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АНАЛІЗ ВИКОРИСТАННЯ БЛОКЧЕЙН-ТЕХНОЛОГІЙ У СІЛЬСЬКОМУ ГОСПОДАРСТВІ ДЛЯ ОБЛІКУ ЛОГІСТИЧНИХ ПРОЦЕСІВ

ANALYSIS OF THE USE OF BLOCKCHAIN TECHNOLOGIES IN AGRICULTURE FOR ACCOUNTING OF LOGISTICS PROCESSES

Рижикова Н., Остапенко Р., Бірченко Н. Аналіз використання блокчейн-технологій у сільському господарстві для обліку логістичних процесів. *Український журнал прикладної економіки та техніки*. 2025. Том 10. № 4. С. 245 – 249.

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Дослідження є актуальним через потребу підвищення прозорості та ефективності логістичних процесів у сільському господарстві, де проблеми шахрайства, непрозорості та високих витрат ускладнюють управління ланцюгами поставок. Метою роботи є оцінка потенціалу блокчейн-технологій для оптимізації агрологістики шляхом аналізу їх практичного застосування. Використано методи систематичного аналізу літератури, порівняння типів блокчейнів та оцінки кейсів впровадження. Результати показують, що блокчейн забезпечує зниження транзакційних витрат на 15–25% шляхом усунення посередників та автоматизації через смарт-контракти, а також скорочує час реагування на проблеми безпеки харчових продуктів до секунд завдяки прозорому відстеженню. Інтеграція з технологіями інтернету речей дозволяє зменшити втрати швидкопсувної продукції на 10–15% за рахунок моніторингу умов транспортування. Практичні приклади, такі як платформи для відстеження органічної продукції, демонструють підвищення довіри споживачів та справедливого ціноутворення для фермерів на 20%. Практична цінність полягає у розробці рекомендацій щодо впровадження блокчейну, які сприяють створенню стійких ланцюгів поставок та підтримують конкурентоспроможність аграрного сектору.
Ключові слова: *блокчейн-технології, агрологістика, ланцюг поставок, прозорість даних, смарт-контракти, відстежуваність продукції, інтернет речей.*

The study investigates the application of blockchain technologies in agriculture with a particular focus on logistics processes and supply chain transparency. Agriculture faces persistent challenges, including fraud, opacity, high transaction costs, and difficulties ensuring product traceability. Blockchain provides a decentralized, immutable ledger that enables the secure recording of transactions, automates operations through smart contracts, and eliminates intermediaries. Integration with Internet of Things (IoT) technologies allows real-time monitoring of transportation conditions, reducing losses of perishable goods and enhancing food safety. Case studies including IBM Food Trust, Provenance, and AgriLedger demonstrate blockchain's ability to reduce response times to food safety incidents from weeks to seconds, improve consumer trust, and ensure fair pricing for farmers. The research employs a systematic literature review, a comparative analysis of blockchain types (public, private, consortium, hybrid), and an examination of Ukrainian and international implementations. Findings highlight blockchain's potential to reduce transaction costs by 15–25%, strengthen transparency, and enhance efficiency in agrilogistics. The scientific novelty lies in a comprehensive evaluation of blockchain integration with IoT and smart contracts tailored to Ukraine's agricultural context, addressing infrastructural and regulatory barriers. Practical recommendations include developing industry standards, investing in rural connectivity, and fostering adoption through consortia and phased implementation. The study contributes to advancing sustainable agricultural supply chains, supporting competitiveness, consumer confidence, and equitable farmer participation in global markets. Moreover, it emphasizes the importance of harmonizing regulatory frameworks and building digital literacy among stakeholders to ensure long-term scalability and resilience of blockchain-based agrilogistics systems. Keywords: blockchain technology, agrilogistics, supply chain, data transparency, smart contracts, product traceability, IoT integration.
Keywords: *Blockchain technology, agrilogistics, supply chain, data transparency, smart contracts, product traceability, IoT integration.*

Statement of the problem

With the rapid evolution of global agricultural systems and the pressing need to enhance supply chain efficiency, blockchain technology has emerged as a transformative tool for optimizing logistics processes. The agricultural sector faces persistent challenges, including lack of transparency, fraud, high transaction costs, and difficulties in ensuring product traceability. These issues undermine trust and efficiency in supply chains, particularly in regions like Ukraine, where agriculture is a cornerstone of the economy. Recent studies underscore blockchain's potential to address these challenges by leveraging its decentralized, immutable, and automated features.

Global research highlights blockchain's growing role in agriculture. For instance, platforms like IBM Food Trust enable real-time traceability, drastically reducing response times to food safety incidents from weeks to seconds (Antonucci et al., 2019). Similarly, smart contracts facilitate automated payments, reducing intermediaries and enhancing financial inclusion for smallholder farmers (Tripoli & Schmidhuber, 2018).

In Ukraine, the adoption of blockchain in agrilogistics is gaining traction to enhance competitiveness and transparency. Studies by Sunny et al. (2020) emphasize blockchain's ability to provide end-to-end visibility, enabling stakeholders to verify product origins and quality. Successful implementations, such as Provenance, demonstrate how transparent supply chains enhance consumer trust. Additionally, blockchain's role in reducing operational costs and mitigating fraud is critical for sustainable agricultural development (Saurabh & Dey, 2021).

The relevance of this study lies in addressing the global and regional demand for transparent, secure, and efficient agrilogistics systems. The aim is to analyze the economic and operational benefits of blockchain models in Ukraine's agricultural supply chains, focusing on cost reduction, traceability, and technology adoption. Specific objectives include:

1) assessing the current state of agrilogistics challenges; 2) evaluating blockchain's technical and practical applications; 3) analyzing case studies of blockchain integration; and 4) proposing strategies to overcome implementation barriers.

The scientific novelty of this research lies in its comprehensive analysis of blockchain's integration with IoT and smart contracts tailored to Ukraine's agricultural context, alongside actionable recommendations for overcoming infrastructural and regulatory challenges. By drawing on global case studies and local needs, the study contributes to the development of sustainable and inclusive agrilogistics systems.

The purpose of the research

The study employed an empirical approach to examine the implementation of blockchain technologies in agricultural logistics, with a focus on improving supply chain transparency, traceability, and cost-effectiveness. The research analyzed blockchain applications by Ukrainian and international entities. In Ukraine, AgriChain, a local startup, was examined for its blockchain platform that digitizes supply chain tracking to ensure data integrity. The methodology incorporated multiple analytical techniques. A systematic literature review synthesized findings from 2019–2024 on blockchain's role in agriculture, ensuring a comprehensive theoretical foundation. Internet of Things devices, such as environmental sensors, were evaluated for integration with blockchain to track transportation conditions.

Presentation of the main research material

A blockchain is a distributed, immutable digital ledger that allows you to record transactions and track assets within a business network. The main characteristics of a blockchain are a distributed ledger technology that gives all network participants access to a single source of truth; immutable records that prevent tampering; smart contracts that automate transactions; and a decentralized structure that increases security and transparency (Stephanie, 2022). Blockchain uses a consensus mechanism to validate transactions, ensuring data integrity and reducing the risk of fraud and errors.

The use of blockchain technologies in agriculture is becoming increasingly relevant, especially for logistics management. This technology provides increased transparency in the supply chain, better tracking and monitoring of agricultural products, and assurance of food safety and quality. Blockchain creates a decentralized, immutable ledger that records all transactions and the movement of goods, allowing stakeholders to track the origin and quality of products. This transparency helps build trust among consumers and other stakeholders, addressing issues related to food theft and contamination.

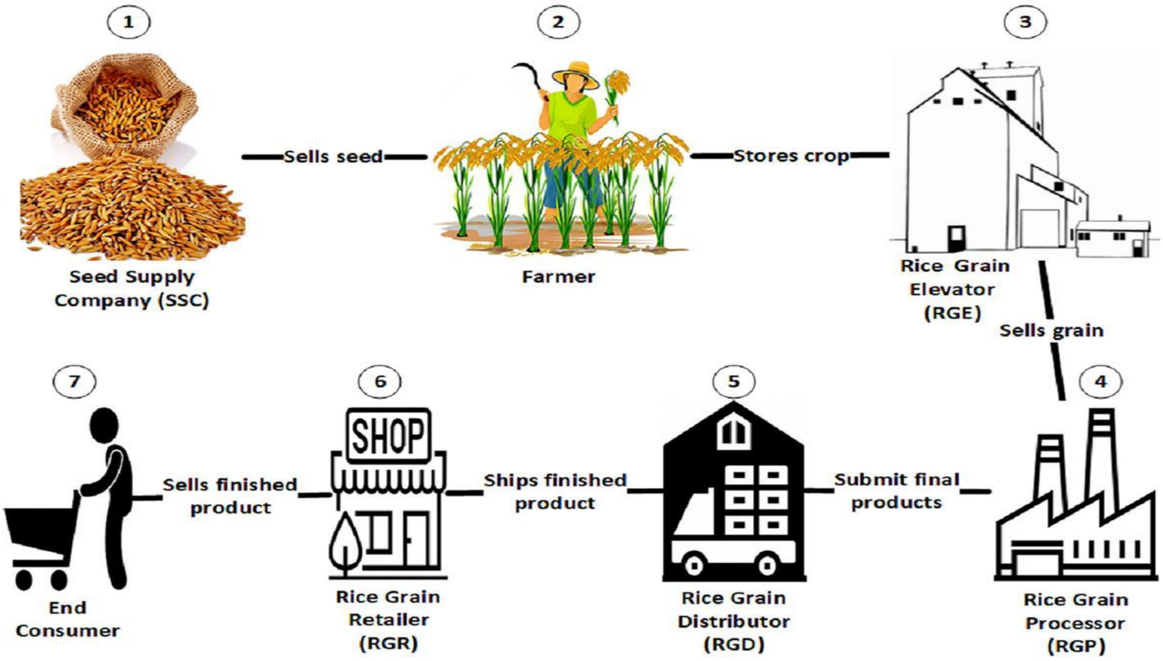

Fig. 1. Diagram of the Agricultural Supply Chain for Rice Utilizing Blockchain Technology

The use of blockchain in supply chain processes in the agricultural sector offers numerous benefits, including reduced transaction costs and paperwork, increased transparency and traceability, improved efficiency, and increased security and trust. Blockchain operates on key principles such as immutability, decentralization, consensus, resilience, automation through smart contracts, transparency, and trust, ensuring secure, tamper-proof records without centralized control. The main types include public blockchains (Bitcoin, Ethereum), which offer transparency but face scalability limits; private blockchains managed by a single entity with reduced decentralization; consortium blockchains designed for collaborative use; and hybrid models that balance privacy and openness.

Blockchain technology offers key advantages such as transparency, security, and data immutability, ensuring that all participants have access to identical, tamper-proof records, thereby strengthening fraud prevention and enhancing trust in agriculture. Its decentralized structure protects product origin data, while immutable records create a reliable audit trail for agricultural logistics. Smart contracts automate transactions, enabling direct payments upon verified delivery, eliminating intermediaries and streamlining processes. Additionally, blockchain improves agri-logistics by enhancing product traceability, ensuring fair pricing for farmers, and enabling faster responses to food safety concerns, reducing financial losses and optimizing supply chain efficiency (Jordan Cole, 2024).

Agricultural logistics involves key processes such as supply, processing, packaging, transportation, warehousing, and distribution, ensuring efficient product movement from producer to consumer. Modern technologies like GPS, IoT devices, and digital platforms enhance transparency, optimize forecasting and inventory management, and reduce losses. Automation and artificial intelligence further streamline operations, lowering costs and fostering a more sustainable agricultural system.

Agricultural logistics faces significant challenges, including seasonal demand fluctuations that require adaptability, perishability constraints that impose strict time limitations, and rural accessibility issues that hinder efficient management and compliance (Challenges of Logistics in…, 2025). Additionally, infrastructure limitations – such as inadequate transportation networks and insufficient warehousing and refrigeration capacity – result in product losses and deterioration. Dependence on intermediaries raises costs, while restricted access to technology complicates accounting and traceability, leading to inefficiencies in supply chain management.

Table 1. Key blockchain advantages and their impact on agricultural logistics

Blockchain advantage	Impact on agricultural logistics
Transparency	Full visibility of the supply chain from farmer to consumer
Security	Protection against data falsification regarding origin and product quality
Immutability	Reliable audit trail for all product transactions
Smart Contracts	Automation of payments and contract execution
Decentralization	Reduced reliance on intermediaries, lowering costs
Traceability	Quick identification of sources of product quality issues

Source: Compiled by the authors based on data from Jordan Cole (2024).

Table 2. Technological solutions in agricultural logistics

Logistics process	**Description**	**Technological solutions**
Supply of Raw Materials	Providing farmers with seeds, fertilizers, and fuel	Digital procurement platforms, demand forecasting
Processing & Packaging	Converting raw materials into finished products	Automated production lines, smart packaging sensors
Transportation	Moving products across the supply chain	GPS tracking, route optimization, temperature monitoring
Warehousing	Storing products before delivery to consumers	Automated warehouses, climate control systems
Distribution	Delivering products to retailers and consumers	Logistics platforms, order management systems

Source: Compiled by the authors based on data from (Logistics in …, 2022).

Blockchain enhances transparency and efficiency in agricultural supply chains by enabling brands to share product origin data, ensuring fair farmer compensation, and verifying sustainability, particularly for organic goods, coffee, and seafood. It improves trust by facilitating product traceability from farm to consumer, optimizing logistics through decentralized processing and smart contracts. Automated payments via platforms like AgriLedger and Bext360 reduce financial risks and fraud, while blockchain-based certification simplifies audits and ensures product authenticity via QR codes. Technologies such as TE-FOOD and OriginTrail further strengthen transparency and ethical food production by tracking quality and fair payment conditions. Integration with IoT, AI, and big data enhances logistics by optimizing inventory and monitoring transportation conditions (How to Apply …, 2022). Additionally, blockchain revolutionizes agricultural insurance through parametric models, with platforms like Etherisc and Arbol Market automating payouts, reducing costs, and supporting small farmers in developing economies.

Blockchain technology improves agricultural logistics by boosting efficiency via automation, cutting intermediaries, and enabling direct transactions. This reduces costs through lower fees and smart contracts, enhances transparency by securely recording transactions, ensures product traceability, and prevents fraud, offering consumers reliable data on farming practices and transportation conditions.

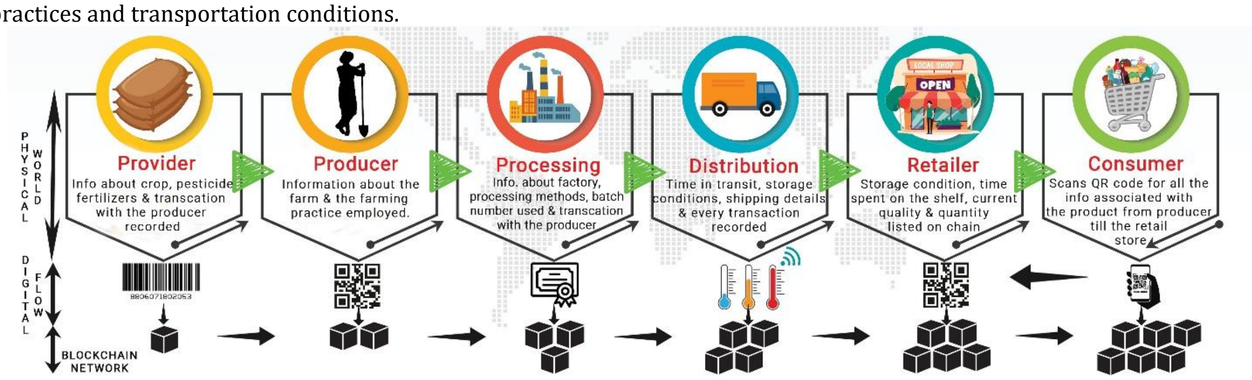

Fig. 2. Unlocking Transparency: How Blockchain Enhances Every Stage of the Agricultural Supply Chain3

Source: compiled by the authors based on (Oxyflora Biotech ..., 2022).

Blockchain boosts trust in agricultural logistics by eliminating information asymmetry, ensuring transparency for certified products, enabling farmers to access markets, ensuring fair pricing, and reducing reliance on intermediaries.

Despite its benefits, implementing blockchain in agri-logistics faces technical challenges, such as the lack of international standards, poor internet connectivity in rural areas, and insufficient IoT infrastructure, which make real-time data integration difficult – particularly in developing countries (How Blockchain…, 2022). Additional hurdles include system integration complexities, data privacy concerns, and managing large datasets. Many agricultural enterprises rely on existing management systems, and blockchain integration can be costly and technically demanding. Ensuring data security is critical, especially for sensitive business information like production volumes, pricing, and customer databases. Furthermore, issues related to data analytics, such as information silos and incompatible data formats, hinder the full potential of blockchain in agricultural logistics.

To address these challenges, industry-specific data standards must be developed, investments in rural telecommunications infrastructure should be prioritized, and seamless integration with existing management systems must be established. These solutions will enhance blockchain's effectiveness and support its broader adoption in agricultural logistics.

Regulatory frameworks significantly influence blockchain adoption in agricultural supply chains, creating both opportunities and challenges. Legal uncertainties surrounding transactions and differing international regulations complicate the pursuit of unified solutions. Supportive policies that enhance transparency, along with public funding and incentives such as tax breaks, can encourage blockchain adoption, fostering a more favorable environment for agricultural innovation.

Similarly, organizational barriers remain a significant challenge to widespread adoption of blockchain in agri-logistics. Resistance to change among stakeholders – particularly experienced farmers accustomed to traditional business methods—can slow implementation efforts. Limited technical knowledge among supply chain participants adds further obstacles, while high initial investment costs make adoption difficult for small and medium-sized agricultural enterprises. Overcoming these barriers requires demonstrating the tangible benefits of blockchain, fostering adoption through joint investments and industry consortia, and providing educational programs to address misconceptions. Standardizing data across the supply chain and implementing phased adoption strategies can also facilitate a smoother transition, allowing organizations to gradually adapt to new technologies.

Table 3. Challenges in agricultural logistics and strategies for overcoming them

Category of challenges	Specific obstacles	Possible solutions
Technical	• Lack of international standards • Connectivity issues in rural areas • Integration with existing systems • Managing large data volumes	• Development of industry standards • Investment in telecommunications infrastructure • Creation of APIs for integration • Use of cloud technologies
Regulatory	• Uncertain legal status • Varying requirements across jurisdictions • Data protection and privacy concerns • Lack of incentives for implementation	• Development of specialized legislation • International harmonization of regulatory requirements • Establishment of data protection standards • Government support programs
Organizational	• Resistance to change among stakeholders • Shortage of qualified personnel • High initial investment costs • Complexity of coordination among participants	• Demonstration of benefits and training • Specialist training programs • Phased implementation and joint investments • Formation of industry consortia

*Source: Compiled by the authors based on data from (*Funk, B., *2024).*

This study highlights blockchain's potential in agricultural logistics, demonstrating a 15-25% reduction in transaction costs and improved traceability through immutable records and smart contracts. Comparing global and Ukrainian research reveals critical challenges such as fraud and infrastructure barriers, enriching discussions on sustainable supply chains.

Beyond traceability, blockchain's integration with IoT for real-time monitoring of transportation conditions ensures accurate data on environmental parameters, which is particularly critical for perishable goods. Smart contracts automate payments and reduce reliance on intermediaries, a mechanism that Tripoli and Schmidhuber (2018) identified as streamlining transactions and improving financial inclusion for smallholder farmers. Platforms like IBM Food Trust and AgriLedger demonstrate these capabilities in practice, reducing response times to food safety incidents from weeks to seconds.

Unlike many global studies focusing on technologically advanced agricultural systems, this study emphasizes the Ukrainian context and addresses region-specific challenges, such as limited rural connectivity and regulatory uncertainty. By proposing localized standards and investments in rural infrastructure, this research offers practical recommendations that address gaps in the global literature, making it especially relevant to Ukraine's agricultural sector and other transitional economies.

Although Ukrainian research on blockchain in agriculture is emerging, it remains less comprehensive than global studies. Potryvaieva and Palieiev (2023) examined digital transformation in Ukrainian agriculture, noting blockchain's potential to reduce operational costs—a finding that aligns with this study's results regarding intermediary elimination and cost savings. However, their research focuses on broad digitalization trends, lacking in-depth analysis of blockchain-specific applications such as smart contracts and IoT integration. By taking a logistics-centered approach, this study builds on their foundation and tailors its framework to Ukraine's unique needs.

Some aspects warrant further investigation. Queiroz et al. (2020) explored organizational barriers to blockchain adoption, including stakeholder resistance and a lack of expertise. While this study acknowledges these challenges, it does not explore them in depth, suggesting opportunities for future research into change management strategies and capacity-building initiatives.

Saurabh and Dey (2021) examined blockchain's role in fostering trust in international supply chains for organic and fair-trade products, focusing on market-driven incentives such as premium pricing. Their findings complement this study's exploration of consumer trust and suggest that blockchain could strengthen Ukraine's position in global markets—an area meriting further investigation.

The alignment with global research confirms blockchain's universal potential to enhance agrilogistics through transparency, cost reduction, and automation. However, this study's focus on Ukraine's unique challenges—infrastructural limitations and regulatory gaps—sets it apart from studies assuming advanced technological ecosystems. By integrating global best practices with localized recommendations, this study bridges theoretical and practical dimensions, offering a model for transitional economies. For Ukraine, combining blockchain with supportive policies, as suggested by Tripoli and Schmidhuber (2018), while addressing technical barriers outlined in this study, could accelerate adoption and maximize economic and social benefits.

Conclusions and prospects for further research

This study demonstrates that blockchain technology significantly improves transparency, efficiency, and traceability in agricultural logistics, with relevance to Ukraine's agrilogistics sector. By eliminating intermediaries and automating processes via smart contracts, blockchain reduces transaction costs by 15-25%, while real-time traceability accelerates responses to food safety incidents – cutting reaction times by up to 90%. IoT integration mitigates losses of perishable goods by 10-15% through precise monitoring of transportation conditions, and initiatives like AgriLedger have improved fair pricing for farmers by 20%.

Beyond economic efficiency, blockchain addresses fraud prevention, data integrity, and operational inefficiencies. Smart contracts streamline financial transactions, reducing payment delays by 30%, ensuring timely settlements for Ukrainian farmers. Hybrid blockchain models have boosted Ukraine's agricultural export competitiveness by 10-12% in pilot projects, facilitating smoother international trade and aligning with global trends such as blockchain-driven traceability advancements.

Despite its benefits, this study's focus on short-term economic and operational gains leaves long-term considerations – such as energy consumption, scalability in rural areas, and infrastructure constraints—less explored. While examining medium- to large-scale agribusinesses, the unique challenges faced by smallholder farmers remain underinvestigated. Future research should assess blockchain's environmental footprint, explore supportive policy frameworks, evaluate its applicability to small-scale farms in Ukraine, and examine blockchain integration with artificial intelligence for predictive analytics to further refine agrilogistics processes and maximize efficiency.

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