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SMART CONTRACTS IN THE FOOD INDUSTRY SYSTEM

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У дослідженні проаналізовано проблеми традиційних ланцюгів постачання в харчовій промисловості, включаючи брак прозорості, труднощі з відстеженням, ризики шахрайства та бюрократичні затримки. Досліджено потенціал смарт-контрактів на основі блокчейна для автоматизації процесів, підвищення надійності даних, прискорення фінансових транзакцій і покращення контролю якості. Оцінка міжнародної практики таких компаній, як Walmart, IBM Food Trust і VeChain, підтверджує ефективність цієї технології в підвищенні безпеки, зниженні витрат і спрощенні аудитів. Визначено ключові фактори, що впливають на прозорість ланцюга постачання, включаючи автоматизацію документообігу, швидкість транзакцій, доступність даних і регуляторний нагляд.

Ключові слова: *державне регулювання, прозорість, ланцюги поставок, блокчейн, смарт-контракти.*

State of the problem. The challenges of implementing smart contracts in the food industry are directly linked to the need for enhancing transparency and efficiency in supply chain management. Traditional systems exhibit several shortcomings, including the complexity of product traceability, high fraud risks, bureaucratic delays in contract verification, and the possibility of data manipulation. In the context of the modern global market, there is a growing demand for innovative solutions that ensure not only food safety and quality but also automated business process management. The integration of smart contracts powered by blockchain technology offers an effective mechanism to address these issues by eliminating human intervention in critical aspects of logistics, financial transactions, and quality control.

Analysis of recent research and publications. The issues of the essence, advantages, disadvantages, and application potential of SMART contracts in Ukraine have been analyzed by the following domestic experts: Bortnikova M., Chirkova Yu. [1], Varavka V. [2], Klimovych S. V. [3], Nekit K. H. [4] and Smaglo O. [5]. However, previous research has not addressed international case studies on the implementation of transparent supply chains in the food industry or provided recommendations for deploying blockchain-based SMART contracts in Ukraine.

The aim of the research analyzes the implementation of smart contracts in the food industry to enhance supply chain transparency and efficiency. The research focuses on evaluating the advantages of blockchain technologies compared to traditional supply chain management systems, identifying key factors influencing transaction security, speed, and accuracy, and formulating recommendations for their integration in Ukraine.

Research methodology. The research methodology is based on the analysis of existing supply chain management models, the study of blockchain applications in the global food industry, and the assessment of the economic and regulatory implications of smart contract implementation. A comparative analysis was conducted between traditional document management systems and blockchain-based digital ledgers in terms of efficiency, accuracy, transaction execution speed, and security. Additionally, international best practices were examined, focusing on blockchain solutions adopted by companies Walmart, IBM Food Trust, and VeChain, which leverage the technology for supply chain traceability, quality control, and anti-counterfeiting measures.

Research results. Traditional supply chains in the food industry face several challenges, including fraud, lack of transparency, difficulties in product traceability, and delays in contract approvals. Given the increasing demands for food safety and logistics efficiency, the adoption of innovative digital solutions has become a critical necessity. Blockchain technologies and smart contracts introduce a new level of automation, reliability, and data transparency within supply chains, ensuring traceability, speed, and financial accountability. Therefore, it is essential to consider key factors that enhance supply chain transparency and reliability through blockchain-based smart contracts (see Table 1).

Table. 1. Key factors that enhance supply chain transparency and reliability through blockchain-based SMART contracts

Factor	Traditional system	Blockchain with smart contracts	Effect of use
Document flow	Paper or digital documents that can be forged	Smart contracts record conditions and transactions in an immutable form	Reducing the risk of fraud and counterfeiting
Traceability	Difficulty in tracing the source of products	Full product history is recorded in the blockchain	Improving product safety and trust
Transaction speed	Long approval process	Automatic fulfillment of conditions	Reducing time costs and accelerating deliveries
Data availability	Closed databases at suppliers	Accessibility for all participants in the chain	Increasing trust and transparency
Quality control	Discrete data with no guarantee of accuracy	Records of temperature, storage conditions are recorded in the blockchain	Reducing the number of defective batches
Error tolerance	Potential human error	Automation reduces the likelihood of errors	Increasing data reliability
Impact on regulators	Requires manual verification and certification	Government authorities can receive data in real time	Simplifying product control and certification
Financial transparency	Potential hidden fees and delays	Payment is tied to the fulfillment of contract conditions	Reducing corruption risks

*Note. * – formed by the author based on sources [1–5]*

The data presented in Table 1 demonstrates that the implementation of smart contracts in the food industry fundamentally transforms supply chain mechanisms by eliminating the shortcomings of traditional systems. Process automation minimizes the risks of fraud, human errors, and document manipulation. Instead of paper or digital documents that can be forged, smart contracts record transaction terms in an immutable format, enhancing security and trust among market participants [1, 4]. Product traceability is significantly improved, as blockchain ensures a complete, tamper-proof record of a product's history, which is crucial for compliance with safety standards and strengthening consumer confidence. The automatic execution of contracts reduces the time required for agreement approvals and accelerates logistics processes. The transparency of blockchain-based data makes information accessible to all supply chain participants, facilitating audits and reducing the potential for manipulations [5].

Quality control becomes more efficient due to the automated recording of storage and transportation parameters, helping to minimize defective batches. Smart contracts reduce human intervention, ensuring the precise execution of contractual terms without manual oversight. Government authorities gain real-time access to data, simplifying regulatory compliance, certification, and oversight processes. Financial transparency also improves significantly [2]. In traditional systems, payment delays and undisclosed financial transactions create risks of corruption. Smart contracts mitigate these risks by automatically linking payments to the fulfillment of contractual obligations [3]. This not only strengthens financial discipline but also enhances cash flow management within the supply chain. Overall, smart contracts create safer, faster, and more transparent supply chains, benefiting all market stakeholders. Despite initial integration costs and the need for legislative adaptation, the long-term benefits far outweigh potential challenges. The minimization of fraud, increased logistics efficiency, and enhanced financial transparency position blockchain as a key driver of innovation in the food industry.

Let us examine the primary benefits of blockchain-based smart contracts for producers, suppliers, consumers, and regulatory authorities (see Table 2). According to the data in Table 2, the implementation of blockchain-based smart contracts brings significant benefits to all participants in the food market. Producers improve quality control, automate sales, and reduce risks, which decreases losses from defective products by 15–20 % and enhances competitiveness. Suppliers optimize logistics, eliminate intermediaries, and accelerate settlements, reducing costs by 10–30 % and improving capital turnover.

Retailers and restaurants, in turn, receive guaranteed product quality and automated product reclamation, minimizing time spent on supply chain control and strengthening their reputation. Consumers gain access to reliable product information, increasing confidence in quality and fostering loyalty due to lower prices. The government receives an effective tool to combat the shadow economy, reducing counterfeit goods and tax losses, thereby strengthening food security. Financial institutions benefit from transparency, ensuring contract fulfillment, reducing fraud, and simplifying lending.

Table. 2. Primary benefits of blockchain-based smart contracts for producers, suppliers, consumers, and regulatory authorities

Category	Benefits of implementing smart contracts	Economic effect	Strategic importance
Manufacturers	Quality control, sales automation, risk reduction	Reduction of losses from defects by 15–20 %	Increasing competitiveness
Suppliers	Logistics optimization, elimination of intermediaries, acceleration of settlements	Reduction of costs by 10–30 %	Accelerating capital turnover
Retail and restaurants	Guarantee of product quality, automation of returns	Reduction of time for control of supplies	Improving brand reputation
Consumers	Reliable information about products, quality assurance	Reduction of prices by reducing intermediaries	Increasing loyalty
Government	Fighting the shadow economy, improving tax control	Reduction of counterfeiting and tax evasion	Increasing food security
Financial structures	Guaranteed contract fulfillment	Reduction of cases of fraud in trade transactions	Simplifying sector lending
Environmental aspect	Reducing waste through logistics optimization	Reduction of carbon footprint of the supply chain	Supporting ESG initiatives
Investors	Increasing market confidence	Increased attractiveness of investment in the sector	Long-term business stability

*Note. * – formed by the author himself*

Logistics optimization also contributes to emissions reduction and supports ESG initiatives. Investors increase their confidence in the market, enhancing its investment attractiveness and long-term stability. Thus, smart contracts create an efficient automated control system that optimizes economic processes and transforms the food industry. The benefits for individual participants complement each other, forming a unified mechanism for transparency, stability, and industry competitiveness.

Let us now examine international case studies of transparent supply chain implementation in the food industry (see Table 3). The international case studies on the implementation of transparent supply chains in the food industry, presented in Table 3, demonstrate the effectiveness of blockchain technology in ensuring traceability, quality control, and increased consumer trust.

Table. 3. Examine international case studies of transparent supply chain implementation in the food industry

Platform	Main functions	Industries of use	Implementation results
IBM Food Trust	Product traceability, quality control, transaction automation	Food industry, retail	Reduced time to verify product origin from 7 days to 2 seconds (Walmart)
VeChain	IoT tracking, smart contracts, logistics monitoring	Pharmaceuticals, food	Transparent product certification, preventing counterfeiting
TE-FOOD	Farm-to-fork tracking, storage monitoring	Agricultural sector, FMCG	Successful implementation in 25 countries, including the EU
Provenance	Supply chain verification, ESG monitoring	Ecologically friendly products	Guaranteed confirmation of product origin
Ambrosus	Product data management, sensor monitoring	Logistics, food industry	Real-time storage monitoring
OriginTrail	Decentralized database for logistics	Retail, manufacturing	Improved supply chains and analytics
FoodLogiQ	Risk control, product recall, traceability	Food products, restaurants	Helps reduce losses from product recalls
Walmart + Blockchain	Supply control, procurement automation	Retail	Improved transparency and efficiency of supply chain management

*Note. * – formed by the author based on sources [6–13]*

Various platforms specialize in specific functions, enabling the adaptation of technology to meet the distinct needs of different market sectors. The IBM Food Trust platform optimizes product origin verification, reducing processing time from 7 days to 2 seconds, which is particularly crucial for retail [6]. VeChain leverages IoT tracking and smart contracts for product certification and counterfeit prevention, which is critical for both the pharmaceutical and food industries [12]. TE-FOOD ensures end-to-end traceability from farm to table and monitors storage conditions, successfully implementing its system in 25 countries, including the EU [7]. Provenance focuses on supply chain verification with an emphasis on ESG compliance, which is essential for the organic food market, providing guaranteed proof of product origin [13]. Ambrosus implements sensor-based monitoring and real-time product data management, enhancing logistics quality in the food industry [8]. OriginTrail offers a decentralized logistics database that improves supply chain visibility and analytics, particularly benefiting retail and manufacturing [9]. FoodLogiQ specializes in risk management, product recalls, and traceability, helping to reduce financial losses associated with product withdrawals in the food industry and restaurant sector [10]. Walmart+ Blockchain integrates supply chain oversight with procurement automation, enhancing transparency and supply chain management efficiency [11].

These platforms demonstrate their diverse applications: some focus on accelerating data verification, others emphasize environmental sustainability, logistics control, or risk management. Collectively, they contribute significantly to food safety, efficiency, and resilience, shaping the overall trend toward digital transformation and process automation in the food industry.

Let us now formulate recommendations for the implementation of blockchain-based smart contracts in Ukraine (see Table 4).

Table. 4. Recommendations for the implementation of blockchain-based smart contracts in Ukraine

Recommendations	Justification	Expected effect	Risks
Creation of a national blockchain platform	Centralized infrastructure for supply control	Supply chain transparency	High initial cost
State subsidies for business	Support for digital transformation	Increasing the pace of technology adoption	Additional financial burden on the budget
Pilot projects in large retailers	Testing the effectiveness of solutions in a real business environment	Scaling successful models	Slow integration of technology
Development of a regulatory framework	Legal consolidation of the legal status of smart contracts	Increasing market participant trust	Resistance of traditional bureaucratic structures
Educational initiatives	Development of digital literacy of entrepreneurs	Training personnel to work with blockchain	Long-term effect of implementation
Integration with international standards	Inclusion of Ukraine in global supply chains	Increasing export volumes	High competition in the international market
Development of API for integration	Compatibility of different platforms	Simplifying the connection of new participants	Complexity of technical implementation
Cooperation with private initiatives	Support for the blockchain ecosystem in business	Accelerated implementation of solutions	Competition for resources

*Note. * – formed by the author himself*

Analyzing the data from Table 4, the implementation of smart contracts based on blockchain technology in Ukraine requires a comprehensive approach that integrates technical, regulatory, and educational aspects. A key milestone is the

development of a national blockchain platform to ensure centralized supply chain oversight and enhance transparency. However, high initial costs may slow down this process, making government support a relevant issue. The introduction of subsidies can facilitate business digitalization but will also impose additional financial pressure on the state budget. To mitigate risks, pilot projects should be launched with major retailers to assess the technology's efficiency in a real business environment. However, slow adoption may hinder scalability. Another critical step is the legal recognition of smart contracts, which would help build trust among market participants. Yet, this process may face resistance from traditional bureaucratic structures, delaying necessary regulatory updates. Parallel investment in digital literacy programs for entrepreneurs is essential, as a skilled workforce will be a decisive factor in the successful deployment of these technologies. Global integration is another crucial direction. Ukraine's inclusion in international supply chains will unlock new export opportunities but will require business models to adapt to intense global competition. Technical complexity remains a challenge, especially for small and medium-sized enterprises (SMEs), which may struggle to integrate API solutions for blockchain interoperability. Expanding partnerships with the private sector can accelerate technology adoption, support blockchain ecosystem development, and drive innovation. At the same time, this could intensify competition for resources, creating additional challenges for smaller companies. However, aligning government and business initiatives can enable the creation of a resilient digital infrastructure, ensuring long-term economic impact.

Conclusion. Summarizing the findings of this study, key challenges of traditional supply chains in the food industry were identified, including low transparency, fraud risks, product traceability issues, and delays in financial settlements. The study presented the potential of blockchain-based smart contracts, which enable automated transactions, data immutability, increased transaction speed, and enhanced quality control. An analysis of international best practices demonstrated that leading companies leveraging blockchain technology achieve higher logistics efficiency, cost reductions, and minimized risks of document forgery. Additionally, the study substantiated the economic and regulatory advantages of smart contract adoption, such as financial transparency, reduced corruption risks, and streamlined government oversight. Thus, the research confirms that smart contracts are a promising tool for the digital transformation of the food industry. Despite the need for regulatory adaptation and initial investments, the long-term benefits significantly outweigh the costs, making them a crucial component of supply chain modernization.

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Annotation

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Smart contracts in the food industry supply chain system

The study examines the problems of traditional supply chains in the food industry, in particular their low transparency, complexity of product traceability, fraud risks and bureaucratic delays. The possibilities of implementing blockchain-based smart contracts are presented, which provide process automation, data reliability, acceleration of financial transactions and improved product quality control. The idea of the role of blockchain technologies in the modern food industry is expanded by analyzing their impact on supply chain participants, including manufacturers, suppliers, retailers, consumers and regulatory authorities. A comprehensive analysis of the international experience of using smart contracts in leading companies Walmart, IBM Food Trust and VeChain is provided, confirming their effectiveness in increasing security, reducing costs and simplifying audits. The key factors influencing the transparency and reliability of supply chains are analyzed, including document workflow automation, transaction speed, data availability, financial transparency, and regulatory oversight. The results obtained indicate that the integration of smart contracts into the food industry contributes to reducing operational risks, improving supply management, and increasing the level of trust between market participants.

Conclusions are drawn about the need for state support, adapting the regulatory framework, and implementing educational initiatives for the effective implementation of the technology. Recommendations are proposed for the development of a national blockchain platform, supporting the digital transformation of business, and integrating Ukraine into global supply chains, which will create the prerequisites for the long-term stability and competitiveness of the industry. A promising direction for further research will be the assessment of the economic efficiency of implementing blockchain solutions in the food industry and their impact on the sustainability of supply chains in the face of global challenges.

Key words: *state regulation, transparency, supply chains, blockchain, Smart contracts.*