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OPTIMIZATION OF RICE SUPPLY CHAIN TRACEABILITY USING BLOCKCHAIN: A CASE STUDY IN BEKASI REGENCY

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ABSTRACT

Rice is a staple food in Indonesia, with a high consumption rate of 81.044 kg per capita annually and a production volume of 31.54 million tons in 2022. Ensuring traceability in the rice supply chain is crucial for food quality and safety. However, the industry faces logistical challenges, such as inadequate infrastructure, poor interagency coordination, and unintegrated information systems. At Menata Citra Selaras (MCS), the largest rice milling unit in Bekasi Regency, manual systems hinder decision-making and product traceability. This study aims to optimize traceability by leveraging blockchain technology. We developed Ricetrack, a prototype application based on Sawtooth blockchain technology, to enhance supply chain traceability. The methodology includes identifying actors and user stories, system modeling, design, and prototype testing in an operational environment. Data analysis, both quantitative and qualitative, showed significant improvements in traceability and data transparency, validated through surveys and stakeholder feedback. The study concludes that blockchain technology offers substantial benefits for the rice supply chain, providing added value to all stakeholders and enhancing operational efficiency for MCS and other companies in the Indonesian rice industry.

KEYWORDS *blockchain, rice supply chain, traceability, sawtooth*

INTRODUCTION

The rice industry in Indonesia, a country with one of the highest consumption rates globally at 81.044 kg per capita per year (Pusat Data dan Sistem Informasi Pertanian 2022) and a production volume of 31.54 million tons in 2022 (BPS RI 2023a), plays a strategic role in the national economy. However, this industry faces various complex challenges. In 2023, rice production in Indonesia is estimated at around 30.90 million tons, a decrease of 645.09 thousand tons or 2.05 percent compared to the previous year (BPS RI 2023b). This decline, coupled with rising demand, threatens a supply-demand imbalance (Octania 2021). Market competition (Hermawan 2013), climate variability (Purboningtyas, Dharmawan, and Putri 2019), an aging farmer population with low youth involvement (Susilowati 2016),

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limited female participation in decision-making (Yuliani 2014), reliance on chemical products (Lestari 2020), and low compliance with food safety regulations and standards (Nurhayati, Satibi, and Sumarni 2022) are significant challenges.

Studies show that the Indonesian rice supply chain system is not integrated, with data processing still conducted manually, leading to inventory management inaccuracies, distribution delays (Putri, Kusnadi, and Rachmina 2013), and inefficiencies in production, post-harvest, and transportation processes (Perdana et al. 2020). Addressing these challenges requires innovative supply chain approaches, such as enhancing traceability (Aung and Chang 2014), transparency (Singwal 2023), and data security (Lo et al. 2019). Blockchain technology can offer a holistic solution for the rice supply chain (Saranya and Maheswari 2022), functioning as a secure and transparent digital ledger, providing irrefutable data on the origin, movement, and current status of rice. Additionally, blockchain can provide audit trails ensuring each supply chain stage complies with food safety regulations and standards.

Zahrah, Arkeman, and Indrawan (2021) developed a rice supply chain traceability system model during the Covid-19 pandemic, focusing on the rice industry in Jabodetabek. The study utilized Unified Markup Language (UML) and found that the pandemic disrupted distribution channels and limited human resources, slowing rice product flow. An integrated traceability system can enhance supply chain transparency and efficiency.

Purwandoko et al. (2019) developed a smart traceability system based on information technology for the Indonesian rice supply chain using the System Development Life Cycle (SDLC) and Data Flow Diagram (DFD) approach. The resulting prototype helps stakeholders monitor production processes and decision-making, improving transparency, efficiency, and product quality.

Blockchain-based solutions have also been developed to support sustainable food supply chains. Baralla (2019) used Hyperledger Sawtooth, Dey et al. (2021) developed FoodSQRBlock, Hidayat, Hermadi, and Ramadhan (2021), Prabantoro, Hermadi, and Arkeman (2021), and Usman, Hermadi, and Arkeman (2021) used Hyperledger Fabric, Wang et al. (2021) combined Ethereum and Hyperledger Fabric, and Bhatia and Albarrak (2023) utilized blockchain and XAI-Faster RCNN to enhance food product safety and quality.

While there is extensive research on blockchain in supply chains, literature on its application in the Indonesian rice industry is limited. This study aims to fill this gap by exploring the application of blockchain in the Indonesian rice supply chain, particularly within the context of Menata Citra Selaras (MCS) in Bekasi Regency, and evaluating its significant contributions to improving traceability, transparency, and data security.

RESEARCH METHOD

The research was conducted in Bekasi Regency, focusing on MCS's rice supply chain points in Pabuaran, Cibitung, and Jatiasih, from August 2023 to May 2024. Data was collected on manual systems, transparency, product tracking, and data security through qualitative methods like in-depth interviews and field observations. Stakeholders such as farmers, collectors, millers, distributors, retailers, and consumers were identified and mapped. User stories were gathered through interviews, and field observations were conducted to understand operational workflows and challenges. User stories were validated with stakeholders, and workflow diagrams were created to identify areas where blockchain and QR codes could enhance traceability, transparency, and data security.

This research employs the Agile Blockchain DApp Engineering (ABCDE) method to optimize traceability and data security in the rice supply chain at MCS using blockchain technology. The ABCDE method combines agile methodology's discipline and flexibility, allowing developers to incorporate user feedback iteratively. This approach ensures the Ricetrack prototype improves traceability, transparency, and data security while adapting to continuous feedback from MCS stakeholders, including farmers, milling staff, distributors, and retailers.

The system design uses UML diagrams to document the data structure, user interactions, and transaction flows, ensuring transparent and secure data processing. Smart contracts on the Sawtooth blockchain platform automate recording and tracking, eliminating inaccuracies and delays. QR codes are employed for authentication, providing real-time data on rice products from planting to distribution. Validation sessions with stakeholders ensure the system meets security and functionality standards, with iterative evaluations incorporating user feedback.

The Ricetrack prototype was developed and tested iteratively in MCS's operational environment, involving rice reception, milling, and distribution. Functional testing focused on automating processes, reducing errors, and improving traceability. Transparency was evaluated by measuring stakeholder access to product and transaction information. Data security was tested through simulations and encryption checks. User feedback was collected through surveys and interviews, used for iterative improvements. User satisfaction was assessed to evaluate the system's impact on traceability and transparency, with performance improvements measured through case studies and comparative analysis.

Validation involved iterative testing with MCS stakeholders to ensure the application met their needs. Stakeholders participated in trials and demonstrations, providing feedback on usability, process efficiency, and data accuracy. Feedback was integrated into the development cycle, ensuring continuous adaptation to user needs. Performance was evaluated against success criteria, ensuring the application was effective and user-friendly. Validation strengthened stakeholder engagement and trust, enhancing the rice supply chain's traceability and transparency.

RESULT AND DISCUSSION

The rice supply chain at PT. Menata Citra Selaras (MCS) involves processes from farmers to end consumers, as shown in Fig. 4. Farmers grow and harvest rice, which is then sold to collectors. Collectors send the rice to MCS milling facilities, where it is cleaned, weighed, and milled into rice. The rice is then distributed through retailers, distributors, Bulog, or sold directly to consumers.

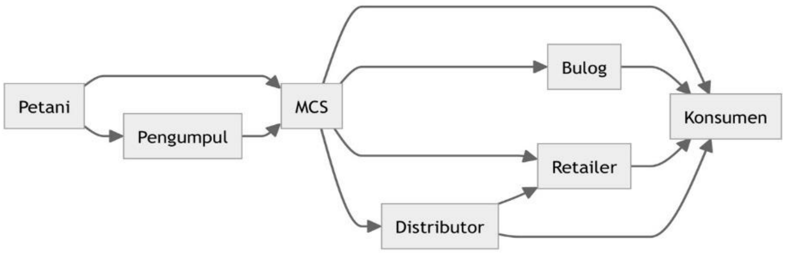


Fig 1. Rice Supply Chain in MCS

MCS has a production capacity of over 180 tons per day using advanced milling and packaging technology, as illustrated in Fig. 5. However, record-keeping is still manual (Fig. 6), leading to errors and difficulties in real-time data tracking. These findings align with previous research by Putri, Kusnadi, and Rachmina (2013) and Perdana et al. (2020), who also identified manual record-keeping as a significant bottleneck in the rice supply chain. External challenges include price fluctuations, market demand changes, and pressure to meet quality standards.

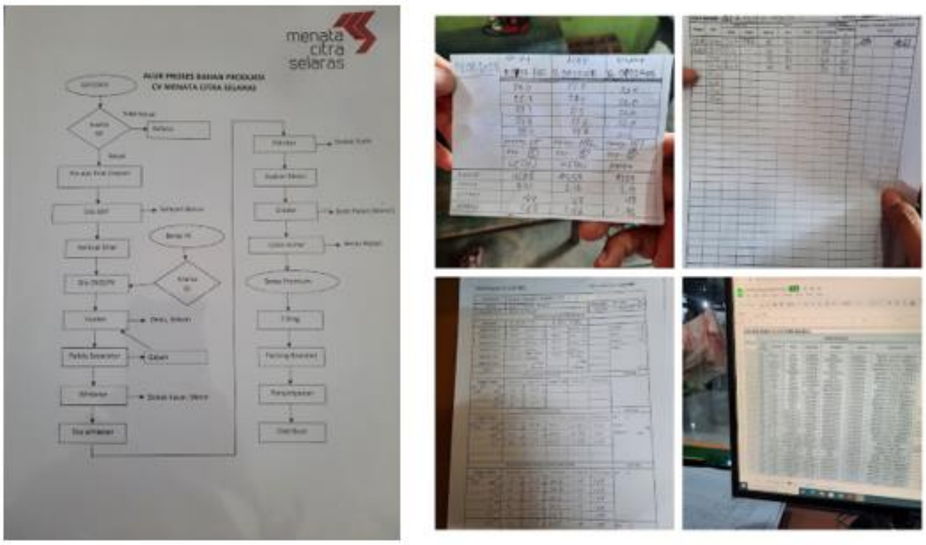
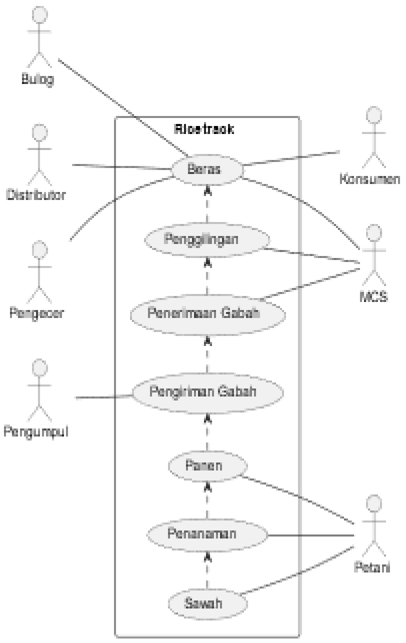


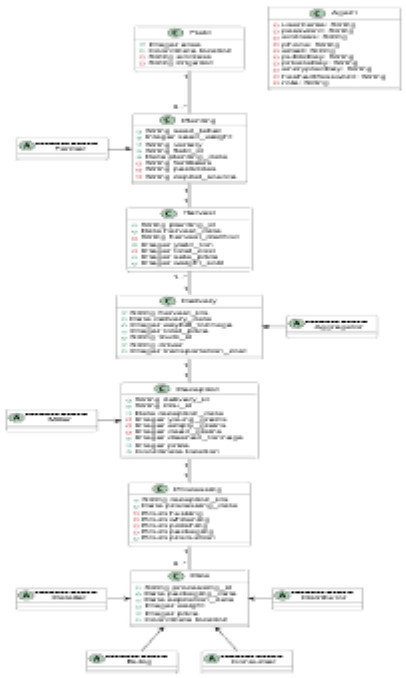
Fig 2

Interviews with farmers, collectors, MCS staff, distributors, retailers, and consumers revealed various challenges in the rice supply chain. Farmers face price fluctuations and high production costs, collectors struggle with coordination and rice quality, and MCS staff deal with raw material quality and manual record-keeping issues. Distributors and retailers experience stock availability and consumer preference challenges, while consumers desire affordable prices, high quality, and transparency about rice origins. These challenges reflect the broader issues in the Indonesian rice supply chain, as discussed by Kurniawati, Mege, and Werdani (2020) and Zahrah, Arkeman, and Indrawan (2021).

Data gathered from interviews and field observations identified stakeholder needs and challenges. Implementing blockchain technology is expected to introduce transparent and immutable record-keeping. Smart contracts can automate quality verification, while QR code integration can improve inventory and distribution management, providing detailed information on rice origins and quality. This approach is supported by findings from Aung and Chang (2014) and Saranya and Maheswari (2022), who highlighted the benefits of blockchain in enhancing supply chain traceability and transparency.

The main actors in the system are farmers, collectors, milling staff, distributors, retailers, and consumers. User stories were developed based on interviews, addressing needs such as monitoring field productivity, tracking grain shipments, systematic record-keeping at MCS, and providing product information to consumers. The system design uses Use Case Diagrams (Fig. 7), Class Diagrams (Fig. 8), and Sequence Diagrams (Fig. 9) to illustrate interactions between actors and the Ricetrack system.





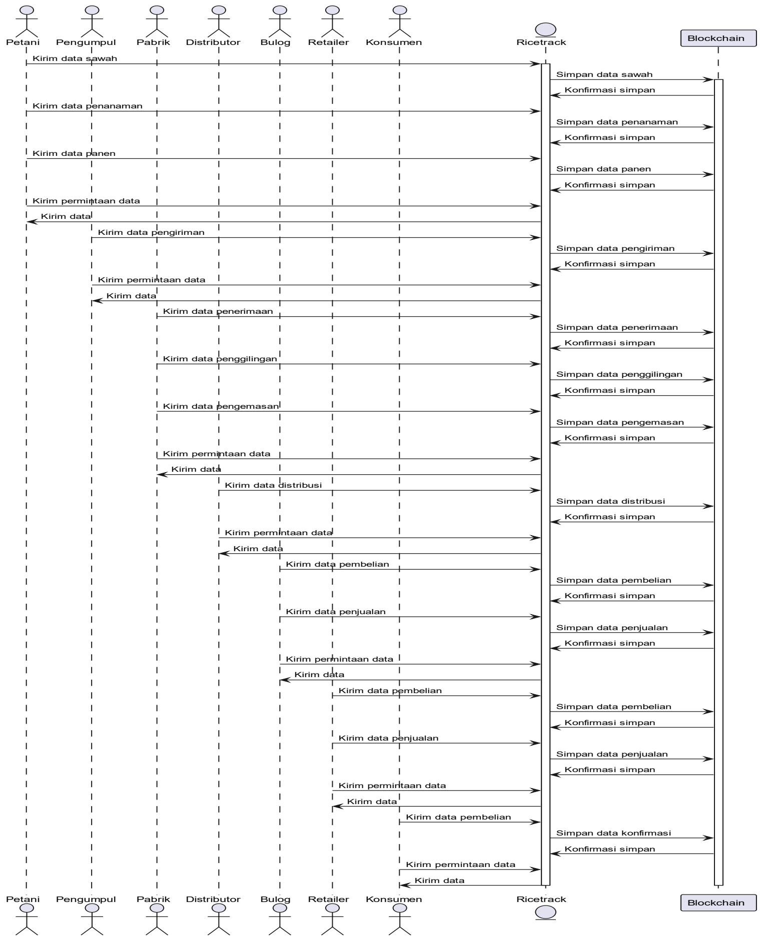


Fig 3. Sequence Diagram

The Ricetrack application was developed iteratively, starting with identifying MCS needs, modeling operational processes, and designing the system. Testing was conducted in isolated and real operational environments at MCS, involving all application aspects. User feedback was used for continuous improvements, ensuring the application met operational needs. This iterative approach aligns with the Agile methodology principles discussed by Pinna et al. (2021).

After testing, the application was implemented in MCS's daily operations. Staff training was conducted to ensure understanding and effective use. QR code implementation in operational processes ensured transparency, efficiency, and data accuracy. Implementation results showed significant improvements in operational speed and accuracy, product traceability, and stakeholder satisfaction. These results support the effectiveness of blockchain technology in addressing supply chain inefficiencies, as demonstrated by previous studies (Patelli and Mandrioli 2020; Wong, Ting, and Atanda 2024).

Application performance was evaluated by comparing operational metrics before and after implementation. Results showed improved tracking system efficiency, data accuracy, user satisfaction, ease of use, and operational efficiency. Validation showed that the Ricetrack application successfully addressed operational challenges at MCS. Record-keeping and data tracking time reduced from an average of 45 minutes per transaction to 5 minutes, an 89% reduction. Data recording errors decreased from 20 errors per 100 transactions to 1 error, a 95% reduction. User satisfaction scores increased from 3.0 to 4.8, a 60% improvement. These improvements reflect the potential of blockchain technology to enhance supply chain management, as suggested by Tapscott and Tapscott (2016) and Pease et al. (2023).

In conclusion, the implementation of Ricetrack at MCS demonstrates significant enhancements in traceability, transparency, and data security within the rice supply chain. The findings validate the theoretical benefits of blockchain technology and provide empirical evidence supporting its adoption in similar supply chain contexts.

CONCLUSION

This research successfully addressed various challenges in the rice supply chain at PT. Menata Citra Selaras (MCS) through the implementation of blockchain technology in the Ricetrack application, achieving significant improvements in data accuracy by greatly reducing recording errors. Traceability, transparency, and data security were enhanced by providing real-time, easily traceable, and secure data through blockchain. User satisfaction also increased, as survey results showed the application's acceptance and tangible benefits. Overall, Ricetrack demonstrated that blockchain technology can enhance efficiency, accuracy, transparency, and user satisfaction in the rice supply chain, highlighting its potential for broader adoption in the rice industry and other agricultural sectors in Indonesia. Based on the research findings, several suggestions for further development and implementation are proposed, including integrating Ricetrack with external systems such as inventory management, finance, and logistics to enhance its functionality. Additional features like predictive market demand analytics and automatic notifications for stakeholders could improve planning and decision-making. Expanding the technology to broader areas or other agricultural products would create more efficient and transparent supply chains in the agricultural sector. Further research should explore other supporting technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI) for precision agriculture, and with continued implementation and development, the Ricetrack application can further contribute positively to the Indonesian rice industry, enhancing supply chain efficiency and transparency.

REFERENCES

Amsari, Ali Ahmad Najib. 2006. “Kinerja Industri Penggilingan Padi Di Indonesia: Suatu Tantangan Ke Depan.” JURNAL PANGAN 15(2).

Antonopoulos, Andreas M. 2015. Mastering Bitcoin: Unlocking Digital Cryptocurrencies. 1. ed. Beijing Köln: O’Reilly.

Aung, Myo Min, and Yoon Seok Chang. 2014. “Traceability in a Food Supply Chain: Safety and Quality Perspectives.” Food Control 39: 172–84. doi:10.1016/j.foodcont.2013.11.007.

Baralla, Gavina. 2019. "Ensure Traceability in European Food Supply Chain by Using a Blockchain System."

Bhatia, Surbhi, and Abdulaziz Saad Albarrak. 2023. "A Blockchain-Driven Food Supply Chain Management Using QR Code and XAI-Faster RCNN Architecture." Sustainability 15(3): 2579. doi:10.3390/su15032579.

BPS RI. 2023a. "Ringkasan Eksekutif Luas Panen Dan Produksi Padi Di Indonesia 2022."

BPS RI. 2023b. "Ringkasan Eksekutif Luas Panen Dan Produksi Padi Di Indonesia 2023 (Angka Sementara)."

Dasaklis, Thomas K., Theodore G. Voutsinas, Giannis T. Tsoulfas, and Fran Casino. 2022. "A Systematic Literature Review of Blockchain-Enabled Supply Chain Traceability Implementations." Sustainability 14(4): 2439. doi:10.3390/su14042439.

Dey, Somdip, Suman Saha, Amit Kumar Singh, and Klaus McDonald-Maier. 2021. "FoodSQRBlock: Digitizing Food Production and the Supply Chain with Blockchain and QR Code in the Cloud." Sustainability 13(6): 3486. doi:10.3390/su13063486.

Hassan, R., B. Whitney, D. L. Williams, K. Holloman, D. Grady, D. Thomas, E. Omoregie, et al. 2019. "Multistate Outbreaks of Salmonella Infections Linked to Imported Maradol Papayas – United States, December 2016–September 2017." Epidemiology and Infection 147: e265. doi:10.1017/S0950268819001547.

Hellani, Houssein, Layth Sliman, Abed Ellatif Samhat, and Ernesto Exposito. 2021. "On Blockchain Integration with Supply Chain: Overview on Data Transparency." Logistics 5(3): 46. doi:10.3390/logistics5030046.

Hermawan, Iwan. 2013. "Analisis Perdagangan Beras dan Ketahanan Pangan di Negara-Negara Asia Tenggara." Politica 4(2).

Hidayat, Muhammad Nur, Irman Hermadi, and Dean Apriana Ramadhan. 2021. "Pengembangan Front-End Sistem Rantai Pasok Bawang Merah Berbasis Blockchain Menggunakan Metode Prototyping." IPB.

Kurniawati, Nurul Imani, Stacia Reviany Mege, and Riandhita Eri Werdani. 2020. "Analisis Manajemen Rantai Pasok Beras di Kabupaten Demak." BISMA: Jurnal Bisnis dan Manajemen 14(3): 155. doi:10.19184/bisma.v14i3.19885.

Lambert, Douglas M, and Martha C Cooper. 2000. "Issues in Supply Chain Management." Industrial Marketing Management 29(1): 65–83. doi:10.1016/S0019-8501(99)00113-3.

Lestari, Tri Rini Puji. 2020. "Penyelenggaraan Keamanan Pangan sebagai Salah Satu Upaya Perlindungan Hak Masyarakat sebagai Konsumen." 11(1).

Lo, Sin Kuang, Xiwei Xu, Chen Wang, Ingo Weber, Paul Rimba, Qinghua Lu, and Mark Staples. 2019. "Digital-Physical Parity for Food Fraud Detection." In , 65–79. doi:10.1007/978-3-030-23404-1_5.

Marchesi, Lodovica, Michele Marchesi, and Roberto Tonelli. 2020. "ABCDE—Agile Block Chain Dapp Engineering." Blockchain: Research and Applications 1(1–2): 100002. doi:10.1016/j.bcra.2020.100002.

Nakamoto, Satoshi. 2008. "Bitcoin: A Peer-to-Peer Electronic Cash System."

Nurhayati, Lyna, Satibi Satibi, and Sumarni Sumarni. 2022. "Faktor Penyebab Ketidakpatuhan terhadap Peraturan Pangan: Studi Kualitatif pada Distributor Pangan Olahan di Kota Gorontalo." Majalah Farmaseutik 18(3): 254. doi:10.22146/farmaseutik.v18i3.65455.

Octania, Galuh. 2021. "The Government's Role in the Indonesian Rice Supply Chain."

Olson, Kelly, Mic Bowman, James Mitchell, Dan Middleton, and Cian Montgomery. 2018. "Sawtooth: An Introduction."

Patelli, Niccolò, and Mauro Mandrioli. 2020. "Blockchain Technology and Traceability in the Agrifood Industry." Journal of Food Science 85(11): 3670–78. doi:10.1111/1750-3841.15477.

Pease, Michael, Keith Stouffer, Evan Wallace, Harvey Reed, and Steve Granata. 2023. "Manufacturing Supply Chain Traceability with Blockchain Related Technology: Reference Implementation." https://csrc.nist.gov/pubs/pd/2023/08/14/manufacturing-supply-chain-traceability-with-block/final (May 26, 2024).

Perdana, Tomy, Yuanita Handayati, Agriani Hermita Sadeli, Dhanan Sarwo Utomo, and Fernianda Rahayu Hermiatin. 2020. "A Conceptual Model of Smart Supply Chain for Managing Rice Industry." MIMBAR : Jurnal Sosial dan Pembangunan 36(1): 128–38. doi:10.29313/mimbar.v36i1.5431.

Pinna, Andrea, Gavina Baralla, Michele Marchesi, and Roberto Tonelli. 2021. "Raising Sustainability Awareness in Agile Blockchain-Oriented Software Engineering." In 2021 IEEE International Conference on Software Analysis, Evolution and Reengineering (SANER), , 696–700. doi:10.1109/SANER50967.2021.00088.

Prabantoro, Muhammad Rifqi, Irman Hermadi, and Yandra Arkeman. 2021. "Pengembangan Prototipe Back End Blockchain Platform untuk Sistem Rantai Pasok Bawang Merah." http://repository.ipb.ac.id/handle/123456789/108003 (May 27, 2024).

Purboningtyas, Titis Pury, Arya Hadi Dharmawan, and Eka Intan Kumala Putri. 2019. "The Impact of Climate Variability on The Livelihood Structure of Farmers Households and Patterns of Adaptation." Sodality: Jurnal Sosiologi Pedesaan 6(3). doi:10.22500/sodality.v6i3.21514.

Purwandoko, Pradeka Brilyan. 2022. "Analisis Kebutuhan Fungsional dan Pemodelan Informasi Ketelusuran pada Rantai Pasok Beras: Studi Kasus Jawa Barat." JURNAL PANGAN 31(1).

Purwandoko, Seminar, Sutrisno, and Sugiyanta. 2019. "Development of a Smart Traceability System for the Rice Agroindustry Supply Chain in Indonesia." Information 10(10): 288. doi:10.3390/info10100288.

Pusat Data dan Sistem Informasi Pertanian. 2022. "Statistik Konsumsi Pangan 2022."

Putri, Tursina Andita, Nunung Kusnadi, and Dwi Rachmina. 2013. "Kinerja Usaha Penggilingan Padi, Studi Kasus Pada Tiga Usaha Penggilingan Padi Di Cianjur, Jawa Barat." Jurnal Agribisnis Indonesia 1(2): 143. doi:10.29244/jai.2013.1.2.143-154.

Saberi, Sara, Mahtab Kouhizadeh, Joseph Sarkis, and Lejia Shen. 2019. "Blockchain Technology and Its Relationships to Sustainable Supply Chain Management." International Journal of Production Research 57(7): 2117–35. doi:10.1080/00207543.2018.1533261.

Saranya, P, and R Maheswari. 2022. "Blockchain-Based Traceability Model with a Case Study of Rice Supply Chain (RSC)." Journal of Engineering Science and Technology (3): 33–40.

Singwal, Priyanka. 2023. "Effective Supply Chain Management Practices in the Food and Beverage Industry: The Role of Traceability and Transparency." journalofcardiovasculardiseaseresearch 12(02). doi:10.48047/jcdr.2021.12.02.99.

Susilowati, Sri Hery. 2016. "Fenomena Penuaan Petani dan Berkurangnya Tenaga Kerja Muda serta Implikasinya bagi Kebijakan Pembangunan Pertanian." Forum penelitian Agro Ekonomi 34(1): 35. doi:10.21082/fae.v34n1.2016.35-55.

Swaminathan, Jayashankar M. 2000. "Supply Chain Management." International Encyclopedia of the Social and Behavioral Sciences.

Swastika, Dewa K.S. and Sumaryanto. 2012. "Rantai Pasok Beras di Indonesia (Kasus Provinsi Jabar, Kalbar, dan Kalsel)." In Bunga Rampai, Rantai Pasok Komoditas Pertanian Indonesia, Bogor Agricultural University, 5–26.

Tapscott, Don, and Alex Tapscott. 2016. Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World. Penguin.

Usman, Meidhianto, Irman Hermadi, and Yandra Arkeman. 2021. "Design of Broiler Supply Chain Traceability System through Blockchain-based Android Application." 3(3).

Verdouw, C. N., H. Sundmaeker, F. Meyer, J. Wolfert, and J. Verhoosel. 2013. "Smart Agri-Food Logistics: Requirements for the Future Internet." In Dynamics in Logistics, Lecture Notes in Logistics, eds. Hans-Jörg Kreowski, Bernd Scholz-Reiter, and Klaus-Dieter Thoben. Berlin, Heidelberg: Springer Berlin Heidelberg, 247–57. doi:10.1007/978-3-642-35966-8_20.

Wang, Keyao, Xiuxia Yan, and Kaiying Fu. 2020. "Research on Risk Management of Agricultural Products Supply Chain Based on Blockchain Technology." Open Journal of Business and Management 8(6): 2493–2503. doi:10.4236/ojbm.2020.86155.

Wang, Lu, Longqin Xu, Zhiying Zheng, Shuangyin Liu, Xiangtong Li, Liang Cao, Jingbin Li, and Chuanheng Sun. 2021. "Smart Contract-Based Agricultural Food Supply Chain Traceability." IEEE Access 9: 9296–9307. doi:10.1109/ACCESS.2021.3050112.

Wognum, Nel, Harry Bremmers, J. Trienekens, Jack Van der Vorst, and Jacqueline Bloemhof-Ruwaard. 2011. "Systems for Sustainability and Transparency of Food Supply Chains - Current Status and Challenges." Advanced Engineering Informatics 25: 65–76. doi:10.1016/j.aei.2010.06.001.

Wong, Elton Kee Sheng, Huong Yong Ting, and Abdulwahab Funsho Atanda. 2024. "Enhancing Supply Chain Traceability through Blockchain and IoT

Integration: A Comprehensive Review." Green Intelligent Systems and Applications 4(1): 11–28. doi:10.53623/gisa.v4i1.355.

Yuliani, Farida. 2014. "Ketidakadilan Gender dalam Pembangunan Pertanian: Studi Pandangan Politik Perempuan Anggota Legislatif di Kabupaten Kudus." 7(2).

Zahrah, Dhia Salsabila, Yandra Arkeman, and Dikky Indrawan. 2021. "Traceability System Model Rice Supply Chain during the COVID-19 Pandemic." International Journal of Research and Review 8(3).