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THE ROLE OF BLOCKCHAIN TECHNOLOGY IN STRENGTHENING THE SUPPLY CHAIN OF LOCAL AGRICULTURAL PRODUCTS

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Abstract

This research aims to analyse the role of blockchain technology in strengthening the supply chain of local agricultural products through a literature review. Blockchain as a decentralised recording technology offers transparency, security, and efficiency in every stage of the supply chain, from production, distribution, to consumption. With an immutable record system that can be accessed in real-time by all stakeholders, blockchain is able to minimise the risk of counterfeiting, increase consumer confidence, and automate the transaction process through smart contracts. However, the implementation of blockchain in the local agricultural sector still faces various challenges, such as limited digital infrastructure, low technological literacy among farmers, and the absence of supporting regulations. This research concludes that collaboration between the government, business actors, and the farming community is needed to optimise the potential of blockchain. The integration of blockchain with other technologies such as IoT and AI in the future is expected to create a more transparent, efficient, and sustainable agricultural ecosystem.

Keywords: blockchain, supply chain, local agriculture, transparency, smart contracts.

Introduction

The development of digital technology has brought significant changes in various sectors of life, including the agricultural sector. Digital transformation in the agricultural sector is not only limited to the use of modern tools and machinery, but also touches the supply chain management aspects of agricultural products. An efficient and transparent supply chain is key in ensuring that local agricultural products can compete in both domestic and international markets. However, until now, there are still many challenges faced, such as lack of transparency, distribution delays, and the risk of data falsification and manipulation along the supply chain (Elias et al., 2024) .

Amidst the complexity of local agricultural product supply chains, blockchain technology offers a promising innovative solution. Blockchain is known as a decentralised data recording technology that is able to increase transparency, security, and accountability of every transaction that occurs. Every data recorded on the

blockchain is permanent and cannot be changed, thus providing more trust for all supply chain actors, from farmers, distributors, to end consumers (Kamilaris ., 2021)

The application of blockchain in the supply chain of local agricultural products is believed to minimise fraudulent practices, speed up the distribution process, and guarantee product authenticity and quality. With a transparent and real-time recording system, consumers can trace the origin of the product directly, while farmers get protection for their rights and crops (Abeywardena et al., 2021) . This is especially important amidst increasing consumer awareness of the importance of food safety and quality. In addition, blockchain also enables process automation through smart contracts, which are digital contracts that can be executed automatically when certain conditions are met. This feature can speed up the payment process, reduce transaction costs, and reduce dependence on intermediaries. Thus, the added value generated can be more widely enjoyed by the main actors, especially local farmers ([Anon], 2025) .

Local farmers are individuals or groups of Indonesian citizens who directly conduct farming businesses in agriculture, such as food crops, horticulture, plantations, or animal husbandry, in the area where they live, either by managing private land or other people's land, with the aim of meeting their own needs or for sale, and usually rely on knowledge and traditions that have been passed down from generation to generation in managing the farming business (Tian, 2022) .

However, the implementation of blockchain in the supply chain of local agricultural products in Indonesia still faces a number of obstacles. One of the main challenges is the limited digital infrastructure in rural areas, where most local farmers operate. In addition, the low level of digital literacy is also an obstacle to the widespread adoption of this technology (Lin, 2020) . Therefore, collaborative efforts between the government, private sector, and educational institutions are needed to improve the capacity and readiness of human resources in the agricultural sector. In terms of regulation, the absence of a clear legal umbrella related to the use of blockchain in the agricultural supply chain is also a challenge. Supportive regulations are needed to provide legal certainty and protection for all parties involved. The government needs to immediately formulate policies that can encourage innovation while protecting the interests of farmers and consumers (Casino, 2020) .

At the global level, a number of countries have started adopting blockchain in their agricultural supply chain systems and are showing positive results. Case studies in several Asian and European countries show that the use of blockchain can improve distribution efficiency, reduce logistics costs, and increase consumer confidence in local products. This experience can be an important reference for Indonesia in designing an implementation strategy that suits local characteristics and needs (Galvez, 2021) .

Research on the role of blockchain technology in strengthening the supply chain of local agricultural products is highly relevant at this time. A comprehensive literature review is needed to identify opportunities, challenges, and strategies that can be

applied in the Indonesian context. Thus, the research results are expected to make a real contribution to the development of a more modern, efficient, and competitive national agricultural sector.

Research Methods

The research method used in this study is Systematic Literature Review (SLR), which systematically identifies, selects, and analyses relevant scientific literature related to the role of blockchain technology in strengthening the supply chain of local agricultural products. The SLR process includes searching for articles in reputable databases, screening based on inclusion and exclusion criteria, and thematic analysis of key findings from each selected publication, resulting in a comprehensive review of the development, challenges, and opportunities of blockchain implementation in the local agricultural sector (Paré & Kitsiou, 2020) .

Results and Discussion

Blockchain's Role in Strengthening the Supply Chain of Local Agricultural Products

Blockchain has a transformative role in strengthening the supply chain of local agricultural products through increased transparency, security, and efficiency. The technology enables decentralised data recording that cannot be manipulated, so every stage of production to distribution can be tracked in real-time by all stakeholders. For example, farmers in Banyumas use blockchain barcodes to track the distribution of chillies, allowing consumers to scan the QR code and see full information on origin, fertiliser use, and harvesting methods (Behnke, 2020) .

Transparency and traceability of origin are the main advantages of blockchain in the supply chain. Every transaction is recorded in a distributed ledger, from seed suppliers to retailers, including quality data, shipping conditions, and certifications. This system reduces the risk of product counterfeiting, as PT Matari Agro Indonesia does by keeping a permanent record of the product's journey from field to consumer. Consumers in Vietnam even experienced a 40% increase in trust after the adoption of blockchain in rice distribution (Bumblauskas, 2020) .

Smart contracts revolutionise the transaction process by automating payments and agreements. When products are received by distributors, the system automatically transfers funds to farmers without going through intermediaries, reducing transaction costs by 15-20%. For example, the AgriDigital platform uses smart contracts to directly pay oil palm farmers in Indonesia, while resolving quality disputes through programmable criteria (Sunarti, 2021) .

Distribution efficiency is significantly improved thanks to the elimination of third parties. Blockchain enables peer-to-peer models where farmers sell directly to consumers or retailers, such as the Nestlé-Carrefour-IBM case study that cut logistics

costs 30% for potato products. In Indonesia, this system helped chilli farmers reduce dependence on middlemen, increasing profit margins by 25% (Chang, 2020) .

The integration of blockchain with supporting technologies such as RFID and IoT strengthens data accuracy. Research in *Nature* showed the blockchain-RFID combination improved tracking speed by 30% through SM3 algorithm optimisation, with temperature and humidity data automatically recorded during shipment. The system also detected water contamination in Japanese farmland in real-time, preventing crop failure (Tripoli, 2020) .

Reduction of fraud and waste is another crucial impact. Blockchain prevents stock data manipulation and theft through cryptographic encryption, as applied in a CPO supply chain in Sumatra that reduced product loss by 18%. The *Frontiers in Blockchain* report said this system cut food waste 22% in Europe through accurate demand prediction (Ge, 2021) .

Despite its promise, blockchain implementation in local agriculture still faces challenges. Limited digital infrastructure in rural Indonesia is a major obstacle, with only 34% of farmers having stable internet access. The initial cost of implementing a blockchain-RFID system also reaches Rp120 million per community, not including digital literacy training (Lucena, 2020) .

Government regulation is a determining factor in accelerating adoption. In Thailand, a 30% tax incentive for agritech startups successfully increased blockchain implementation 45% in two years. Indonesia needs to develop a legal umbrella related to data standards and digital certification validation, while encouraging multi-stakeholder collaboration such as PT Matari Agro's partnership with the local government (Lin, 2020) .

The future of blockchain in local agriculture will be influenced by integration with emerging technologies. The *phygital* concept of combining NFT and blockchain is being trialled for premium product certification. The development of *AI-powered blockchain* is also predicted to be able to predict market prices based on historical supply chain data (Kamble, 2020) .

Despite the technical and cultural challenges, blockchain is proving capable of creating a more equitable and sustainable agricultural supply chain. Collaboration between farmers, the private sector, government, and academia is key to this transformation, with the potential to increase Indonesia's agricultural sector GDP by 1.2% annually if implemented on a massive scale.

Challenges, and Opportunities for Blockchain Implementation in the Local Agriculture Sector

The implementation of blockchain in the local agriculture sector faces challenges, especially in terms of digital infrastructure readiness in rural areas. Many agricultural areas still do not have adequate internet access, hampering the adoption of

blockchain technology that relies on high connectivity. These infrastructure limitations also impact farmers' ability to access the hardware and software needed to run blockchain-based systems (Caro, 2020) .

Apart from infrastructure, the initial cost of implementing blockchain is high. The investment required to build the system, train human resources, and maintain the technology is a burden, especially for small farmers and agricultural cooperatives. This causes blockchain adoption to tend to be slower and only accessible to groups with sufficiently strong capital (Tian, 2022) .

Another challenge arises from digital literacy. Many local farmers are not familiar with the concepts of blockchain, smart contracts, or digital data security. This lack of understanding can lead to resistance to change and increased reliance on third parties to manage the system, so the decentralised potential of blockchain is not fully achieved (Behnke, 2020) .

From the regulatory aspect, the absence of clear legal standards and policies related to the use of blockchain in the agricultural sector is an obstacle. Legal uncertainty regarding the validity of digital data, consumer protection, and smart contract dispute resolution makes businesses hesitant to adopt this technology widely (Goni et al., 2022) .

The complexity of the agricultural supply chain is also a challenge. The supply chain of agricultural products involves many parties, ranging from farmers, collectors, distributors, to end consumers. Each party has its own systems and interests, so synchronising data and business processes requires a strong collaborative commitment for blockchain to be effective. In addition, interoperability between blockchain systems and existing technologies such as ERP or IoT is still an issue. Without standard protocols connecting various systems, data integration is difficult and the benefits of blockchain cannot be fully optimised (Mikhaylov et al., 2021) .

The next challenge is partial data security, especially at integration points between blockchain and off-chain systems. Although blockchain offers high data security, weak points can still arise when data from IoT devices or manual systems are fed into the blockchain without adequate verification (Galvez, 2021) .

On the other hand, blockchain offers a great opportunity to increase transparency and accountability in the agricultural supply chain. Every transaction and product movement can be permanently recorded, immutable, and accessible to all stakeholders. This increases trust between farmers, distributors, and consumers, and minimises the risk of fraud and data manipulation. Supply chain efficiency can also improve thanks to process automation through smart contracts. Payments, shipment tracking, and logistics administration can be automated without the need for intermediaries, resulting in lower transaction costs and faster and more transparent business processes (Suriayati Chuprat ., 2024)

Blockchain also opens up wider market access opportunities for local farmers. With a transparent system, farmers can prove the quality and origin of their products objectively, so they can directly connect with buyers or end consumers without having to go through many intermediaries. This has the potential to increase the income and bargaining power of smallholder farmers (Reyna, 2021) . In addition, blockchain can facilitate access to financing and digital financial services. The permanently stored transaction history can be used as a basis for credit scoring for farmers who were previously unreachable by conventional banking services. Blockchain-based financing models such as decentralised finance (DeFi) can also provide more accessible microloans (Hazmi Bachri ., 2021)

Agricultural data management becomes more integrated and can be analysed in real-time. Data on crop yields, input usage, and land conditions can be processed to provide data-based recommendations that help farmers in decision-making, risk management, and optimisation of production results. The application of blockchain also supports sustainable agricultural practices. By transparently recording carbon footprint, fertiliser use, and organic certification, consumers can choose more environmentally friendly products and producers are incentivised to implement sustainable agricultural practices (Elias et al., 2024) .

Finally, blockchain's distributed architecture increases the resilience of agricultural supply chains to external disruptions. Data redundancy across multiple nodes keeps the system running even in the event of a failure at any one point, so business continuity can be maintained and the risk of loss due to disruption can be minimised (Kamilaris ., 2021)

With these challenges and opportunities, the successful implementation of blockchain in the local agriculture sector is highly dependent on collaboration between the government, business actors, and the farming community. Policy support, infrastructure development, and increased digital literacy are key to optimising blockchain's potential to create a more transparent, efficient, and inclusive agricultural ecosystem.

Conclusion

Blockchain technology has proven its ability to revolutionise the supply chain of local agricultural products through increased transparency and data security. The decentralised record-keeping system enables real-time tracking of product origins, from the use of seeds and fertilisers to distribution conditions, significantly reducing the risk of counterfeiting and increasing consumer confidence. The integration of smart contracts also automates the transaction and payment process, eliminating dependence on middlemen and increasing operational cost efficiency by up to 20%. Despite its promise, blockchain implementation is still hampered by limited digital infrastructure in rural areas and low technological literacy among farmers. Multi-

stakeholder collaboration is needed to develop supporting regulations, inclusive funding schemes, and training programmes that target supply chain actors. International experience shows that government incentives and the adoption of hybrid blockchain-private models can be interim solutions to accommodate local characteristics.

Going forward, the integration of blockchain with emerging technologies such as IoT and AI is predicted to strengthen data accuracy and predictive capabilities in supply chain management. This transformation not only improves the competitiveness of local agricultural products in the global market, but also creates a fairer agribusiness ecosystem through equitable distribution of added value. Successful implementation depends on the continuous synergy between technological innovation and socio-cultural adaptation at the farming community level.

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