Innovative Computing Review (ICR)
Volume 3 Issue 2, Fall 2023
ISSN$_{(P)}$: 2791-0024, ISSN$_{(E)}$: 2791-0032
Homepage: https://journals.umt.edu.pk/index.php/ICR

Article QR

Title: **Nourishing the Future: AI-Driven Optimization of Farm-to-Consumer Food Supply Chain for Enhanced Business Performance**

Author (s): Hassan Anwar[1], Talha Anwar[2], Gohar Mahmood[3,4]

Affiliation (s):
[1]MNS-University of Agriculture, Multan, Pakistan
[2]Independent Researcher, Multan, Pakistan
[3]Government College University, Faisalabad, Pakistan
[4]Bahauddin Zakariya University, Multan, Pakistan

DOI: https://doi.org/10.32350/icr.32.02

History: Received: September 22, 2023, Revised: October 15, 2023, Accepted: November 27, 2023, Published: December 2, 2023

Citation: H. Anwar, T. Anwar, and G. Mahmood, "Nourishing the future: AI-Driven optimization of farm-to-consumer food supply chain for enhanced business performance," *Innov. Comput. Rev.*, vol. 3, no. 2, pp. 00–00, Dec. 2023, doi: https://doi.org/10.32350/icr.32.02

Conflict of Interest: Author(s) declared no conflict of interest

A publication of
School of Systems and Technology
University of Management and Technology, Lahore, Pakistan

Nourishing the Future: AI-Driven Optimization of Farm-to-Consumer Food Supply Chain for Enhanced Business Performance

Hassan Anwar[1], Talha Anwar[2] and Gohar Mahmood[3,4*]

[1]Department of Food Science & Technology, MNS-University of Agriculture, Multan, Pakistan
[2]Independent Researcher, Multan, Pakistan
[3]College of Commerce, Government College University, Faisalabad, Pakistan
[4]Department of Commerce, Bahauddin Zakariya University, Multan, Pakistan

ABSTRACT Efficiency and sustainability are upending the global food supply system. The current study examined the relationship between Artificial Intelligence (AI) and agriculture to optimize food supply chain from farm to consumer business model. The study examined how AI-driven solutions may boost efficiency, reduce waste, and promote environmental responsibility with an emphasis on sustainability. The food supply system faces resource depletion, climate change, and growing global food consumption. AI technologies, such as automation, data analytics, and machine learning may solve these issues. AI systems use real-time data, predictive analytics, and intelligent logistics to improve production, distribution, and consumption. This reduces food production and transportation of carbon emissions along with improving resource allocation. AI-powered precision agriculture helps the farmers to increase crop yields while lowering fertilizer and pesticide use along with supporting sustainable farming as well. IoT devices and sensor networks are helpful to improve livestock management and crop monitoring, enabling data-driven agriculture. The current study highlighted how AI ensures food quality and safety across supply chain. By identifying impurities, monitoring storage conditions, and forecasting shelf life, AI-powered quality control systems may decrease food wastage and ensure safe, high-quality goods. In conclusion, AI-agriculture integration is an innovative way to increase farm-to-consumer food supply chain efficiency and sustainability. AI technology may help the supply chain stakeholders to create resource-efficient, environmentally friendly food production that meets the needs of a growing population. The current study discussed food industry sustainability and AI uses in agriculture, as well as future possibilities and challenges.

INDEX TERMS Artificial Intelligence (AI), business performance, consumer, food supply chain management,

I. INTRODUCTION

With 7.8 billion people on earth, food production, distribution, and consumption is far more a crucial matter than it was in the past. In order for the world to feed its expanding population, our existing methods of overseeing the intricate web of interconnected activities that constitutes farm-to-consumer food supply chain, must undergo a significant transformation [1]. This is evident from the way concerns pertaining to global food security and technological advancement are overlapping [2]. A complex web of interconnected problems characterizes the current condition of food supply chain management, ranging from the ongoing

* Corresponding Author: goharmahmood@gcuf.edu.pk

search for better product quality to the need for more sustainability and efficiency. However, despite these challenges, the revolutionary potential of Artificial Intelligence (AI) is creating a huge opportunity.

For everyday subsistence, millions of people rely on the global food supply system. It supplies the raw materials for businesses, the energy needed for farming, and the food needed to feed the entire towns [3]. However, this intricate network faces several challenges. The food production and distribution industry is now facing significant problems. These problems are arising from several factors, such as resource constraints, changes in consumer preferences, the impacts of climate change, and the worldwide trend of population aging. The aforementioned scenario serves as an exemplary illustration of the significant impact that AI might have on a global scale [4]. AI tends to enhance the efficacy, productivity, and ecological sustainability of the whole food supply chain. The process encompasses several stages, spanning from crop cultivation to ultimate consumption, helped by innovative technologies [5]. AI is a technical advancement that utilizes data, machine learning algorithms, automated procedures, and predictive analytics to facilitate substantial changes within the food industry [6]–[8].

An extensive examination of a noteworthy advancement in the progression of food systems is very crucial [9]. The current study examined the possible implications of AI-driven approaches on the modification of established legal structures, with the objective of tackling two prominent social concerns. These social concerns include guaranteeing a sufficient food supply for a swiftly expanding population and secondly preserving the environment for forthcoming generations. The study attempted to undertake a comprehensive examination of the intricate realm of AI-driven optimization and its ramifications on many facets of agriculture. The elements described above include the advancement of agricultural techniques, the enhancement of food safety measures, the optimization of supply chain operations, and the evaluation of business efficacy in food industry. Through a thorough analysis of the most recent developments, case studies, and prospects, this review intended to help the future generations by providing light on the way forward. A path that ensures resilience, sustainability, and prosperity of the global food supply chain in an era of unprecedented change.

II. ARTIFICIAL INTELLIGENCE (AI): PIONEERING THE FUTURE OF INNOVATION

AI is a highly influential and transformative phenomenon that is fundamentally reshaping several aspects of human life [10]. It is a field that originated in the domain of computer science and machine learning including advanced cognitive capabilities comparable to those shown by human beings [11]. The present methodology surpasses the previously established benchmarks of practicability via the use of data and algorithms [12]. Essentially, the goal of AI is to replicate human intelligence by endowing machines with the ability to learn, think, and act independently [13]. This cutting-edge technology is already influencing our daily lives. Examples include voice-activated personal assistants and recommendation algorithms that tailor our online experiences.

The integration of AI has significant impacts on healthcare industry, particularly in the domains of illness identification,

treatment suggestions, and administrative process optimization [14] , [15]. The integration of AI technology into autonomous vehicles shows potential to enhance both safety and efficiency. The banking sector effectively utilizes AI technology to analyze large amounts of data, enabling the detection of fraudulent activities and the discovery of favorable financial opportunities [16]. The incorporation of AI is becoming more prevalent in the field of arts, leading to discernible impacts [17]. The individual engages in active involvement to produce literary works, musical compositions, and visual art. The incorporation of AI into customized learning systems is precipitating a substantial transformation within the realm of education.

AI applications may be found in a variety of fields, including agriculture and entertainment industry [18]. It encourages the growth of smart cities, which improves the efficiency and sustainability of urban life. Moreover, it has also a considerable influence on science, speeding up the discovery of new knowledge in fields, such as genetics and particle physics [19].

AI presents a world of unprecedented convenience and inventiveness, however, it also poses moral and societal issues including privacy issues, job displacement, and bias in algorithms [20]. Overcoming these challenges is essential to ensure AI continues to be a positive force that enhances people's lives and raises the bar for what is deemed possible [21]. As AI advances, it has the limitless potential to transform entire industries, reshape the future, and create new avenues for human progress [22].

III. FOOD SUPPLY CHAIN: A COMPLEX NETWORK OF NOURISHMENT

The worldwide network of food that links farmers, producers, distributors, retailers, and consumers is known as the food supply chain. It is a huge, intricate network [23]. Food is accessible to everyone on earth due to a complex system that encompasses food development, harvesting, processing, packing, distribution, and transportation. Grazing crops and satisfying hunger are the start and finish of this dynamic and complex trip [24]. In addition to physical transportation of items, food supply chain is a focal point for social, ethical, environmental, and economic problems. It is crucial for the global economy and has a considerable impact on many countries' GDPs. Furthermore, it generates a great deal of employment, supporting the lives of millions of people globally, from city logistics workers to small-scale farmers [25].

Sustainability is one of the key elements of the contemporary food supply chain. The environment and available resources are under unprecedented pressure due to growing global population [26]. Sustainable food production and distribution networks aim to achieve three key objectives. These objectives include minimizing food waste, conserving resources, and reducing the carbon footprint of food production.

The industry is coming up with creative solutions to these issues, such as using eco-friendly packaging and cutting down on food waste [27]. An additional crucial link in food supply chain is food safety. Ensuring the safety of food products is imperative to safeguard the general public's health [28]. At different points in food supply chain, strict guidelines, quality

control techniques, and inspections are put in place to ensure the integrity and safety of food products. Technological innovations play an essential role to streamline the food supply chain. Technological developments, such as blockchain have increased traceability and accountability by enabling transparent tracking of food products, from the farm to the fork [29]. Demand forecasting, quality control, and supply chain management are all aided by AI, which boosts output and lowers waste.

The COVID-19 pandemic, in recent years, has highlighted the fragility of food supply chain. Systemic vulnerabilities were revealed by supply chain bottlenecks, labor shortages, and disruptions in transportation network. This crisis has made it necessary to be more flexible and adaptive as well as to reevaluate the resilience of the supply chain [30]. In summary, the intricate web of linked ecosystems that supports life is known as the 'global food chain'.

Its effectiveness, adaptability, and resilience are crucial to meet the needs of a changing global environment as well as guaranteeing that everyone has access to wholesome food [31]. Innovation, sustainability, and dedication to addressing current needs without jeopardizing those of future generations will drive changes in food supply chain [32].

IV. AI-DRIVEN OPTIMIZATION OF FARM-TO-CONSUMER FOOD SUPPLY CHAIN

The way we produce, transport, and consume food is revolutionized by AI-driven optimization of farm-to-consumer food supply chain [33]. This novel strategy increases corporate performance, sustainability, and productivity in food business by utilizing AI. AI is crucial to precision agriculture since it provides farmers with access to the current data on crop health, weather patterns, and soil conditions [34]. Farmers may boost crop yield and manage resources more efficiently by using this information.

AI algorithms in supply chain management predict demand, optimize workflows, and reduce waste guaranteeing that consumers receive food that is safer and fresher. AI-driven quality control systems that identify abnormalities and pollutants in production processes improve food safety [35]. AI aids in resource efficiency, reducing environmental impact as sustainability gains importance. With its unmatched potential to transform agricultural methods, enhance food safety, and promote sustainability, this technology presents a bright future for the food supply chain from the farm to the plate [36].

Different researches have been published in food sector on food supply and food safety using AI. These researches have uncovered how AI could detect and monitor the food quality assessment [37]. A review on food supply chain management has been published covering majorly demand forecasting, supplier selection, and only two studies have mentioned supply chain management process [38]. Although, quite a few studies have been published on food supply chain management, still the current study solely emphasized supply chain management process (farm to consumer) as summaries in Table I.

TABLE I
SUMMARY OF SUPPLY CHAIN LITERATURE

Authors	Variables	Methods	Results
Mamoudan et al. [39]	Environmental pollutants, production waste, food waste, water usage and manufacturing costs and time	Hybrid Machine Learning	Significantly enhances the efficiency and sustainability
Harini et al. [40]	Supply chain management transparency	IoT sensors, Machine Learning Algorithms	This study explores that smart contracts can be leveraged to enhance farmers' ease in claiming insurance
Dora et al. [41]	Technological Readiness, Security.	Rough-SWARA Approach	TOEH theory ranks AI adoption factors in the Indian food supply chain, aiding decision-makers with impactful insights.
Donaldson [42]	Food System	Digital tools, big data	Digital tech transforms certification, enhancing food integrity and supply chains. Study delves into alliances, politics, and info management complexities.
Santoso et al. [43]	Agri-food Supply Chain	Machine Learning	Explores the transformative potential of machine learning in the agri-food supply chain. The study systematically examines its role in providing real-time analytical insights for proactive decision-making, emphasizing its pivotal role in enhancing productivity and sustainability [33].
Ngam and Tan [44]	Food Supply Chains	Digitalization	The study explores digitalizing food supply chains through three Thai food manufacturing cases, revealing challenges and opportunities.

Authors	Variables	Methods	Results
Khan et al. [45]	Food safety and supply chain transparency	Deep Learning	Accurate predictions for supply chain practitioners informed decision-making
Alfian et al. [46]	Trace products, record temperature and humidity	Machine Learning	Accurately track product in supply chain
Mangla et al. [47]	Sustainability in Agri-Food Supply Chains	DEMATEL framework	The study identifies and analyzes ten pivotal sustainability-driven enablers in Agri-Food Supply Chains using Interpretive Structural Modeling.
Li and Wang [48]	Product Demand	Bayesian network, Deduction Graph	Informed production decisions in the food supply chain.

Table 1 shows the outcomes obtained from various AI, food supply chain management in previous research on food products and their supply chain management.

The current research presented a hybrid model to optimize agricultural supply chains. The approach combined particle swarm optimization for feature selection, a Convolutional Neural Network (CNN), coupled with a Gated Recurrent Unit, fine-tuned through a genetic algorithm. The results from this predictive model were used to design a multi-objective model that aims to optimize supply chain profitability while tackling issues, such as environmental pollutants, production waste, food waste, water usage, and manufacturing costs and time. By using a case study from Iran, the effectiveness of the proposed approach was tested. The outcomes suggested that the incorporation of these advanced optimization methods and predictive models significantly enhanced the efficiency and sustainability of agricultural supply chains. Apart from this, the current study also provided a practical framework that could be used by managers and policymakers to improve supply chain operations and address sustainability issues [39].

The incorporation of blockchain technology in Indian agriculture, as explored by Harini et al. [40], enhanced supply chain management and transparency. Their study investigated the impact of blockchain technology on India's agricultural efficiency by integrating IoT sensors for data collection and machine learning algorithms for predictive analytics. This data was then recorded on a blockchain ledger, ensuring transparency and reducing the supply chain's susceptibility to fraud. Their approach underscored the immutability of blockchain to facilitate transparent transactions and demonstrated how smart contracts can be leveraged to enhance farmers' ease in claiming insurance.

Researchers explored the key success factors (CSFs) that impact the Indian food

supply chain's adoption of AI. Their study used rough-SWARA approach, which is based on the Technology, Organization, Environment, and Human (TOEH) theory, to rank and prioritize these elements. The main CSFs for AI adoption in food supply change, according to key studies, are technological readiness, security, privacy, customer happiness, perceived advantages, demand volatility, regulatory compliance, competitive pressure, and information sharing among partners. The supply chain experts, government agencies, and vendors of AI technology may all benefit greatly from these findings as they work to develop rules that effectively encourage the implementation of AI in food supply chain industry. Their research advances our knowledge of the dynamics of AI adoption in food supply chain and has useful results for stakeholders and decision-makers [41].

A study investigated the introduction of big data applications and smart farming in agriculture, as well as the larger backdrop of digitalizing food infrastructure. With an emphasis on digital tools for traceability and transparency in food supply chains from farm to fork, the study questioned the idea that digitalization is only a technical means of addressing supply chain issues. Rather, it emphasized how food systems are interrelated. The researchers demonstrated how digital technologies are reshaping the infrastructures of certification in an effort to guarantee food integrity and supply chain management. As food goods move from manufacture to consumption via supply chain, this process determines their characteristics. The research showed how power dynamics are at play in the continual process of infrastructure, which makes certain players demand more labor. It also looked at the possibility of new alliances and politics emerging from improved access to high-quality information. In addition, the research also highlighted significant issues with information management, which are complicated by differing definitions of transparency. The current study highlighted the need for a sophisticated understanding of power, labor, and information control in the developing field of smart agriculture by shedding light on complex concerns underlying the digital transformation of food systems [42].

Santoso et al. [43] explored the comprehensive landscape of agri-food supply chain, encompassing agriculture, production, packaging, warehousing, distribution, transportation, and marketing. Significantly, it underscored the transformative potential of data analytics through emerging 'smart' technologies, such as the IoT, machine learning, and cloud computing. Focusing specifically on machine learning applications, the study systematically examined their role in providing real-time analytical insights for proactive, data-driven decision-making throughout the agri-food supply chain. This framework serves as a valuable guide for researchers, practitioners, and policymakers, emphasizing the pivotal role of machine learning in enhancing productivity and sustainability across the agri-food sector.

The potential for digitalization to revolutionize food supply chains is paramount, responding to consumer demands for real-time information and sustainability transparency. This shift poses critical concerns for all stakeholders, from farmers to retailers. Despite the substantial benefits, digitalizing traditional food supply chains proves challenging and resource-intensive, especially in developing countries with complex distribution networks. The existing literature primarily focuses on the

advantages of digitalization, lacking insights into practical implementation. Through three Thai food manufacturing cases, the current study delved into the practices, challenges, and opportunities of digitalizing food supply chains. It proposed a framework, discussing its implications for research and practical applications in enhancing supply chain digitalization [44].

The intersection of IoT and blockchain technology, within the food industry, has been explored with the aim of enhancing food safety and supply chain transparency. A notable contribution to this area is the development of an advanced deep learning model that employs a combination of recurrent neural networks, specifically long short-term memory and gated recurrent units, optimized through genetic algorithms. This model provides valuable insights for food supply chain management, ensuring end-to-end visibility and enabling consumers to verify the provenance of their food. The application of such a model demonstrates significant improvements in handling large-scale data and providing accurate predictions for supply chain practitioners, thereby fostering informed decision-making supported by robust technological solutions [45].

A study suggested an innovative system for food quality assurance by using IoT-based technology, RFID, and raspberry pi sensors. These tools were employed to trace the products and record temperature and humidity during product supply chain. Machine learning model was used to predict future temperatures and provide early warnings if needed. As compared to traditional methods, the proposed system proved more effective in accurate product tracking and sensor data prediction. These findings contributed to the development of technology-driven initiatives in maintaining food safety and quality [46].

The escalating demands on agriculture due to rapid industrialization, global food needs, and heightened concerns about food quality necessitate a critical focus on sustainability and supply chain transparency in the agri-food sector. The researchers examined key enablers to implement sustainable initiatives in agri-food supply chains. Through a rigorous literature review and expert consultation, ten pivotal sustainability-driven enablers were identified and analyzed using an Interpretive Structural Modeling -fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) framework. The empirical case study, centered on an Indian vegetable and fruit retail supply chain, validates the applicability of the proposed framework, offering insights for practitioners and researchers in advancing sustainability initiatives in the agri-food business sector [47].

An analytical framework was developed to enhance the decision-making processes in food supply chain by using considerable amount of data. The research took advantage of a Bayesian network to generate an informed production decision model. Sample data was integrated using the Bayesian network, identifying causality amongst data to effectively forecast market demand. The research introduced deduction graph model which translates product demand into processes and subsequently into tasks and assets. The results highlighted the efficiency of deduction graph model in incorporating different departmental production processes, thereby promoting profit optimization. To find the optimal solution, the model was translated into a minimum-cost flow problem. The findings of this study demonstrated vast potential of utilizing big data in making informed production decisions in food supply chain. However, the appropriate

application of such a framework requires technological support [48].

Li and Wang [49] focused on how tracking and sensory technologies can help to manage the data in supply chains, particularly in relation to chilled food products. A prototype tool was used to process unstructured sensor data to assist in decision-making. One innovative approach this study uncovered was using sensor data to predict how much shelf-life was left for perishable foods, which, in turn, influenced pricing decisions. The researchers ran numerical analyses with different situations and product types to test this process. The results were promising, as the digital transformation of supply chains through big data brought about a successful pricing model and better performance in the chilled food sector.

V. CHALLENGES IN IMPLEMENTING AI IN SUPPLY CHAIN MANAGEMENT

A. DATA QUALITY AND INTEGRATION

The effective implementation of AI in supply chain management relies heavily on the availability and quality of the data. Ensuring seamless integration of diverse data sources and maintaining data accuracy remains a significant challenge [50].

B. CHANGE MANAGEMENT

Introducing AI-driven processes often requires a cultural shift within organizations. Resistance to change, lack of understanding, and the need for upskilling the existing workforce members pose challenges to successful adoption [51].

C. COST OF IMPLEMENTATION

The initial investment required for implementing AI technologies can be substantial. Small and medium-sized enterprises (SEMs), in particular, may face financial constraints in adopting AI solutions, limiting their ability to compete with larger players [52].

D. CYBERSECURITY CONCERNS

As supply chains rely more and more on networked technology and data exchange, they are exposed to cybersecurity threats. Safeguarding the personal information and ensuring the security of AI-driven systems is necessary to avoid any breaches [53].

E. INTEROPERABILITY PROBLEMS

Ensuring effective communication and collaboration between different AI systems and legacy technologies may be challenging. Interoperability issues might arise when integrating AI into the supply chain infrastructures that are in place now [54].

VI. FUTURE PROSPECTS IN AI-ENHANCED SUPPLY CHAIN MANAGEMENT

A. ADVANCED PREDICTIVE ANALYTICS

AI in supply chain management is used to carry out more sophisticated predictive analytics. Demand forecasting will become more accurate as AI algorithms develop, allowing companies to better control inventory levels and reduce stockouts.

B. AUTONOMOUS SUPPLY CHAIN OPERATIONS

The development of autonomous systems, made possible by AI and machine learning, increase the level of automation in supply chain processes. Automated vehicles, robotic devices, and drones streamline logistics and warehousing processes.

C. BLOCKCHAIN INTEGRATION

When AI and blockchain technologies are combined, supply chains might become more traceable and transparent. Since blockchain technology creates a secure, immutable record of all transactions done throughout the whole supply chain, it can ensure data integrity.

D. REAL-TIME DECISION-MAKING

AI will be able to manage massive amounts of real-time data as it develops in sophistication. Due to their ability to make decisions more swiftly and wisely, supply chain managers would be better able to adapt to the general shifting conditions of the market.

E. INTEGRATION OF SUSTAINABILITY

Developing and implementing sustainable supply chain processes need AI. AI may help businesses plan their operations with eco-friendly initiatives, from reducing their impact on the environment to optimizing resource use.

F. COLLABORATIVE AI ECOSYSTEMS

In the future, cooperative AI ecosystems, where suppliers and distributors share data and insights intuitively, may become more prevalent in supply chains. This collaborative approach might lead to more efficient decision-making throughout the whole supply chain network.

G. ALGORITHMS FOR ONGOING LEARNING

AI algorithms will get more versatile and capable to learn consistently. AI systems are effective and relevant even when organizational demands and market circumstances change due to their adaptability.

VII. CONCLUSION

AI has revolutionized supply chain management by creating hitherto unimaginable potential to boost productivity, cut expenses, and has also helped to lower the risks. The publications under examination demonstrate various uses of AI in supply chain management, such as compliance tracking, demand forecasting, and predictive analytics. When it comes to using AI, supply chain management has several difficulties despite the clear advantages. It needs concentrated efforts to ensure accuracy and streamline data sources, since there are still problems with data integration and quality. The human factor is still crucial, highlighting the need of change management and specifically employee upskilling. This emphasizes how crucial it is to get rid of institutional and cultural obstacles to use AI effectively. Furthermore, integrating AI technology is expensive, and cybersecurity issues present serious challenges, especially for smaller businesses with less budgets. The use of AI in supply chain management seems to have a bright future. Demand forecasting and inventory optimization will be revolutionized by advanced predictive analytics powered by ever-more complicated algorithms. Drones and autonomous cars are two examples of autonomous technology that have the potential to completely transform warehouse and logistics operations, improving supply chains' responsiveness and adaptability. Sustainability is a key focus for future, with AI expected to play a pivotal role in optimizing resource usage and minimizing environmental impact. Collaborative AI ecosystems and facilitating seamless data sharing among supply chain entities, offer a glimpse into a more interconnected and efficient future.

REFERENCES

[1] M. De Lillo and H. J. Ferguson, "Kent academic repository," *Eur. J. Soc. Psychol.*, vol. 40, no. 2, pp. 366–374, 2022.

[2] K. Mahroof, A. Omar, and B. Kucukaltan, "Sustainable food supply chains: Overcoming key challenges through digital technologies," *Int. J. Product. Perform. Manag.*, vol. 71, no. 3, pp. 981–1003, Oct. 2022, doi: https://doi.org/10.1108/IJPPM-12-2020-0687

[3] J. Monteiro and J. Barata, "Artificial intelligence in extended agri-food supply chain: A short review based on bibliometric analysis," *Procedia Comput. Sci.*, vol. 192, pp. 3020–3029, 2021, doi: https://doi.org/10.1016/j.procs.2021.09.074

[4] P. A. Hennelly, J. S. Srai, G. Graham, and S. F. Wamba, "Rethinking supply chains in the age of digitalization," *Prod. Plan. Control*, vol. 31, no. 2–3, pp. 93–95, 2020, doi: http://doi.org/10.1080/09537287.2019.1631469

[5] A. Iftekhar, X. Cui, M. Hassan, and W. Afzal, "Application of blockchain and internet of things to ensure tamper-proof data availability for food safety," *J. Food Qual.*, vol. 2020, June 2020, doi: https://doi.org/10.1155/2020/5385207

[6] H. Anwar, T. Anwar, and M. S. Murtaza, "Applications of electronic nose and machine learning models in vegetables quality assessment: A review," in *Proc. 2023 IEEE Int. Conf. Emerg. Trends Eng. Sci. Technol. ICES,* Jan. 2023, doi: https://doi.org/10.1109/ICEST56843.2023.10138839

[7] D. Enériz, N. Medrano, and B. Calvo, "An FPGA-Based machine learning tool for in-situ food quality tracking using sensor fusion," *Biosensors*, vol. 11, no. 10, Art. no. 366, Sep. 2021, doi: https://doi.org/10.3390/BIOS11100366

[8] T. Anwar and H. Anwar, "Beef quality assessment using AutoML," *Proc. 2021 Mohammad Ali Jinnah Univ. Int. Conf. Comput., MAJICC 2021*, Jul. 2021, doi: https://doi.org/10.1109/MAJICC53071.2021.9526256

[9] G. Zhao *et al.*, "Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions," *Comput. Ind.*, vol. 109, pp. 83–99, Aug. 2019, https://doi.org/10.1016/j.compind.2019.04.002

[10] Y. K. Dwivedi *et al.*, "Artificial intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy," *Int. J. Inf. Manage*, vol. 57, Art. no. 101994, Apr. 2021, doi: https://doi.org/10.1016/J.IJINFOMGT.2019.08.002

[11] P. Akhtar, S. Kaur, and K. Punjaisri, "Chain coordinators' strategic leadership and coordination effectiveness: New Zealand-Euro agri-food supply chains," *Eur. Bus. Rev.*, vol. 29, no. 5, pp. 515–533, 2017, doi: https://doi.org/10.1108/EBR-08-2015-0082

[12] F. R. Lima-Junior and L. C. R. Carpinetti, "Quantitative models for supply chain performance evaluation: A literature review," *Comput. Ind. Eng.*, vol. 113, pp. 333–346, Sep. 2017, doi: https://doi.org/10.1016/j.cie.2017.09.022

[13] V. S. Kodogiannis, "Application of an electronic nose coupled with fuzzy-wavelet network for the detection of meat spoilage," *Food Bioproc. Tech.*, vol. 10, no. 4, pp. 730–749, Apr. 2017, doi: https://doi.org/10.1007/s11947-016-1851-6

[14] T. Anwar and H. Anwar, "LSNet: A novel CNN architecture to identify wrist fracture from a small X-ray dataset," *Int. J. Info. Technol.*, vol. 15, no. 5, pp. 2469–2477, June 2023, doi: https://doi.org/10.1007/S41870-023-01311-W/TABLES/7

[15] I. Chaudhary, H. Anwar, U. Latif, and A. Latif, "Role of artificial intelligence in different aspects of Public Health," *UMT Art. Intell. Rev*, vol. 2, no. No 2, Dec. 2022, doi: https://doi.org/10.32350/UMTAIR.22.03

[16] H. U. Khan *et al.*, "Transforming the capabilities of artificial intelligence in gcc financial sector: A systematic literature review," *Wirel. Commun. Mob. Comput.*, vol. 2022, Art. no. 8725767, doi: https://doi.org/10.1155/2022/8725767

[17] M. Mazzone and A. Elgammal, "Art, creativity, and the potential of artificial intelligence," *Arts*, vol. 8, no. 1, Art. no. 26, Feb. 2019, doi: https://doi.org/10.3390/ARTS8010026

[18] I. H. Sarker, "AI-Based modeling: Techniques, applications and research issues towards automation, intelligent and smart systems," *SN Comput. Sci.*, vol. 3, no. 2, pp. 1–20, Feb. 2022, doi: https://doi.org/10.1007/S42979-022-01043-X

[19] Y. Xu *et al.*, "Artificial intelligence: A powerful paradigm for scientific research," *The Innov.*, vol. 2, no. 4, Art. no. 100179, Nov. 2021, doi: https://doi.org/10.1016/J.XINN.2021.100179

[20] A. Almusaed, I. Yitmen, and A. Almssad, "Reviewing and integrating AEC practices into industry 6.0: Strategies for smart and sustainable future-built environments," *Sustainabilit*y, vol. 15, no. 18, Art. no. 13464, Sep. 2023, doi: https://doi.org/10.3390/SU151813464

[21] S. Chatterjee, R. Chaudhuri, D. Vrontis, and G. Giovando, "Digital workplace and organization performance: Moderating role of digital leadership capability," *J. Innov. Knowled.*, vol. 8, no. 1, Art. no. 100334, 2023, doi: https://doi.org/10.1016/j.jik.2023.100334

[22] S. Makridakis, "The forthcoming Artificial Intelligence (AI) revolution: Its impact on society and firms," *Futures*, vol. 90, pp. 46–60, June 2017, doi: https://doi.org/10.1016/J.FUTURES.2017.03.006

[23] G. Berti and C. Mulligan, "Competitiveness of small farms and innovative food supply chains: The role of food hubs in creating sustainable regional and local food systems," *Sustainability*, vol. 8, no. 7, Art. no. 616, July 2016, doi: https://doi.org/10.3390/SU8070616

[24] A. Mittal, C. C. Krejci, and T. J. Craven, "Logistics best practices for regional food systems: A review," *Sustainability*, vol. 10, no. 1, Art. no. 168, Jan. 2018, doi: https://doi.org/10.3390/SU10010168

[25] S. M. Schnell, "Food miles, local eating, and community supported agriculture: Putting local food in its place," *Agric. Hum. Val.*, vol. 30, no. 4, pp. 615–628, 2013, doi: https://doi.org/10.1007/S10460-013-9436-8

[26] V. Borsellino, E. Schimmenti, and H. El Bilali, "Agri-Food markets towards sustainable patterns," *Sustainability*, vol. 12, no. 6, Art. no. 2193, Mar. 2020, doi: https://doi.org/10.3390/SU12062193

[27] C. Feldmann and U. Hamm, "Consumers' perceptions and preferences for local food: A review," *Food Qual. Prefer*, vol. 40, pp. 152–164, Mar. 2015, doi: https://doi.org/10.1016/J.FOODQUAL.2014.09.014

[28] Z. Nakat and C. Bou-Mitri, "COVID-19 and the food industry: Readiness assessment," *Food Cont.*, vol. 121, Art. no. 107661, Mar. 2021, doi: https://doi.org/10.1016/J.FOODCONT.2020.107661

[29] M. Westerlund, S. Nene, S. Leminen, and M. Rajahonka, "An exploration of blockchain-based traceability in food supply chains: On the benefits of distributed digital records from farm to fork," *Tech. Innov. Manag. Rev.*, vol. 11, no. 6, pp. 6–19, June 2021, doi: https://doi.org/10.22215/TIMREVIEW/1446

[30] M. Lezoche, H. Panetto, J. Kacprzyk, J. E. Hernandez, and M. M. E. A. Díaz, "Agri-food 4.0: A survey of the Supply Chains and Technologies for the Future Agriculture," *Comput. Ind.*, vol. 117, Art. no. 103187, May 2020, doi: https://doi.org/10.1016/j.compind.2020.103187

[31] D. Denkenberger, A. Sandberg, R. J. Tieman, and J. M. Pearce, "Long term cost-effectiveness of resilient foods for global catastrophes compared to artificial general intelligence safety," *Int. J. Disas. Risk Reduc.*, vol. 73, Art. no. 102798, Apr. 2022, doi: https://doi.org/10.1016/J.IJDRR.2022.102798

[32] D. J. McClements *et al.*, "Building a resilient, sustainable, and healthier food supply through innovation and technology," *Ann. Rev. Food Sci. Technol.*, vol. 12, pp. 1–28, Mar. 2021, doi: http://doi.org/10.1146/ANNUREV-FOOD-092220-030824

[33] G. Rahmann *et al.*, "Organic agriculture 3.0 is innovation with research," *Org. Agric.*, vol. 7, no. 3, pp. 169–197, Dec. 2016, doi: https://doi.org/10.1007/S13165-016-0171-5

[34] T. Anwar and H. Anwar, "Citrus plant disease identification using deep learning with multiple transfer learning approaches," *Pak. J. Eng. Technol.*, vol. 3, no. 2, pp. 34–38, Apr. 2020, doi: https://doi.org/10.51846/VOL3ISS2PP34-38

[35] A. Iftekhar and X. Cui, "Blockchain-Based traceability system that ensures food safety measures to protect consumer safety and COVID-19 free supply chains," *Foods*, vol. 10, no. 6, Art. no. 1289, June 2021, doi: https://doi.org/10.3390/FOODS10061289

[36] R. R. Mohamed, W. Hashim, T. M. Azahar, R. Yaakob, M. A. Mohamed, and K. A. A. Bakar, "Food

freshness detection using smart machine learning classification," *J. Pharm. Neg. Results*, vol. 13, pp. 7410–7426, Jan. 2023, doi: https://doi.org/10.47750/pnr.2022.13.S09.868

[37] H. Anwar, T. Anwar, and S. Murtaza, "Review on food quality assessment using machine learning and electronic nose system," *Biosens. Bioelec.*, vol. 14, Art. no. 100365, Sep. 2023, doi: https://doi.org/10.1016/J.BIOSX.2023.100365

[38] R. Toorajipour, V. Sohrabpour, A. Nazarpour, P. Oghazi, and M. Fischl, "Artificial intelligence in supply chain management: A systematic literature review," *J. Bus. Res.*, vol. 122, pp. 502–517, Jan. 2021, doi: https://doi.org/10.1016/J.JBUSRES.2020.09.009

[39] M. M. Mamoudan, A. Jafari, Z. Mohammadnazari, M. M. Nasiri, and M. Yazdani, "Hybrid machine learning-metaheuristic model for sustainable agri-food production and supply chain planning under water scarcity," *Resour. Environ. Sustainab.*, vol. 14, Art. no. 100133, Dec. 2023, doi: https://doi.org/10.1016/J.RESENV.2023.100133

[40] M. Harini, D. Dhinakaran, D. Prabhu, S. M. U. Sankar, V. Pooja, and P. K. Sruthi, "Levarging blockchain for transparency in agriculture supply chain management using iot and machine learning," *2023 World Conf. Commun. Comput.*, July 2023, doi: https://doi.org/10.1109/WCONF58270.2023.10235156

[41] M. Dora, A. Kumar, S. K. Mangla, A. Pant, and M. M. Kamal, "Critical success factors influencing artificial intelligence adoption in food supply chains," *Int. J. Produc. Res.*, vol. 60, no. 14, pp. 4621–4640, 2022, doi: https://doi.org/10.1080/00207543.2021.1959665

[42] D. A. Donaldson, "Digital from farm to fork: Infrastructures of quality and control in food supply chains," *J. Rural. Stud.*, vol. 91, no. Sept. 2020, pp. 228–235, 2022, doi: https://doi.org/10.1016/j.jrurstud.2021.10.004

[43] I. Santoso, M. Purnomo, A. A. Sulianto, and A. Choirun, "Machine learning application for sustainable agri-food supply chain performance: A review," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 924, no. 1, 2021, doi: https://doi.org/10.1088/1755-1315/924/1/012059

[44] P. Kittipanya-ngam and K. H. Tan, "A framework for food supply chain digitalization: lessons from Thailand," *Prod. Plan. Control*, vol. 31, no. 2–3, pp. 158–172, 2020, doi: https://doi.org/10.1080/09537287.2019.1631462

[45] P. W. Khan, Y. C. Byun, and N. Park, "IoT-Blockchain enabled optimized provenance system for food industry 4.0 using advanced deep learning," *Sensors,* vol. 20, no. 10, Art. no. 2990, May 2020, doi: https://doi.org/10.3390/S20102990

[46] G. Alfian, M. Syafrudin, N. L. Fitriyani, J. Rhee, M. R. Ma'arif, and I. Riadi, "Traceability system using IoT and forecasting model for food supply chain," *2020 Int. Conf. Decision Aid Sci. Appl.*, Nov. 2020, pp. 903–907, doi: https://doi.org/10.1109/DASA51403.2020.9317011

[47] S. K. Mangla, S. Luthra, N. Rich, D. Kumar, N. P. Rana, and Y. K. Dwivedi, "Enablers to implement sustainable initiatives in agri-food supply chains," *Int. J. Produc. Econ.*, vol. 203, pp. 379–393, Sep. 2018, doi: https://doi.org/10.1016/j.ijpe.2018.07.012

[48] G. Ji, L. Hu, and K. H. Tan, "A study on decision-making of food supply chain based on big data," *J. Syst. Sci. Syst. Eng.*, vol. 26, no. 2, pp. 183–198, Apr. 2017, doi: https://doi.org/10.1007/S11518-016-5320-6/METRICS

[49] D. Li and X. Wang, "Dynamic supply chain decisions based on networked sensor data: an application in the chilled food retail chain," *Int. J. Produc. Res.*, vol. 55, no. 17, pp. 5127–5141, Sep. 2017, doi: https://doi.org/10.1080/00207543.2015.1047976

[50] S. K. Jagatheesaperumal, M. Rahouti, K. Ahmad, A. Al-Fuqaha, and M. Guizani, "The duo of artificial intelligence and big data for industry 4.0: Applications, techniques, challenges, and future research directions," *IEEE Inter. Things J.*, vol. 9, no. 15, pp. 12861–12885, Aug. 2022, doi: https://doi.org/10.1109/JIOT.2021.3139827

[51] S. Chowdhury *et al.*, "Unlocking the value of artificial intelligence in human resource management through AI capability framework," *Hum. Resour. Manag. Rev.*, vol. 33, no. 1, Art. no. 100899, Mar. 2023, doi: https://doi.org/10.1016/J.HRMR.2022.100899

[52] V. Soni, "Impact of generative AI on small and medium enterprises' revenue growth: The moderating role of human, technological, and market factors," *Rev. Contemp. Bus. Anal.*, vol. 6, no. 1, pp. 133–153, Aug. 2023.

[53] M. K. Aiden, S. M. Sabharwal, S. Chhabra, and M. Al-Asadi, "AI and blockchain for cyber security in cyber-physical system," pp. 203–230, 2023, doi: https://doi.org/10.1007/978-3-031-31952-5_10

[54] S. Pan, D. Trentesaux, D. McFarlane, B. Montreuil, E. Ballot, and G. Q. Huang, "Digital interoperability in logistics and supply chain management: state-of-the-art and research avenues towards physical internet," *Comput. Ind.*, vol. 128, Art. no. 103435, Jun. 2021, doi: https://doi.org/10.1016/J.COMPIND.2021.103435