinctive requirements of processors might enhance the adoption of AI technologies.

The outcomes of AI-driven optimization in the cassava processing supply chain revealed substantial decreases in food waste and enhancements in efficiency. Nonetheless, obstacles including resistance to change, data management concerns, and infrastructure constraints highlighted the significance of stakeholder participation, data integrity, and continuous training. By addressing these difficulties, the cassava processing sector may establish sustainable methods that optimize resource use and improve food security in Southwestern Nigeria.

Implication of Findings

The outcomes of the AI-enhanced optimisation of the cassava processing supply chain in Southwestern Nigeria reveal important information about reducing food waste, making operations more efficient, and the overall effectiveness of using new technologies in traditional farming methods. This section examines the consequences of these discoveries, contrasts the outcomes with conventional approaches, advances supply chain theory, and offers advice for practitioners.

The substantial decrease in food waste and enhancements in efficiency via AI interventions highlight the technology's capacity to revolutionize agricultural supply systems. The research suggests that utilizing AI enables processors to improve their operating procedures while tackling the critical issue of food waste—a persistent global crisis (Khan et al., 2021). The results confirm the feasibility of AI applications in agriculture and highlight the necessity for comprehensive strategies that include stakeholder involvement, training, and infrastructure enhancement to ensure effective adoption.

Conventional cassava processing techniques frequently exhibit inefficiencies, substantial waste, and restricted scalability. Before the use of AI, the processing phases relied on manual oversight and decision-making, resulting in product quality variations and significant food waste. Research by Asif et al. (2020) indicated that conventional methods in cassava processing led to an average waste of up to 50% during the grating and storing stages. The AI-driven approach resulted in a 40% decrease in food waste and improved efficiency across multiple performance metrics, including production time and transportation expenses. Processing units were able to work more efficiently by using AI algorithms for quality control, monitoring, and predictive analytics (Kumar et al., 2023) (Kumar et al.). This comparison demonstrates the revolutionary capacity of AI to enhance efficiency and foster sustainability throughout the agricultural supply chain.

The study's findings enhance supply chain theory by offering empirical data about technology's involvement in optimizing agricultural processes. The incorporation of AI into the cassava supply chain illustrates the notion of "smart supply chains," wherein data-driven insights and automation improve decision-making processes (Zhang et al., 2022). This study adheres to the Resource-Based View (RBV) theory, indicating that the implementation of modern technologies like AI can function as a significant resource, resulting in competitive benefits for companies in the agriculture industry (Barney, 1991).

Furthermore, the study enhances the existing literature on sustainable supply chain management by elucidating the relationship between technology and environmental sustainability. Food waste significantly contributes to greenhouse gas emissions, underscoring the necessity of implementing new strategies to attain sustainability objectives within the supply chain (Pérez-Valls et al., 2020). This research integrates AI applications with sustainability outcomes, enhancing the discussion about the future of agricultural supply networks.

This study's implications and conclusions yield various recommendations for agricultural practitioners. Agricultural processors must prioritize investments in technology infrastructure to enable the integration of AI solutions. This encompasses the improvement of internet connectivity, access to computational resources, and data management systems, as highlighted by Khan et al. (2021). Involving stakeholders during the implementation phase is crucial for promoting adoption and efficient use of AI technologies. We must establish training programs to enhance the technical competencies of processors and farmers, ensuring their proficiency in successfully utilizing AI tools (Kumar et al., 2023).

Practitioners must establish rigorous data collection and management protocols to guarantee the precision and uniformity of information used in AI algorithms. Frequent audits and revisions of data management policies can improve the dependability of AI-generated insights (Zhang et al., 2022). Collaborations with research institutes can enhance knowledge transfer and foster innovation in AI applications. Collaborative initiatives can result in the creation of customized solutions that tackle the particular difficulties encountered by processors in the cassava supply chain (Asif et al., 2020). Practitioners must include sustainability in their operational strategies by emphasizing methods that reduce food waste and improve resource efficiency. This strategy not only tackles environmental issues but also enhances the sustainability of the cassava processing industry (Pérez-Valls et al., 2020).

Summary of Key Findings

The application of AI-driven optimization methods in the cassava processing supply chain in Southwestern Nigeria produced many notable results:

The implementation of AI technology resulted in a significant reduction in food waste, with an overall decrease of almost 40%. Enhanced monitoring, predictive analytics, and quality control protocols implemented at multiple phases of the supply chain primarily contributed to this decrease.

The study highlighted notable enhancements in operational efficiency. Processing times decreased an average of 30%, while transportation costs fell by 25% as a result of optimized route planning and inventory management enabled by AI solutions.

The findings underscored the essential importance of stakeholder interaction in the effective implementation of AI technologies. The active engagement of farmers, processors, and other supply chain stakeholders facilitated greater acceptance of innovative approaches and enhanced results.

The incorporation of AI not only lowered waste but also fostered sustainability throughout the cassava supply chain. The results correspond with international initiatives to reduce food waste, essential for tackling environmental challenges and attaining food security.

The study convincingly compared traditional ways of processing cassava to methods that are driven by AI. It showed how technology has the potential to completely change how supply chains work. Conventional approaches proved ineffective and led to increased waste, while AI solutions exhibited considerable benefits for waste minimization and operational efficacy.

The execution of AI solutions encountered obstacles. Essential lessons acquired were the significance of data quality control, the imperative for ongoing stakeholder training, and the requirement for a resilient infrastructure to facilitate AI applications.

Conclusion

These findings demonstrate the significant potential of AI to transform agricultural supply chains, especially in poor nations where conventional approaches have long prevailed. This study's findings on AI-driven farm-to-table supply chain optimization significantly impact food waste reduction and operational efficiency in the cassava processing industry. This research presents a complete framework for practitioners aiming to improve sustainability and efficiency in agricultural supply chains by comparing AI-driven approaches with traditional ways and contributing to supply chain theory while delivering actionable advice.

References

Aschemann-Witzel, J., & Zielke, S. (2019). Can "Nudging" Reduce Food Waste? *Journal of Cleaner Production*, 238, 117892.

Asif, M., Kahn, A., & Hameed, S. (2020). *Sustainable Practices in Agricultural Supply Chains: A Comparative Analysis of Traditional and Modern Methods.* Journal of Cleaner Production, 252, 119783.

Barney, J. (1991). *Firm Resources and Sustained Competitive Advantage.* Journal of Management, 17(1), 99-120.

Bennett, A., et al. (2020). The Role of Regulations in Food Waste Prevention. *Waste Management*, 113, 22-30.

Champions 12.3. (2020). *The Champions 12.3 coalition*. Retrieved from https://champions123.org

Choudhary, A., et al. (2020). AI in Inventory Management: Strategies for Reducing Food Waste. *Supply Chain Management: An International Journal*, 25(5), 629-642.

de Lange, M., et al. (2020). Effective Interventions to Reduce Food Waste in Grocery Stores. *Waste Management*, 106, 35-43.

Duncan, M. C., et al. (2020). Food Waste: Challenges and Opportunities for Sustainable Solutions. *Sustainability*, 12(12), 4875.

FAO. (2019). *The State of Food and Agriculture 2019: Moving forward on food loss and waste reduction*. Rome: Food and Agriculture Organization of the United Nations.

Fischer, C., Hennchen, E., & Behrens, A. (2021). Food Waste Management in Urban Areas: Concepts, Strategies, and Technologies. *Sustainability*, 13(5), 2500.

Fischer, C., Hennchen, E., & Behrens, A. (2021). Food Waste Management in Urban Areas: Concepts, Strategies, and Technologies. *Sustainability*, 13(5), 2500.

Garrone, P., Melacini, M., & Perego, A. (2020). Food waste in the food supply chain: An overview of the state of the art and future perspectives. *Waste Management*, 104, 130-139.

Garrone, P., Melacini, M., & Perego, A. (2020). Food waste in the food supply chain: An overview of the state of the art and future perspectives. *Waste Management*, 104, 130-139.

Global Food Security Index. (2021). *Food Security: Data and Analysis*. Retrieved from https://foodsecurityindex.eiu.com

Hassan, A., Farooq, M. Z., & Asad, S. (2020). Food waste in food supply chain: A systematic literature review. *Waste Management*, 113, 258-270.

Hübner, A., et al. (2021). The Impact of AI on Demand Forecasting and Food Waste Reduction. *International Journal of Production Economics*, 231, 107878.

Kallbekken, S., & Sælen, H. (2021). The role of consumer awareness in reducing food waste. *Journal of Cleaner Production*, 317, 128268.

Kallbekken, S., & Sælen, H. (2021). The Role of Consumer Awareness in Reducing Food Waste. *Journal of Cleaner Production*, 317, 128268.

Kallbekken, S., & Sælen, H. (2021). The role of consumer awareness in reducing food waste. *Journal of Cleaner Production*, 317, 128268.

Khan, M. I., Khan, A. A., & Ullah, R. (2021). *The Role of Technology in Reducing Food Waste in Supply Chains: A Systematic Review.* Resources, Conservation and Recycling, 165, 105143.

Kumar, A., Gupta, S., & Singh, R. (2023). *AI in Agriculture: Challenges and Opportunities for Sustainable Food Supply Chains.* Agricultural Systems, 194, 103294.

Kumar, V., & Singh, R. (2021). Food Processing and Waste Management. *International Journal of Waste Resources*, 11(2), 1000215.

Kumar, V., & Singh, R. (2021). Food Processing and Waste Management. *International Journal of Waste Resources*, 11(2), 1000215.

Macharis, C., & Melo, S. (2019). The Role of Transport in Reducing Food Waste: A Review. *Sustainability*, 11(7), 2068.

Norrman, A., & Jansson, U. (2021). Food supply chain management and food waste: A systematic literature review. *Journal of Cleaner Production*, 289, 125689.

Pérez-Valls, J., Colom, S., & Gallego, M. (2020). *Sustainability in Food Supply Chains: The Role of AI and Data Analytics.* Journal of Supply Chain Management, 56(4), 23-45.

Popp, A., et al. (2021). The Effectiveness of Food Waste Reduction Policies in the European Union. *Waste Management*, 124, 153-163.

Reffat, R., Bader, M. M., & Wong, J. (2021). The impact of food waste legislation in France: A review. *Waste Management & Research*, 39(1), 12-20.

Stangherlin, I. N., et al. (2021). Consumer Engagement in Food Waste Reduction: The Role of Technology. *Food Quality and Preference*, 89, 104091.

Tummala, V., Hsu, C., & Meixell, M. (2020). A new food supply chain framework: Enhancing collaboration for sustainable food systems. *Sustainable Production and Consumption*, 24, 75-87.

UNEP. (2021). *Food Waste: The Environmental Impact*. Retrieved from https://www.unep.org/resources/report/food-waste

United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. New York: United Nations.

Van Herpen, E., et al. (2021). Behavioral Nudges for Reducing Household Food Waste. *Food Policy*, 97, 101890.

World Bank. (2020). *Food Waste in the World: A Global Perspective*. Washington, DC: World Bank.

Xiong, Z., et al. (2022). Technology-Driven Solutions for Food Waste Reduction: A Systematic Review. *Waste Management*, 139, 119-134.

Zhang, Y., et al. (2020). AI-Driven Demand Forecasting: Implications for Food Supply Chains. *Journal of Operations Management*, 66(6), 845-861.

Zhang, Y., Wang, J., & Liu, Z. (2022). *Smart Supply Chains: The Integration of AI and Blockchain.*