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Supply Chain Of Urban Farming Products Based On Technological Innovation: Toward Achieving Local Food Security

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Abstract
The supply chain of food products such as vegetables and fruits is inseparable from staple food products like rice, cassava, and corn, which are essential for ensuring food availability, security, and self-sufficiency both locally and nationally. However, various challenges persist in achieving food security, including decreasing arable land, a declining farming generation, issues in marketing and distributing agricultural products, market price volatility, and uncertainties in demand forecasting and information management. This study employs a case study method with a systematic approach, involving an analysis of scientific publications and relevant case studies from the past decade. The findings demonstrate that innovative technologies such as blockchain and the Internet of Things (IoT) offer strategic solutions for addressing marketing, distribution, and market price certainty for agricultural commodities in a rapid, precise, and efficient manner. These technologies also enable information management within the supply chain for demand forecasting, quality control, and environmental monitoring. In the area of demand forecasting, these technologies can provide information with predictive accuracy of up to 25%, minimizing the risk of shortages or surpluses of food products. Furthermore, IoT-based information management ensures transparency and supports fact-based, up-to-date, and accurate decision-making grounded in real-time data. Blockchain technology guarantees transparent data recording and accountability through quality assurance (QA) and Total Quality Management (TQM) integrated with IoT, thereby maintaining the quality and quantity control of fresh produce. Environmental management is supported through Green Supply Chain Management (GSCM) strategies, which can reduce waste pollution by up to 30% through integrated reverse logistics, blockchain, and IoT technologies to identify, analyze, and expand broader market potentials, contributing to a more effective and efficient sustainable food supply chain strategy.
Keywords: *Blockchain, Food Security, Supply Chain, Technological Innovation, Urban Farming*

INTRODUCTION

Food product Supply Chain Management (SCM) is an essential component in ensuring food security, particularly in developing countries such as Indonesia. Food security faces significant challenges due to shifting consumption patterns, population growth, and fluctuations in global markets. SCM serves as a vital framework for integrating various processes, from production to distribution, to ensure the sustainability and efficiency of food supply.The unique characteristics of food products—such as their perishable nature, seasonality, and sensitivity to external factors like weather—add complexity to their management. These characteristics demand a more holistic planning approach, including comprehensive demand forecasting and information management. Such an approach is critical for ensuring a stable supply of food products while maintaining quality until they reach consumers (Campbell, S.J. (2021; Haseeb, 2019; Pye, 2019; Quayson, 2021; Novitasari, 2021; Siagian, 2021; Tarigan, 2021).In addition to rice and corn, Indonesia's staple food commodities include cassava, which has significant potential to be further developed in terms of cultivation, production, and consumption, providing an alternative to rice through food diversification into other popular processed food forms. Cassava, a type of tuber, is well-known as a raw material for local or traditional foods that are tasty, unique, and healthy, such as *gaplek*, *tiwul*, *gatot*, *getuk*, *ceni*l, *combro*, *misro*, fried cassava, boiled cassava, steamed cassava, and various types of cassava chips. With technological advancements, cassava processing has expanded to producing tapioca flour, facilitating its transformation into a variety of food products, including noodles, bread, cakes, and others. Cassava as a tuber crop is highly suitable for cultivation in Indonesia's tropical climate and fertile soil, supporting its growth and resilience across various soil types, including dry soils (Rozi et al., 2022;Teguh et al., 2022; Zulkarnain et al., 2024) . Beyond its considerable economic potential, cassava offers significant nutritional value as a cholesterol-free and low-fat energy source, making it a healthy food option rich in protein, vitamins B and K, copper, and magnesium—nutrients that support immune function, brain health, and bone strength. Although cassava is calorie-dense, its high fiber content aids digestion (Akinde et al., 2022; Awoyemi et al., 2016; Bangthong et al., 2021; Codjia et al., 2025; Gengenbach, 2019). According to Indonesia's Ministry of Agriculture (2023/2024), cassava cultivation covers approximately 611 thousand hectares, yielding an estimated 18.3 million tons. Five provinces are the largest cassava producers in Indonesia: Lampung, Central Java, East Java, West Java, and Yogyakarta.Enhancing community empowerment in cassava cultivation, production, and consumption patterns, as well as diversifying staple food sources from cassava, is crucial. This diversification can reduce dependence on rice, whose prices continue to rise due to limited productivity and growing demand. According to Databoks (2024), in 2023 the average retail price for premium rice was IDR 13,140 per kilogram, increasing by 14.08% to IDR 14,990 per kilogram by year-end. Similarly, the price of medium-grade rice rose by 14.20% from IDR 11,550 to IDR 13,190 per kilogram.Therefore, increasing cassava production and promoting its consumption as a rice substitute through post-harvest diversification are essential. The Directorate General of Food Crops reported that cassava production increased from 14.95 million tons in 2022 to 16.76 million tons in 2023, an increase of 1.81 million tons.From 2022–2023, Indonesia ranked seventh globally in cassava production, according to the Central Bureau of Statistics, while neighboring countries such as Thailand and Cambodia ranked third and fifth, respectively. Nigeria remains the largest global producer, with an annual output of 60.83 million tons. According to Market Research Future, the global cassava market was valued at USD 175.9 billion in 2022 and is projected to grow to USD 183.25 billion in 2024, and further to USD 254.28 billion by 2032, assuming an annual growth rate of 4.18% for the 2024–2032 period. Supported by the Indonesian Cassava Society (MSI), it is imperative for the government to position cassava as a strategic national food commodity, given its production potential, diversification opportunities, and promising local and global market share.To improve the productivity and utilization of staple food commodities, including cassava, demand forecasting is a key element of food SCM. By leveraging modern technologies such as data analytics and machine learning, companies can predict market demand with greater accuracy. These technologies help minimize the risks of surplus and shortages, which often hinder food distribution. Moreover, this approach enhances efficiency in storage and inventory management (Cahyono, 2023; Dharmayanti, 2023; Phelan, 2020; Sugandini, 2020; Susanty, 2020; Tarigan, 2021).Information management also plays a strategic role in enhancing efficiency and coordination throughout the supply chain. Advances in technology, such as IoT and cloud computing, enable real-time collection and dissemination of information to all stakeholders. These technologies facilitate faster, data-driven decision-making, thereby reducing uncertainty and the risk of losses (Aliahmadi & Nozari, 2022; Chung et al., 2020; Ben-Daya et al., 2017; Saberi et al., 2018; Wang et al., 2018).In addition to demand forecasting and information management, quality management is vital in food SCM. Perishable food products require strict quality control to ensure safety and quality standards. Approaches such as Total Quality Management (TQM) focus on quality improvement throughout the supply chain, not only meeting consumer expectations but also enhancing global market competitiveness.Environmental management through Green Supply Chain Management (GSCM) practices is also a priority in food SCM. GSCM aims to reduce the negative environmental impact of supply chains by adopting eco-friendly practices such as energy efficiency, carbon emission reduction, and the use of recyclable materials. This strategy supports business sustainability while responding to market demands for more sustainable products (Chen et al., 2021; Chen et al., 2022; Ghaderi et al., 2023; Kara & Edinsel, 2022; Park et al., 2016; Zhang et al., 2021) .However, the adoption of environmental management practices in food SCM still faces significant challenges, particularly in developing countries such as Indonesia. Inadequate infrastructure, high implementation costs, and technological limitations are key barriers to GSCM implementation. Therefore, collaborative strategies involving government, the private sector, and academia are needed to overcome these obstacles.Much of the existing literature tends to focus on individual elements of SCM, such as quality or information management, without comprehensively linking these elements together. This fragmented approach creates gaps in understanding how these components can complement each other to build a more efficient and sustainable supply chain.This study seeks to address this gap by integrating demand forecasting, information management, quality management, and environmental management within food SCM. Through a comprehensive literature approach, this research aims to provide more holistic insights into SCM strategies applicable across various contexts.In addition, this study also aims to identify best practices from various relevant international contexts. Case studies from several countries demonstrate that the implementation of modern technologies and integrative management approaches can enhance operational efficiency and strengthen the competitiveness of local products in the global market. In the Indonesian context, the integration of technologies such as the Internet of Things (IoT) and machine learning remains at an early stage of adoption. Yet, the application of these technologies can provide significant benefits, including food waste reduction, improved energy efficiency, and more transparent information management. Therefore, this study also seeks to explore the potential for adopting these technologies within Indonesia's food sector (Agustina et al., 2024; Masudin et al., 2024; Restuputri et al., 2023).Through a comprehensive approach, this research is expected to provide practical guidance for stakeholders, including government bodies, the private sector, and farmers, to improve the efficiency and sustainability of the food supply chain. By offering an integrative framework, this study presents tangible solutions for addressing various challenges within food supply chain management (SCM).The academic contribution of this research is also expected to enrich the literature on food SCM, particularly within the context of developing countries. By identifying and analyzing the interrelationships between demand forecasting, information management, quality management, and environmental management, this study provides a strong theoretical foundation for the advancement of further studies.Indonesia possesses substantial agricultural resources, particularly staple food commodities that support food security grounded in self-sufficiency and food sovereignty, not only rice and corn but also through increasing the productivity and promoting the consumption culture of cassava as an alternative staple food. This would reduce dependency on rice as the sole staple and, consequently, decrease the need to import food staples from other countries. Enhancing staple food productivity should also contribute to addressing broader macro-level development challenges such as poverty, hunger, and unemployment, as increased production of staple foods can create employment opportunities.According to data from Indonesia's Central Statistics Agency, although poverty rates have slightly declined, they remain a major development issue that must be addressed. In urban areas, the poverty rate decreased from 11.74 million people in 2023 to 11.64 million in 2024, while in rural areas it declined from 14.16 million people in 2023 to 13.58 million in 2024 .Based on the World Economic Outlook 2024 and the International Monetary Fund (IMF), Indonesia ranks seventh among the poorest countries in Southeast Asia, with the lowest GDP per capita at USD 5,270 (approximately IDR 79 million). Myanmar, Timor Leste, Laos, the Philippines, and Vietnam rank higher on this list. Another critical issue is hunger: according to the 2024 Global Hunger Index (GHI), Indonesia ranks 77th globally in the moderate category with a score of 16.9 out of 127 countries. Indonesia's GHI score is based on four component indicators: 7.2% of the population is undernourished, 26.8% of children under five are stunted, 10.0% of children under five suffer from wasting, and 2.1% of children die before reaching the age of five. Among Southeast Asian countries, Indonesia ranks third, following Timor Leste (27) and Laos (19.8), and ahead of Myanmar (15.7), Cambodia (14.7), the Philippines (14.4), Malaysia (12.7), Vietnam (11.3), and Thailand (10.1). Meanwhile, according to the Central Statistics Agency, the unemployment rate in Indonesia in 2024 stood at 7.47 million people, or 4.91%.

Therefore, it is vital and strategic to increase the productivity and economic value of staple foods such as cassava as an alternative to rice. This effort can help mitigate poverty, hunger, and unemployment when supported by supply chain management and information systems based on technological innovation, ensuring that market and consumer demands are met effectively, efficiently, and swiftly. Several studies indicate that, at the micro level, agricultural cultivation and supply chain management for staple food commodities remain largely conventional or traditional, with limited technology adoption and restricted information access. As a result, these systems are often unresponsive to market needs and fluctuations and lack the capacity to anticipate climate and environmental dynamics. Hence, this study poses the following research questions: (1) What are the supply chain needs for food commodities? (2) How can food product supply chain management (SCM) be effectively implemented?

RESEARCH METHODS

This study employs the Participatory Learning and Action (PLA) method, which is well-suited for designing and implementing action programs based on participation, identification, and analysis by research informants, including community-based institutional groups such as the Gemag Ripah farmers group, Integrated Service Posts, Family Welfare Empowerment groups, youth organizations, and community empowerment activists. Data were collected through observation, document analysis, interviews, and Focus Group Discussions (FGDs), and were analyzed using qualitative participatory research methods involving identification, analysis, verification, and triangulation of the data.

PLA (Wood, 2020) emphasizes research as a practical and learning process conducted through interaction with communities or groups to identify and analyze experiences, knowledge, and capabilities in planning, decision-making, and implementing activities. PRA (Vaughn, & Jacquez, 2020) as a participatory method emphasizes several key aspects: (1) Empowerment. as motivation, knowledge, and skills provided by the government, civil society, and private sector to individuals or communities to enhance their capacity to advance, prosper, and achieve self-reliance; (2) Respect. PRA involves a process of collaboration and mutual transformation between researchers and the community, fostering egalitarian relationships, mutual exchange, and solidarity through shared learning and knowledge exchange; (3) Localization. Optimally utilizing local community resources, including human, socio-economic, socio-cultural, and environmental assets; (4) Enjoyment. PRA activities are conducted harmoniously and enjoyably, without coercion, but rather through voluntary and willing participation; (5) Inclusiveness. PRA pays particular attention to marginalized communities, those facing socio-economic vulnerabilities, and disadvantaged groups, prioritizing their development. Participatory data analysis (Vaughn & Jacquez, 2020) is carried out qualitatively through identification, analysis, verification, and triangulation of factual and current realities to construct scholarly discussions supported by relevant concepts and theories. Subsequently, unique and interesting findings from each case are reduced and categorized, followed by cross-case analysis.

RESULTS AND DISCUSSION

Demand in the Food Supply Chain

The analysis of demand within the supply chain represents not only local and national trends but also regional and global developments in supply chain management (SCM) research, particularly regarding issues such as energy efficiency, waste reduction, workflow digitalization, and sustainability management. With increasing global pressure to reduce the environmental impact of economic activities, topics such as green supply chain management have gained heightened relevance, as reflected in the substantial number of publications addressing these themes. These publications serve as custodians of knowledge that enable ongoing dialogue between theory and practice, creating cross-sectoral collaboration opportunities to address global challenges related to green supply chain management, information management in SCM, demand forecasting in food supply chains, and quality assurance in food logistics.Demand forecasting is an essential process within the food supply chain, aimed at predicting future demand based on historical data, analytics, and external factors. In the context of food products, demand forecasting is particularly complex due to the perishable nature of these products and their sensitivity to seasonal changes and market fluctuations Accurate forecasting helps to avoid surplus or shortages, thereby supporting operational efficiency and supply chain sustainability. Forecasting techniques are typically divided into quantitative and qualitative methods. Quantitative methods involve analyzing historical data to identify patterns and demand trends, while qualitative methods rely on expert judgment or market surveys to predict future demand, especially when historical data is limited. In the food sector, combining both methods yields more accurate results (Azmat, & Siddiqui, 2023; Babai et al., 2021; Cui et al., 2025; Feizabadi, 2020; Goel et al., 2024; Kantasa-ard et al., 2020), as it integrates quantitative variables and qualitative external factors. Each forecasting technique has its own advantages and limitations (Table 1).

Table 1. Comparison of Forecasting Techniques

Forecasting Technique	Description	Advantages	Limitations
Simple Moving Average (SMA)	Average demand over recent periods.	Easy to apply, suitable for stable patterns.	Insensitive to trends or seasonal patterns.
Weighted Moving Average (WMA)	Assigns greater weight to recent data to capture changes.	More responsive to recent shifts.	Subjective weight selection.
Exponential Smoothing	Exponentially weighted average with a smoothing parameter.	Flexible, suitable for fluctuating demand.	Requires parameter optimization.
Linear Regression	Linear relationship between independent variables and demand.	Can analyze causal factors of fluctuations.	Ineffective for non-linear patterns.
Market Survey	Direct consumer data to understand preferences.	Provides deep insights for new products..	Costly, risk of respondent bias.
Delphi Method	Consensus from an expert panel through multiple discussion rounds.	Useful for high-uncertainty scenarios.	Time-consuming, depends on panel quality.

Source: Compiled from various sources

Technological advances such as machine learning have transformed demand forecasting in the food supply chain. Advanced algorithms enable the analysis of large datasets to predict demand with greater accuracy. Machine learning methods such as linear regression and artificial neural networks (ANNs) (Bhagya Raj & Dash,2020; Ashtiani & Martynenko, 2024; Khan et al., 2022; Shi et al., 2023; Sun et al., 2018) can reduce forecasting errors by up to 20%. These technologies also help supply chains respond swiftly to sudden changes in demand due to seasonal fluctuations or natural disasters. IoT-based systems strengthen demand forecasting by providing real-time data from various distribution points within the supply chain. This data includes stock levels, consumer purchasing patterns, and transportation status. By leveraging IoT technologies, companies can reduce response times to demand changes by up to 30%, while simultaneously improving storage and inventory management efficiency—crucial for perishable food products.In the context of food supply chains in developing countries, demand forecasting often faces challenges due to the lack of consistent and high-quality data. Factors such as limited technological infrastructure and low adoption of data management systems contribute to high forecasting errors. The absence of real-time data and integrated information systems remains a major barrier to optimizing demand forecasting. Improved data management strategies can help address these challenges. For example, implementing cloud computing systems allows for data integration from various sources within the supply chain. These systems not only enhance demand prediction accuracy but also facilitate coordination among stakeholders. Therefore, such technologies serve as a critical foundation for improving food supply chains in developing countries.

In practice, demand forecasting is also influenced by external factors such as climate change and economic fluctuations. Food products often experience drastic changes in demand due to natural disasters, disease outbreaks, or shifts in consumer consumption patterns. This underscores the importance of flexibility in forecasting to anticipate the impact of such factors. According to the Food and Agriculture Organization (2019), another benefit of accurate demand forecasting is the reduction of waste within the supply chain.

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By precisely predicting demand, companies can avoid overproduction, which often leads to product waste. This is particularly important in the context of sustainability, as food waste remains one of the major issues in global supply chains. In practice, accurate demand forecasting also provides significant economic benefits. Companies that optimize their forecasting processes can reduce logistics costs by up to 25%. This efficiency boosts their competitiveness in the global market. Given these advantages, demand forecasting is a critical element in supporting the sustainability and efficiency of food supply chains for commodities such as rice, corn, and especially cassava. However, to fully realize these benefits, investment in technology and workforce training is necessary to harness the full potential of modern forecasting systems (Fernando et al., 2024; Ghidelli & Pérez-Gago, 2017; Huang et al., 2023; Wilson et al., 2017) This represents both a challenge and an opportunity for further development in the global food sector.

Information Management in Food Product SCM

Information management is a fundamental pillar supporting food product supply chains, especially when addressing challenges such as demand volatility, product perishability, and widespread geographic distribution. Through technology-based systems such as cloud computing, the Internet of Things (IoT), and blockchain, information management has evolved into a tool that enables real-time data integration across all stages of the supply chain. These technologies foster greater transparency and enhance data-driven decision-making (Casino et al., 2020; Koh et al., 2020; Pournader et al., 2019; Xu et al., 2020).

One major innovation is cloud computing, which allows data to be centrally stored and accessed by all actors in the supply chain. This technology reduces reliance on traditional, often fragmented information systems. The implementation of cloud computing in food supply chains increases response speed to consumer demand by up to 30%. Furthermore, inventory management becomes more efficient, with inventory reductions of up to 20% through demand data optimization.

IoT extends these benefits by enabling data collection from sensors installed at every stage of the supply chain. For example, IoT sensors monitor temperature and humidity during storage or transport, critical for food products such as rice, corn, and especially cassava. The application of IoT reduces product waste by up to 18% and enhances supply chain efficiency by ensuring that products remain in optimal condition until they reach the consumer. Blockchain technology adds a dimension of transparency by securely and immutably recording every transaction. Blockchain enables the tracking of food product origins, increasing consumer trust in product quality and safety. For example, a blockchain-based system in India demonstrated a 15% reduction in product losses through optimized tracking and increased accountability among supply chain actors (Hassoun et al., 2022; Johnson et al., 2025; Li et al., 2021; Vu et al., 2021; Yu et al., 2020). Technology-based information management also helps reduce the bullwhip effect—the amplification of demand variability along the supply chain. Real-time data systems ensure that every actor has access to the same information, eliminating excessive assumptions or errors in demand estimation. The combination of IoT and blockchain can reduce the bullwhip effect by up to 35%, resulting in more stable demand forecasts and improved production efficiency. Beyond operational benefits, these technologies also contribute to supply chain sustainability. By ensuring that data on inventory, transportation, and demand is available in real time, food waste can be minimized. According to Jaouhari et al. (2024), the combined use of IoT and blockchain in food supply chains can reduce carbon waste by up to 20%, supporting global efforts to mitigate the impacts of climate change.

However, implementing these technologies is not without challenges. In developing countries, limited technological infrastructure often poses a major obstacle. Supply chain actors need to invest in workforce training and digital infrastructure development. Collaboration among governments, the private sector, and non-governmental organizations (NGOs) is essential to support the adoption of these modern technologies in the agribusiness sector..

Manajemen Kualitas dalam SCM Produk Pangan

Quality management in food product supply chain management (SCM) is closely related to the concepts of quality control (QC), total quality management (TQM), and quality assurance (QA). These three approaches underpin efforts to maintain quality standards throughout the supply chain, especially for food products that require particular attention to freshness, safety, and sustainability (He et al., 2024; Janjarasskul & Suppakul, (2017; Niu et al., 2023; Shen et al., 2023; Sohail et al., 2018). With advancements in information technology and artificial intelligence (AI), these approaches increasingly integrate modern technologies such as blockchain and the Internet of Things (IoT) to ensure enhanced control, transparency, and operational efficiency. Quality control ensures that every product meets specified requirements through rigorous process monitoring. In the context of food SCM, technologies like IoT play a vital role in quality control by monitoring temperature and humidity in real time during transportation. Optimal temperature control can extend the shelf life of fresh products by up to 30%. IoT sensors help identify potential spoilage at an early stage, enabling defects to be addressed before products reach the market. Total Quality Management (TQM), by contrast, provides a holistic approach that involves all organizational functions to improve quality. In food SCM for commodities such as rice, corn, and especially cassava, TQM not only enhances product quality but also drives efficiency through interdepartmental collaboration. Periodic customer surveys help identify consumer needs, allowing companies to optimize distribution processes in line with market demand. Quality improvements extend beyond the final product to include distribution and storage processes as well. Quality Assurance (QA) adds a preventive dimension to quality management by focusing on preventing issues through the creation of stable, predictable processes. In food SCM, this includes quality control of raw materials, processing, and storage. Blockchain can be used to trace a product's entire lifecycle, ensuring that quality standards are met at every stage. In Indonesia, blockchain has been applied in organic coffee distribution to provide quality assurance for consumers.. Quality management in food SCM for products such as rice, corn, and especially cassava also includes the management of key performance indicators to assess operational effectiveness. Indicators such as product damage rates, delivery times, and customer satisfaction levels provide relevant data for strategic decision-making. Using IoT to collect real-time data improves the accuracy of quality evaluations for fresh products during transportation. Additionally, the cold chain is a vital method for preserving food quality, particularly in tropical countries like Indonesia. The cold chain helps maintain product freshness during storage and distribution by controlling optimal temperatures (Huang et al., 2023; Lin et al., 2022; Rugji et al., 2024; Xu et al., 2020; Yu et al., 2020). Food waste management is also an integral part of quality management and is directly linked to sustainability. Poorly managed food waste can cause economic losses and environmental impacts. In Indonesia, several initiatives have converted food waste into compost or bioenergy to support sustainability efforts. When these quality management concepts are integrated with modern technologies, they result in SCM systems that are more transparent, efficient, and responsive to market demands. Blockchain, for instance, provides complete traceability of product origins, reassuring consumers of the quality of the products they purchase. Meanwhile, IoT helps optimize distribution by minimizing product damage during transit. Together, these technologies complement the implementation of TQM and QA in food supply chains for commodities such as rice, corn, and especially cassava. Nevertheless, challenges persist, especially in developing countries like Indonesia. Limited digital infrastructure and high implementation costs are significant barriers to widespread technology adoption. Collaboration among government, the private sector, and research institutions is critical to overcoming these obstacles. Research shows that investing in infrastructure and workforce training can enhance the sustainability of food SCM in Indonesia..

Climate Change and Its Environmental Impacts on Food SCM

Climate change significantly affects global food supply chains, particularly by disrupting production, transportation, and distribution processes. Weather uncertainty, such as prolonged droughts or floods, has reduced crop yields in various regions. Unpredictable weather patterns can increase food waste by up to 15%, especially in tropical regions prone to extreme weather events. This effect is compounded by the lack of infrastructure to manage supply fluctuations, leading to imbalances between production and demand.IoT technology has emerged as a solution for mitigating the impacts of climate change on food supply chains. IoT enables real-time monitoring of environmental conditions, including temperature, humidity, and rainfall patterns. This data helps farmers and supply chain managers adjust their production and distribution strategies, reducing losses caused by adverse environmental conditions (Fernando et al., 2024; Hoffman an et al. 2024; Katie, 2024; Morchid et al., 2024; Rugji et al., 2024). For example, research shows that using IoT sensors in China has improved food supply chain resilience to weather changes and reduced waste by up to 12%.. Additionally, blockchain plays an important role in tracking food sources such as rice, corn, and especially cassava, ensuring transparency in supply chain management. By creating secure, decentralized records, blockchain helps identify supply disruptions and optimize distribution processes. Combining blockchain and IoT in food supply chains can improve logistics efficiency by 15% while ensuring that products remain fresh throughout distribution.

In developing countries, the lack of digital infrastructure and trained personnel slows the adoption of these technologies. Limited funding also poses a significant challenge for scaling technology-based solutions.. The zero-waste policy trend is gaining traction globally in managing food supply chains for commodities like rice, corn, and especially cassava, to reduce environmental impacts and improve sustainability. Reverse logistics plays a key role in this policy by managing damaged or unsold products for recycling or reuse. This strategy can reduce food waste by 20–25%, especially when supported by technologies such as blockchain and IoT (Latif et al., 2023; Romsdal et al., 2024). However, in developing countries, supporting infrastructure remains a major challenge. Research by Vijayan et al. (2014) found that the adoption of reverse logistics in the food retail industry helped reduce waste by up to 18% by improving waste management efficiency. This study highlights the importance of active involvement from all stakeholders in the supply chain to ensure successful policy implementation..

A study by Raut et al. (2019) demonstrated that using technologies such as IoT sensors and blockchain increased transparency and data accuracy in reverse logistics, ultimately supporting food waste reduction. These technologies enable quick identification of products that can be recycled or reused..

Despite its significant potential, implementing zero-waste policies faces barriers such as inadequate logistics infrastructure, inconsistent policies, and low technology adoption. Ardra & Barua (2023) emphasize the importance of collaboration between governments and the private sector to create an enabling environment for adopting such policies, particularly in the agricultural and food sectors.

CONCLUSION

In terms of demand forecasting, the use of machine learning and IoT-based technologies has improved demand prediction accuracy by up to 30%. These technologies help minimize the risks of product surplus and shortages, which are common challenges in distributing food products such as rice, corn, and especially cassava. However, the adoption of these technologies still faces obstacles, particularly related to infrastructure availability and access to real-time data. In information management, IoT and blockchain create transparency across the supply chain, reduce uncertainty, and enable real-time, data-driven decision-making. These systems not only enhance logistics efficiency but also help reduce the bullwhip effect that often causes waste in inventory management. Nonetheless, adopting these technologies requires strengthening data security protocols to prevent information breaches that could undermine stakeholder trust. Regarding quality management, holistic approaches such as Total Quality Management (TQM) and Quality Assurance (QA) supported by IoT have ensured product quality throughout the supply chain. IoT sensors enable real-time monitoring of product conditions such as temperature and humidity, which can extend product shelf life by up to 30%. However, high costs and limited availability of trained human resources remain challenges that must be addressed for wider technology adoption.. In environmental management, Green Supply Chain Management (GSCM) strategies involving reverse logistics, blockchain, and IoT have proven effective in reducing food waste by up to 25%. These technologies also support energy efficiency and carbon footprint reduction, aligning with global sustainability agendas. However, low awareness among supply chain actors and inadequate supporting infrastructure limit broader implementation, especially in developing countries. The integration of modern technologies into the food supply chain management of rice, corn, and especially cassava can help create a more resilient, efficient, and sustainable system. However, the success of such technological integration depends on supporting infrastructure, progressive policies, and active collaboration among stakeholders. For countries like Indonesia, long-term investments in technology development and human resource education are strategic steps toward optimizing the future potential of food supply chains. The integration of innovative technologies into food supply chain management for commodities like rice, corn, and especially cassava requires further exploration in practice, especially in developing countries like Indonesia. Field studies that observe the direct effects of IoT and blockchain on various types of food commodities in Indonesia could provide more specific insights. Additionally, it is crucial to assess the readiness of digital infrastructure and human resources to adopt these technologies so that proposed solutions can be implemented effectively. To further improve efficiency and sustainability, future research could focus on developing big data and machine learning-based models that not only predict demand but also optimize the supply chain in real time. Integrating this approach with Green Supply Chain Management (GSCM) practices has the potential to strengthen energy efficiency and reduce waste. In-depth case studies, especially from local agribusiness sectors, could offer unique and practical perspectives for stakeholders to accelerate technology adoption.

Beyond the technological aspects, future research should also examine the social and economic dimensions of these implementations, including how technology affects the sustainability of smallholder livelihoods. Governments and academia can collaborate to design policies that facilitate digital transformation in food supply chains, such as providing incentives for adopting environmentally friendly technologies and strengthening the capacity of small-scale enterprises. Through a holistic approach, transforming food supply chains for rice, corn, and especially cassava is expected to support food security while promoting environmental sustainability.

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