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INTEGRATIVE REVIEW OF IOT IMPLEMENTATION IN AGRI-FOOD SUPPLY CHAIN: FINDINGS AND ANALYSIS

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ABSTRACT

The study focuses on the Internet of Things (IoT) implementation in Agri-food supply chain, due to the increasing benefits gained from implementation these technology on this industry. Traditional farming methods are unable to cope with the demand, leading to the use of fertilizers that can have negative impacts on agricultural productivity. The paper examines the various research related with components of smart farming, such as IoT, smart farming, technologies, wireless communication technology, sensors, and hardware, and highlights the need for careful selection of these technologies in different agricultural practices to increase mechanization. The study also provides an extensive review of the implications of automation in agriculture and discusses the benefits of digital transformation, coordinating and production system, modern sensors, wireless communication technologies, and hardware. The paper also addresses the challenges associated with agriculture automation and explores future applications for crop health, human health, and machine health. The objective of this article is to present a comprehensive overview of the enabling technologies in IoT implementation with smart and sustainable agriculture and discuss potential avenues for improvement in the future.

Keywords: *IoT, Agri-food, Supply Chain.*

1. INTRODUCTION

Agriculture remain as one of important sector to be emphasized due to current environmental and needs, especially post Covid 19 disease and movement restriction around the world. The frequently research themes on agricultural sector were food supply chain, food waste, sustainability, food safety, supply chain management, food industry, and food security. However, there is new research themes in these research field, such as blockchain; Internet of Things (IoT); contract; resilience; short food supply chain; life cycle assessment; environmental impact; packaging; water use; food waste; and carbon footprint (Barbosa, M. W., 2021).

In terms of IoT technologies, there is six IoT technologies and their applications in the context of agriculture supply chain (Luthra, S. et al, 2018) . These technologies were radio-frequency identification, vibrational spectroscopy, bio/wireless sensors/ mechanisms, traceability, artificial intelligence, and high pressure processing. However, there is certain issues to adopt IoT technologies in agriculture supply chain towards developing countries. The issues related with an employability and knowledge of technological terms, high costs, low level of research and development facilities and equipment, and low standards of industries.

In order to sustain agri-food supply chain and industries, government interference also play significant roles. It is also related with top management support especially for training, awareness on environmental regulations, and pollutants reducing; IoT based infrastructure to provide an important data about global demand; quality standards, and logistic; cold chain to controlling the quality of the products; education and training especially towards the farmers; information sharing among the multi-tier suppliers; and smart packaging of agri-products (Yadav, S. et al., 2021).

2. DATA AND METHODS

This study explores the literature of the IoT (Internet of Thing) implementation in Agri-Food supply chain, related with Block-Chain System by employing integrative literature analysis methods. This methods is able to reduce any potential biases by searching specific words, and examining the trends in these article (Denyer, D.

& Tranfifield, D., 2009). The papers were selected only from 2018 until 2022 because block-chain technology adopted since 2017 in supply chain management.

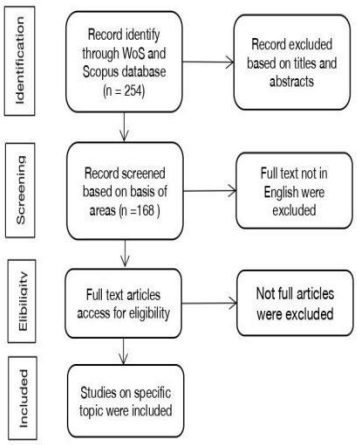

Figure 1: PRISMA Diagram for Inclusion Articles

Firstly, the most relevant studies by key word searching in Google Scholar database were collected. The final key words include'blockchain, 'supply chain management', 'Agri-Food', 'Internet of Things (IoT) Based System', "Artificial Intelligence' and 'Food and Technology'. The papers were considered peer-reviewed journal articles through Google Scholar (www.scholar.google.com) and Web Of Sciences from June 2022 until October 2023. First searching of articles resulted 254 papers related on these research area. However, after refined specific issues, total of 26 references refined.

Table 1 indicates a literature summary of these 26 references. As in the table, the most common words were 'IoT Based System', 'Block Chain', and 'Supply Chain Management'. Previous study examined on IoT implementation (Xie, J. et al, 2022) in Agri-food supply chain with discussion through the case studies or literature review (Yadav, S. et al., 2021; Dadi, V. et al, 2021) with bringing the gaps in traceability system (Tagaris et al, 2021; Tagaris, A. C. et al, 2021). Cocco, L. et al (2021); Niknejad, N. et al (2021); Kamblea, S. S. et al (2020) and Kaijun, L. et al (2018) investigated on a blockchain in Agri-food or Agri-culture. While Manning, A. et al (2022) consider the ethical narrative used when adopt AI (Artificial Intelligence) in supply chain. Saurabh, A. S and Kushankur (2020) and Fua, H. et al (2020); study on blockchain technology adoption and sustainable agri-food supply chain. Visconti, P. et al (2020) were developed software platform for smart farming through implementation of IoT. While Rejab, A. et al (2022) discussed on digitalization in food supply chains. Furthermore, Almadani, B. and Mostafa, M (2021); Yadav, S. et al (2020) and Luthra, S. et al (2018) introduced IOT and blockchain (Bhat, S. A. et al, 2022) on multimodel for Agro-Industres or Agri-Culture and supply chain. Moreover, Egwuonwu, A. et al (2022) examined the infleunce of blochain and IoT on global value chain. Finally, Barbosa, M. W. (2021) critically reviewed on Agri-food supply chain management by bibliometric study. Detailed descriptions on these topics can be found in the next section.

No.	Key Words	Author/Year
1	IoT, Agro-Industries	Almadani B. & Mostafa S. M. (2021)
2	Agri-food Supply Chain	Barbosa M. W. (2021);
3	Block Chain, IoT	Bhat, S. A., Huang, Nen-Fu, Sofi, I. B.; Sultan, M. (2022)
4	Block Chain, Agri-food	Cocco, L., Mannaro, K., Tonelli, R., Mariani, L., Lodi, M. BB., Melis, A., Simone, M., Fanti, A. (2021)
5	Block Chains, IoT	Egwuonwu, A., Mordi, C., Egwuonwu, A., Uadiale, O. (2022)
6	Agri-food, Supply Chain	Dadi, V., Nkhil, S. R., Mor, R. S., Agarwal, T., Arora, S., (2021)
7	Block Chain, Agri-food	Fu, H.; Zhao, C., Cheng, C., Ma, H. (2020)
8	Block Chain, Agrifood	Jahanbin, P., Wingreen, S. C., Sharma, R., Ijadi, B., reis, M. M. (2023)
9	IoT and Block Chain	Hasan, I., Habib, M. M., Mohamed, Z., Tewari, V. (2023)
10	Smart Agriculture	Jararweh, Y., Fatima, S., Jarrah, M., AlZu'bi, S. (2023)
11	Agri-cultural Supply Chain	Kaijun, L., Ya, B., Linbo, J., Nieuwenhuyse, I. V. (2018)
12	Block Chain, Agri-culture	Kamble, S. S., Gunasekaran, A., Sharma, R. (2020)

13	Technologies, Agrifood	Konfo, T. R. C., Djouhou, F. M. C., Hounhouigan, M. H., Dahouennon-Ahoussi, E., Avlessi, F., Sohounhloue, C. K. D. (2023)
14	IoT, Supply Chain	Luthra, S., Mangla, S. K., Garg, D., Kumar, A. (2018)
15	Supply Chain	Manning, L., Brewer, S., Craigon, P. J., Frey, J., Gutierrez, Jacobs, A. Kanza, N., S., Munday, S., Sacks, J., Pearson, S. (2022)
16	Block Chain, Agriculture	Niknejad, N., Ismail, W., Bahari, M., Hendradi, R., Salleh, A. Z. (2021)
17	Smart Farming, IoT	Prakash, C., Singh, L. P., Gupta, A., Lohan, Sk. K., (2023)
18	Food Supply Chain	Rejab, A., Rejab, K., Abdollahi, A., Zailani, S., Iranmanesh, M. (2022)
19	Block Chain, Agri-food	Saurabh, S., & Dey, K. (2021)
20	IoT Based System	Tagaris, A. C., Benos, L., Kateris, D., Tsotsolas, N, Bochtis, D. (2021)
21	IoT Based System	Trenerry, B., Chng, S., Wang, Y., Suhaila, Z. S.,Lim, S. S.; Lu, H. Y.; Oh, P. H. (2021)
22	Agri-food	Visconti, P., Fazio, R. D., Velazquez, R., Del-Valle-Soto, C. (2020)
23	IoT, Traceability	Xie, J., Wan, C., Becerra, A. T., Li, M. (2022); Guangjie, L. V., Caixia, S., Pengmin, X., Zhiguo, Q., Heyu, s., Yi., L. (2023)
24	IoT System	Wang, T., Wang, X., Jiang, Y., Sun, Z., Liang, Y., Hu, X., Li, H., Shi, Y., Xu, J., Ruan, J. (2023)
25	IoT, Agri-food	Yadav, S., Luthra, S., Garg, D. (2021)
26	IoT, Agri-food Supply Chain	Yadav, S., Luthra, S.; Garg, D. (2022)

Table 1. Literature Summary (Final Access in December 2022)

Each article includes a set of 4-6 keywords that are specific to the authors and help describe the content of the papers. When these keywords co-occur, it indicates the evolution and development of a particular field of study over time. The size of the nodes in the diagram represents the frequency of occurrence, with larger nodes indicating higher frequency. The lines connecting the nodes show co-occurrence. The most frequently used keywords in this analysis were "Agri-food supply chain, Supply chain, agri-food, block chain, IoT based system, ethical language interaction, production system, digital transformation, smart farming, traceability, food industries, technologies, coordinating systems, smart agri-cultural, IoT, and agro-industries. These keywords had the highest occurrences, highlighting the emphasis on the issues related on IoT and agri-food supply chain. Color coding was used to distinguish between different clusters represented on the map (see Figure 2).

3.0 DISCUSSION

3.1 IoT and Agriculture Supply Chain

The main issues has been studied by researchers in agri-food supply chain industries were blockchain system. Nicknejad, N. et al (2021) highlighted three categories research trends on blockchain technology on agri-food studies including traceability, transaction, IoT, safety, and food supply chain. Traceability seems as the most highlighted when Kamble, S. S. et al (2020) found that traceability were the main reason of blockchain implementation for managers and policy makers. The other reason were auditability, immutability, and provenance. Saurabh, S. and Dey, K. (2021) in their research approved that traceability, dis-intermediation, price, trust, compliance, coordination and control as blockchain ICT's integrated were important influence on supply chain application.

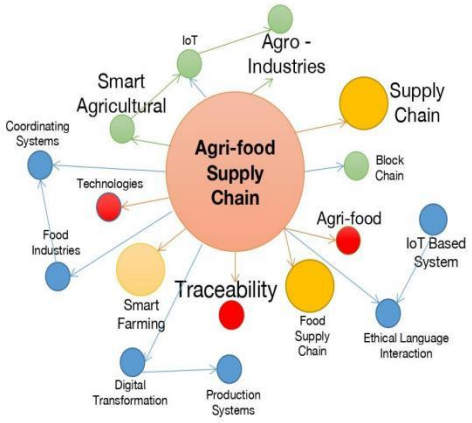

Figure 2: Key Words Co-occurence Analysis Map

To maximized transparency and auditability traceability, quality of the products, and hygienic condition along the supply chain process, Cocco, L. et al (2021) in their research proposed the Near Field Communication (NFC) and RFID as model implementation on an IOT blockchain based system in Carasau Bakery's.

3.2 Blockchain System

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3.3 Traceability System

The revolution on agri-food technological advanced influenced by IoT leading benefits and optimization productive processes lead Visconti, P. et al (2020) to developed smart traceability for farm management system based on IoT, proposed suitable software to support the process of decision making, designed and testing solar-powered wireless sensor network (WSN), Bluetooth Low Energy (BLE) as low cost sensor tag to monitor the parameter of failure processing products, and mobile application for monitoring tracking information and sharing the data of the products. However, all the prototype were tested on 5.6 months with certain particular devices, only several tested carried out to verify the function on certain application.

On the other side, there is also emerging demands of clean, hygienic, and fresh fruits and vegetables in the current world market. These demands become as one of the push factors towards agri-food industries. However, certain challenges faced including increasing of the cost related on transportation, processing, packaging, handling, and shipping. Thus, it is very important to develop the reliable agri-food supply chain to maximized the food safety. There is a study proposed the system that incorporated IoT and websites, as well as an android as platform to monitor the quality of the fruits and vegetables throughout the agri-food supply chain processes. One of the system named as AgroTRACE with user-friendly open access tracing system, and data sharing on operational processes, as proposed by Tagaris, A. C. et al (2021).

However, the prevention on food safety, security, and traceability in agri-food supply chain need to be emphasized rather than only responding and reacting by peoples (Dadi, V. et al, 2021). Digitlization, and advanced tehnological usage remains as the important solutions towards agri-food supply chain industries. In addition, there is certain scope of the issues need to explore in future related with the implementation cost, cyber-security, block chain technology (BCT) application, combination and integration of technologies, and stakeholders issues on implementation.

Despite from all this research, most of the previous studies on traceability applications in agri-food products has not been accessed on how far the systems effectively implemented. Xie, J. et al (2022) introduces an integrated system machine to machine connections in Organic Apple production that automatically collecting information in operation field. The IoT base system integrated with hardware system, a platform of Smart Farm Cloud (SFC), and a mobile application including collect, upload, and stores an information. Throughout the system, QR code generated to provide traceability information by consumers. Therefore, it is important to focus on the efficiency of the IoT systems and trustworthy manner of practical application rather than the methodology issues. The implemented IoT system will obtain increasing the customers confidence towards the products, as well as increasing the product value.

However, optimization of the storage scale, the ability on inter-operations, encounter the security and privacy issues of personal data, as well as the storage concerns on agriculture supply chain systems also need to be focused. Bhat, S. A. et al (2022) presents Agri-SCM-BIoT (Africulture Supply Chain Management using Blockchain and Internet of Things). There is also a discussion on security treats classification with an IoT infrastructure as mechanism by blockchain based defense. The study also emphasized on the emerge needs of trustworthy block-chain based cross-chain in supply chain management system to encounter the issues related with confidentially, integrity, and availability.

In other study, Kaijun, L. et al (2018) found that certain chain from agri-food sector were

applicable to adopted in Chinese Public Service Sector. Thus, the study used double chain architecture for security of information, seeking resources, increasing credibility and efficiency of the public service systems.

On the other hand, it is important to focused on the reformation of agri-food supply chain management with blockchain technology from the institutional economics perspective, rather than only on the application of blockchain from technological perspective. Fu, H. et al (2020) described possible situation on how to utilised opportunities effectively based on block chain agri-food supply chain aspect (uncertainty, trading frequency, asset specificity). While, there is also important to look a from broad perspective, on how to ensure the business will able to remain sustain in the industries. Egwuonwu, A. et al (2022) were discussed on the enhancement impact of combination blockchain technology and IoT ecosystem towards global value chain (GVC) and value creation. Their study approved that combination on blockchain technology and IoT were able to improve GCV in terms of scalability, security, and traceability. It is also recognized that these combination creates significant value for value chain partners to increase competitive advantage.

3.4 Digital Transformation

Alongside with issues on IoT, blockchain, and traceability system, digital transformation towards IoT implementation in agri-food suply chain need to be emphasized. Trenerry, B. et al (2021) proposed the information on digital transformation across multi-disciplines and integrated the findings into multi-level framework (individual, group, organization). At the individual level, the factors of employees' effective digital transformation were technological adoption; perceptions and attitudes on technological changes; skills and training; workplace adaptability; and work related well-being. While the factors of digital transformation at the group level were team communication and collaboration; workplace relationship and team identification; and team adaptability and resilence. Finally there is three factors of digital transformation at organization level like leadership; human resources; and organizational culture/climate. However, the other future research may provides an integrated rich body of literature on technology adoption with the process of digital transformation and the outcomes.

At the same time, the involvement of Information, Communication, and Technology (ICT) on digital transformation cannot be denied. Rejab, A. et al (2022) focus on ICT and implementation towards agri-culture and food security, IoT and blockchain on food supply chain (FSC). The study found that the FSCs papers has significantly grown from 1975-June 2021. Thus, it is suggested to explore numerous research on the strategy to ensure successfully adopt sustainability and circular economy into technology enable on agri-food supply chain, increasing research on transformation traditional supply chain and business modal to non-linear sustainable systems, emphasizes the needs of collaboration between industry and academia, country between another country for initiating solutions on food safety and security in future.

3.5 Coordinating System, Production System, and Ethical Language Interaction

The implementation of IoT in agri-food supply chain also can be seen from another perspectives which likely not highlighted by researchers. There are coordinating system, production system, and ethical language interaction. Coordinating system in agri-food supply chain is able to become as a framework towards enables' relationship and improve coordination with operational and strategic decisions. Yadav, S. et al (2022) developed DEMATEL-ISM method to support coordinating system with IoT influences. Throughout the process, seven enables has been identified. The purpose of these method to After adopt these method, it is found that Top Management Support (TMS) were the main driver value. Aside from that, there is also involvement of stakeholder theory in developing IoT with coordination system on AFSCM. These study contributed as a guide for managers in developing strategies using strength-weaknesses-opportunities-threats (SWOT) analysis.

Production system in agro-food supply chain is important to precise the operation in production system, and reduced the unnecessary cost. Almadani, B. and Mostafa, S. M. (2021) reviewed the literature on current industrial revolution on technological in agriculture sector, with emphasized on the gap in supply chain management and identify specific issues on multi-vendor production system in industrial and agricultural sector. The study also proposed multi-model for communication model on systematic integration of multi-vendor agricultural production systems.

Growing of artificial intelligence (AI) into agri-food supply chain industries arises the studies on ethical language by stakeholders, when there is an issues on failure to differentiate nuance meanings that become a barrier on technology adoption. Manning, L. et al (2022) published a review paper to consider embedded ethical language perspective by stakeholders collaborated with AI adoption in food supply chain. The study increased an understanding on the used language, exploring ethical interaction

and increasing engagement between AI technology and management activities. Although there is discussion on benefits of seven aspects of AI technology and algorithm application to considered into food supply chain (transparency, traceability, explainability, interpretability, accessibility, accountability, responsibility), it is also lead towards algorithmic bias only for one groups in food supply chain over another groups of AI in decision making.

4.0 CONCLUSION

The agriculture industry has undergone a significant transformation in recent years, shifting from traditional practices to a more intelligent approach known as "Agri-Food 4.0". This involves incorporating information and communication (ICT) technology into the cultivation process. By utilizing wireless sensor networks, IoT sensors, traceability systems, optimization techniques, and machine learning algorithms, smart farming can maximize agricultural productivity. These emerging technologies have the potential to improve crop productivity and quality, reduce costs, and decrease the environmental impact of traditional farming methods.

A key focus in smart farming is maximizing crop productivity with minimal human involvement. IoT-based systems offer numerous advantages in addressing this concern for both the global population and farmers. These systems incorporate wireless technologies, modules, sensors, and gateways to collect vast amounts of real-time data for optimization and analysis. This article provides an overview of the latest advancements in IoT-based farming methods and technologies, with the aim of assisting researchers in developing a global solution for smart farming.

As the global population grows and agricultural land diminishes, there is a pressing need for smarter, healthier, and more efficient agricultural practices. Advanced farming techniques have evolved over time, and ongoing research continues to yield impressive developments. Machine learning models and big data solutions play a crucial role in predictive analytics for smart farming. However, overcoming challenges related to inequity, implementation scope, infrastructure feasibility, and cost is necessary for the widespread adoption of machine learning models. Comprehensive approaches to adopting these models are required to effectively analyze systems, solutions, and the agricultural life cycle in smart farming conditions.

Recent research has demonstrated significant progress in the field of agriculture, particularly regarding data mining through IoT in smart farming. This approach enables farmers to make informed decisions under challenging farming conditions by providing valuable insights such as yield prediction, optimal harvest timing, and suitable crop selection for specific seasons. In conclusion, data mining through IoT systems empowers farmers with actionable insights, enhances productivity, and promotes sustainable farming, thereby driving the transition toward modern agriculture.

Future research in IoT-based smart farming should focus on optimizing the integration of IoT technologies in various farming aspects, utilizing data analytics and AI for informed decision-making, enhancing security and privacy measures, ensuring scalability for small-scale farmers, and exploring IoT-based supply chain management to streamline agricultural processes and improve overall efficiency.

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Perkara di atas adalah dirujuk.

2. Adalah dimaklumkan bahawa pihak kami ingin memohon kelulusan tuan untuk mengimbas (*digitize*) dan memuat naik semua jenis penerbitan di bawah UiTM Cawangan Perak melalui Repositori Institusi UiTM, PTAR.

3. Tujuan permohonan ini adalah bagi membolehkan akses yang lebih meluas oleh pengguna perpustakaan terhadap semua maklumat yang terkandung di dalam penerbitan melalui laman Web PTAR UiTM Cawangan Perak.

Kelulusan daripada pihak tuan dalam perkara ini amat dihargai.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"

Setuju.

27.1.2023

PROF. MADYA DR. NUR HISHAM IBRAHIM
REKTOR
UNIVERSITI TEKNOLOGI MARA
CAWANGAN PERAK
KAMPUS SERI ISKANDAR

Saya yang menjalankan amanah,

SITI BASRIYAH SHAIK BAHARUDIN
Timbalan Ketua Pustakawan

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