**Unraveling the Role of Information and Communication Technology (ICT) in Food Systems**

**Surabhi Pandey and Dr. Ratna Shanker Mishra**

**Abstract**

India's food processing sector is growing. The food industry, which contributes around 26% of India's GDP, is anticipated to grow significantly over the next several years. This growth requires subsequent management of food production, processing and distribution. The food sector is being pushed more to reveal information about their products in order to maintain quality standards and protect their products from food fraud as the consumers awareness is increasing day by day. A number of tools are included in information and communication technologies (ICT) for the gathering, retrieval, exchange, processing, and transfer of digital data. Global food supply chains might be made better by ICT, which also has the ability to cut operating costs, assure sustainable development through productivity gains, and expand market reach and capacity.

**Keywords:** Information technology, supply chain, food safety, quality

**Introduction**

Over the next ten years, it is predicted that the world's food demand will double, making an increase in supply the only viable option. According to the most recent UN estimate, there are currently 7.3 billion people on the planet, with a predicted increase to 9.7 billion by the year 2050. Together with increased income in developing nations (which prompts dietary changes like eating more meat and protein), this growth is fueling an increase in the world's demand for food. By 2050, the demand for food is anticipated to increase by 59 to 98 percent. Additionally, a number of rumors about food production, security, and safety have emerged, affecting the global commodity markets and demand-supply chain. Increased food loss and deteriorated food quality as a result of insufficient quality monitoring systems across the whole food production, processing, and transportation stages are only two of the problems that the food supply chain is faced with. The increasing global population and rising food consumption are to blame for these problems. Food safety has become a critical issue for developing countries like India, where the demand for food has grown by 60–90% (Kumar et al. 2019, Schmitz et al., 2017). The dairy business is one of many that contribute to the increase in food demand by wasting products. Ineffective storage facilities, tacky packaging, losses resulting from improper transportation management, and inadequate inventory management are the main causes of food waste (Bravi et al., 2019; Bharucha, 2018; Sheahan et al, 2017).

There are several risks and hazards involved with production, processing, transportation, and storage that might swiftly change quality and result in losses in both quantity and quality. In order to address these sustainability challenges in agri-food systems without diminishing other resources, it is crucial to do so. The food sector is being pushed more to reveal information about their products in order to maintain quality standards and protect their products from food fraud. Examples of information and communication technology (ICT) include desktop and laptop computers, software, external devices, and Internet connections. ICT is a field of study and research that focuses on these and other technologies that are used to process and communicate information. Customers can now immediately address their demands thanks to information technology (IT), and businesses can now manage their supply chains more quickly to satisfy client demand. The role of food integrity assurance may be transformed from one that strictly adheres to compliance to one that addresses a wide range of business-critical concerns, including quality, safety, and authenticity solutions, thanks to recent advances in IT and big data analytics. In the transportation, storage, processing, and packaging of food products, the Internet of Things (IoT) and wireless sensors are becoming more and more significant. The information gathered by wireless sensor technologies at each step of the product's lifespan along the supply chain may be linked to a traceability system.

Software and hardware standardization—a part of IT application—plays a significant role in the implementation of open systems, not only for supply chain management but also in the packaging industry, given that about 90% of foods, including specialty crops and vegetables, are processed and packaged using machinery and automation technology in developed countries (Cheruvu et al., 2008; Mahalik, 2014). Traceability, for instance, might also involve identifying the packing device. Additionally, faulty equipment reduces production. Machine providers keep a close eye on the tools and machinery used in processing and packaging operations in this regard.

**Components of information and communication technologies**

ICT encompasses a number of steps at the industrial scale, from data collection through processing and display (Figure 1). Getting the essential information from the processing or transportation end points is the first step in data transfer and ICT processing. The target nodes, where the data must be gathered, are equipped with a variety of sensor devices in order to do this. These sensors often gather information in the form of pictures, electrical signal outputs, etc. Applications for chemical and biological sensors are expanding rapidly, and they provide potential applications for quality monitoring across a range of food processing industrial areas. Wireless sensors provide a surprising insight into the possibilities of machine-to-machine (M2M) process control, equipment management, robotic mechanical control, and process control systems in the food sectors through the spatial data collection at the working sites (Wang et al., 2006). Environmental monitoring, machine and process control, facility automation, and food traceability systems are some of the typical uses for these wireless sensors. A wireless sensor network (WSN) typically consists of radio frequency (RF) transmission and receiving systems, electronic-based sensors, microprocessors, and power sources. A torrent of information has resulted from the use of real-time quality monitoring and traceability systems throughout the food supply and processing chains. Even with the aid of computers and simple mathematical analytic techniques, so large data is challenging to analyse. Recent research has identified two fast developing technologies that are important to ICT: big data and cloud computing. Through the application of big data analysis technologies, extensive data gathering is translated into information that can be used for operational and commercial decision-making. Big data analysis offers unequaled promise in the chemical processing, pharmaceutical, and food industries, where enormous volumes of data are used in real-time (Chiang et al., 2017).

**Figure 1: Components of ICT**

**Artificial Intelligence (AI) in Food Industry**

Systems utilizing AI and machine vision make enormous data accessible, which is crucial for the processing and manufacturing of food. The introduction of AI-driven processes and equipment into the agricultural and food business has transformed how crops are grown, produced, and processed. Startups in the food industry powered by AI are expanding quickly and have the potential to improve both the public and private food systems in the future decades. Numerous researchers have stressed the need of utilizing AI in robotics, machine learning, computer vision, robotic farming (Sheth et al., 2017), pattern recognition for crop health monitoring (Tian et al., 2020), and demand-driven food supply chains (Griffin et al., 2018). Anselma et al. (2017) created "augmented personalized health," an AI-based program for the food and nutrition industry, to help consumers customize their nutritional consumption. A shift to fewer environmental consequences, improved resilience, and better health might be supported by AI and the food systems (Camarena, 2020). Supply chain management, food sorting, production development, food quality improvement, and excellent industrial hygiene are just a few areas where AI has been applied (Garver, 2018; Sharma, 2019; Utermohlen, 2019).

**Internet of Things (IoT) in Food Industry**

The Internet of Things (IoT) is one of the most significant and recent innovations in the world of IT. IoT in the supply chain can enhance human-to-human connection and object coordination while elevating supply chain communication (Ellis et al., 2015). The Internet of Things is a network of interconnected mechanical and digital computer devices that use sensors attached to machines, animals, and people to provide vast quantities of critical and in-depth data about systems that can be used to enhance them. By upholding safety requirements, lowering food waste, handling unanticipated changes, and tracking and monitoring food quality, IoT benefits the food industry. Due to the wide range of sensors that are now on the market and the even wider range of software solutions available for data analysis, IoT applications in the food industry are almost limitless. Deploying IoT enables better overall control over the food supply chain, from raw materials in the plant through product distribution to clients and consumers.

When transporting food, for example, the product may need to address concerns with temperature control, hygiene and pest control, traceability, product management (i.e., movement of goods, damage, rejection, and safety), preventative maintenance of the vehicle/container, and staff management, handling, personal hygiene, safety, policies, and training). All food-related actions may be tracked with the help of the Internet of Things. One of the most efficient and affordable IoT methods for tracking food goods is RFID technology. RFID tags can readily connect over a wireless network and store precise and significant information about the food goods being sent. Alerts are quickly transmitted across the supply chain in the case of a food recall or food safety issue, and the contaminated product is immediately quarantined. The main results obtained by adopting IoT in the food industry are improved food security and control (Balamurugan et al., 2020; Beker et al., 2016), enhanced traceability and transparency in the supply chain (Maksimovic et al., 2015; Grecuccio et al., 2020), strengthening sustainability and minimizing waste (Jagtap et al., 2019; Cho et al., 2017) and optimizing transportation (Kumat et al., 2020; Reddy et al., 2020).

**Table 1: Applications of IoT in Food Industry**

|  |  |  |
| --- | --- | --- |
| **Process** | **Impact** | **Reference** |
| Food Transportation | More precise delivery dates are made possible by systems that can identify and evaluate events, such as traffic accidents, inside a distribution network. | Chauhan et al. (2021) |
| Food Logistics | Tools (such as delivery vans) that can find the quickest or most fuel-efficient route | Moudoud et al. (2019) |
| Food Production | Systems that can be utilized to optimize food production systems without human intervention by automating labor processes and processes | Rejeb et al. (2021) |
| Resource/waste management | reducing the production of food waste, energy use, and water use | Pal and Kant (2020) |
| Maintaining food quality | Systems that can continually check the product quality can detect and instantly correct any deviations from the established criteria. | Kayikci et al. (2020); Khan et al. (2020) |
| Food supply chain | Systems that might result in improved labor management, lower costs, and quicker lead times | Alfian et al. (2020) |

Advantages of ICT –

•Globalization – Video conferencing saves money on flights and accommodation. ICT

has not only brought the countries and people closer together, but it has allowed the

worlds economy to be become a single interdependent system to contact either a business

to make them exceptionally cost effective.

•Cost effectiveness – The feels free to send an email and without doubt cheaper than

phone calls. ICT has also helped to automate business practices, to make them

exceptionally cost effective.

•More Time – You may have your goods delivered right to your doorstep with having to

move a single muscle by clicking the items to be purchased via internet and making

payment electronically.

•Creation of new jobs- The best advantage of ICT has been the creation of new activate

and interesting job. Computer programmers, system, hardware, and software developers

and web designers are some of the many new employment opportunities created with the

help of IT.

•Education – Computer’s along with their programs and the internet have created

educational opportunities not available to previous generations. A degree can be

completed online from person’s home. it is possible to hold a job and still do degree.

Advantages of ICT –

•Globalization – Video conferencing saves money on flights and accommodation. ICT

has not only brought the countries and people closer together, but it has allowed the

worlds economy to be become a single interdependent system to contact either a business

to make them exceptionally cost effective.

•Cost effectiveness – The feels free to send an email and without doubt cheaper than

phone calls. ICT has also helped to automate business practices, to make them

exceptionally cost effective.

•More Time – You may have your goods delivered right to your doorstep with having to

move a single muscle by clicking the items to be purchased via internet and making

payment electronically.

•Creation of new jobs- The best advantage of ICT has been the creation of new activate

and interesting job. Computer programmers, system, hardware, and software developers

and web designers are some of the many new employment opportunities created with the

help of IT.

•Education – Computer’s along with their programs and the internet have created

educational opportunities not available to previous generations. A degree can be

completed online from person’s home. it is possible to hold a job and still do degree.

Globalization – Video conferencing saves money on flights and accommodation. ICT

has not only brought the countries and people closer together, but it has allowed the

worlds economy to be become a single interdependent system to contact either a business

to make them exceptionally cost effective.

•Cost effectiveness – The feels free to send an email and without doubt cheaper than

phone calls. ICT has also helped to automate business practices, to make them

exceptionally cost effective.

•More Time – You may have your goods delivered right to your doorstep with having to

move a single muscle by clicking the items to be purchased via internet and making

payment electronically.

•Creation of new jobs- The best advantage of ICT has been the creation of new activate

and interesting job. Computer programmers, system, hardware, and software developers

and web designers are some of the many new employment opportunities created with the

help of IT.

•Education – Computer’s along with their programs and the internet have created

educational opportunities not available to previous generations. A degree can be

completed online from person’s home. it is possible to hold a job and still do degree.

**Advantages of ICT**

* The rise of globalization - Travel and hotel expenses are decreased with video conferencing. ICT has increased social interaction between people and across nations. It has also allowed for the integration of the global economy into a single, linked system, which has helped corporations communicate and become tremendously efficient.
* Cost-effectiveness - Unquestionably cheaper and more convenient to send than phone calls are emails. ICT has also greatly reduced the cost of business procedures by automating them.
* Extended Time - You may have your items delivered right to your door without lifting a finger by making your selections and making your payment online.
* Development of new jobs: The creation of new, exciting roles has been the major advantage of ICT. Web designers, system, hardware, and software developers, as well as computer programmers, are just a few of the many new jobs that IT has created.
* Educational opportunities - Computers, their programs, and the internet have made it possible for current generations to access educational possibilities that were not possible in the past. Online courses may be taken from home to get a degree. You may work while pursuing your degree.
* Standardization: Machines can help to make work more uniform. No one can afford to disregard the benefits of standardization since it ensures consistency uniformity in both the quality and quantity of work.
* Authenticity and Efficiency: Proper message delivery is essential for the recipient to comprehend in the same spirit and respond appropriately. Accuracy is promoted by the automated and methodical technologies. Efficiency often improves with new technologies (Sooryanarayana et al. 2000).

**Applications**

* **Monitoring the food supply chain, product recalls, and traceability:** Applications of tracking sensors for location and quality tracing of food commodities throughout the supply chain at every level are traced using ICT to increase traceability and the possibility for product recall in the case of a quality change or degradation in the product. Additionally, it improves the supply chain's visibility of food ingredients and their quality. However, the FSC's disjointed structure requires consistency in the design of its traceability. To do that, traceability support models must be created that may synchronize data from different food supply chain segments and analyses to facilitate effective decision-making (Gallo et al., 2021).
* **Quality evaluation of foods using non-destructive methods:** The analytical technique known as near infrared, or NIR, spectroscopy may be used to quickly and accurately examine foods. Food contamination is a constant issue, and the two things that are most frequently contaminated are meat and alcohol. In the food and beverage business as well as the agriculture sector, food quality is a major problem. Food suppliers, retailers, and their clients must all have complete trust in the readily available food on a national and worldwide basis. NIR measurement assists several elements of food processing, such as: Identifying components and additives, composition analysis for food labeling, and the quality control of a wide variety of foods. Detecting food fraud and improving production and manufacturing methods. Due to the availability and applicability of numerous calibration techniques as well as the advancement of contemporary computer science, potential applications in the field of food analysis have garnered a lot of interest. Detecting food fraud and improving production and manufacturing methods. Due to the availability and applicability of numerous calibration techniques as well as the advancement of contemporary computer science1, potential applications in the field of food analysis have garnered a lot of interest. Off-line, anline, on-line, and in-line measurements can be classified depending on how a process is implemented (FAO, 2017; UNEP, 2018; Spaargaren et al. 2013, for example).
* **Consumer transparency:** Greater transparency in product-related information is made possible by ICT technologies, giving consumers a clear understanding of all the necessary product data. Customers may scan and identify any food product with just their phone thanks to the use of numerous scannable tags and labels, including QR codes, NFC tags, data matrix codes, barcodes, and RFID systems. ICT facilitates easy access to information in the food supply chain, but there is a possibility that it may exclude farmers and processors who are not tech-savvy. In order to achieve transparency with a range of food qualities, ICT must be modernized with user interfaces that are simpler for complex and dynamic FSC (Manning, 2018).
* **Food Production:** Agricultural innovation is the timely availability and application of pertinent information to solve opportunities and difficulties. In low-income countries, outreach and advisory organizations commonly use ICTs to notify farmers through SMS, online portals, and call centers about market prices for resources, weather forecasts, crop and animal ailments, and other information (Allahyari et al. 2018; FAO, 2017). The FAO's research and dissemination systems (VERCON) are among the innovative application and service models that have been made possible by ICT. Thanks to ICT, particularly mobile phones, farmers may now inexpensively access financial services (such as savings, credit, insurance, payment methods, and money transfers).
* **Enhanced food safety and quality:** Wireless sensing technologies are used to remotely monitor and communicate the quantitative measurements of temperature, humidity, gas concentrations in storage environments, and other quality characteristics in order to maintain and improve product quality during production, storage, and transportation. The domains of food quality assurance require more research in order to develop cutting-edge methods for assessing food quality that might be integrated with ICT technologies.
* **Sorting Fresh Produce:** The cataloguing of food may be greatly automated by food processing enterprises using cameras, lasers, machine learning, and artificial intelligence, enabling more efficient food sorting. By merging sensor-based optical sorting technologies with artificial intelligence, for instance, the slow, time-consuming techniques for sorting fresh fruit may be abolished, leading to increased yields of better-quality produce and less waste. AI is utilized to reduce costs and waste, handle a variety of product sizes, and enhance machine calibration (Sebastin, 2018).
* **Improved inventory management:** Additionally, ICT-based technologies have been employed to digitally change products using smart packaging, which instantly updates the inventory status of every product and offers simple inventory management options. Organization-specific framework optimization needs to be looked into as soon as possible for efficient inventory management systems in the food sector.
* **Reduction in food wastage:** Product expiry date detection and cloud storage application control aid in reducing food waste at both the industrial and consumer levels. Researchers have lately looked into ways to decrease food waste at consumer points using smart refrigerators with cameras (Liegeard and Manning, 2020), applications for sharing food on mobile devices, information sharing, and advertising-based techniques. The believability of these tactics is, however, only partially supported by measurable data (Reynolds et al., 2019). To significantly reduce food waste, this must be addressed, and additional ICT-based solutions can be investigated.
* **Authenticity assurance:** The availability of authenticating food goods through the use of scannable digital tags also makes it possible to spot fake food products on the market. Additional information is required about how to integrate technology with genuine food supply chains (such as halal FSC) and the difficulties that may arise due to technical immaturity, end users' resistance, and financial and legal constraints (Rejeb et al., 2021).
* **Automation as a shield against pandemic breakouts:** Due to panic purchasing, hoarding, and slumping food outputs with factory closures and personnel absenteeism during the COVID-19 pandemic, there were tremendous stresses on the food supply chain (Mavridou et al., 2019). Automating manufacturing facilities using "machine vision technologies" would reduce food contamination and aid with pandemic-related concerns. It is necessary to further investigate the techno-economic viability of ICT in assessing the dynamically changing food quality in the supply chain caused by toxins found in food and environmental conditions.
* **Sustainability:** A system of production and consumption that is sustainable ensures food security for all people on the world while having the least possible negative effects on the environment. This is accomplished through minimizing waste, improving food production, and utilizing agri-food techniques that are both ecologically and socially sustainable. A useful instrument for achieving sustainability in the food business is the Internet of Things. The IoT allows data to be collected from drones and sensors in fields, silos, and farms. Once processed by the IoT system, this data gives farmers crucial knowledge they need to produce sustainably. It specifically enables farmers to gauge the amount of water used to irrigate their fields, providing information on where it is required and preventing waste, as well as to identify which plants want fertilizer and which require pesticides or how much feed to give cattle (Maroli et al., 2021).

**Table 2: Examples of ICT applications in food industries**

|  |  |  |
| --- | --- | --- |
| **Area** | **Application** | **Reference** |
| Agri-food supply chain | a production, processing, storage, and sales-focused agrifood supply-chain traceability solution that incorporates blockchain and RFID | Tian (2016) |
| Supply Chain | based on HACCP (Hazard Analysis and Critical Control Points), blockchain, and the Internet of Things, built a food supply-chain traceability system for real-time food tracing. | Tian (2017) |
| Fish supply chain | Internet of Things analysis of the idea of virtual food supply networks and a proposal for an architecture to build enabling information systems | Caro et al. 2018 |
| Virtual food supply chain development | To create a virtual food supply chain, IoT-based systems with cloud storage and data processing will be used to track the location, temperature, microbiological information, and other quality criteria of food ingredients. | Verdouw et al. 2016 |
| Process control for improved process quality | Wireless sensors can be used to collect data on temperature or sulfur dioxide, and fuzzy analysis or other big data analytical techniques can be used to make decisions about process control. | Ranasinghe et al. 2013 |
| Supply chain management of perishable food materials | determining food quality and estimating shelf life by keeping an eye on environmental factors and mobility states | Wang et al. 2015 |
| Fruit quality detection | Using wireless sensors, principal component analysis, and gas sensors to detect the concentration of ethylene gas, one may determine the stages of fruit ripening. | Pang et al. 2010 |
| Meat supply chain | Data gathering on the carbon footprint of the meat supply chain at various points and analysis of the data using big data analytical tools for decision-making on activities to reduce the carbon footprint of the meat supply chain | Alfian et al. 2017 |
| Food waste reduction | Intelligent packaging of foods (use of barcodes, QR codes, RFID, gas indicators, time temperature indicators, pathogenic indicators, and biosensors) | Feng et al. 2015 |
| Food waste reduction | Intelligent refrigerators (using barcodes or RFID technology to alert users when food is about to expire, monitoring and controlling temperature and humidity, and identifying purchasing trends using IoT or AI technology) | Qiao et al. 2017 and Shweta (2017) |
| Quality of Milk | IoT and AI applications for the viscosity and other milk quality parameter profiling utilizing wireless sensors to detect adulteration in food products | Rajakumar et al. 2018 |
| Juice Quality Detection | Using an electronic tongue system linked to an Internet of Things system, support vector machine (SVM)-based purity detection may be used for juices. | Ma et al. 2018 |
| Microbial spoilage detection in food materials | Real-time microbial identification using smart sensors made of nanomaterials and deep learning techniques | Alafeef et al. 2020 |
| Agri supply chain | Agriculture made possible by technology has improved food quality, safety, demand and supply balance, real-time information, trackability, and traceability. | Nayal et al. 2021 |
| Dairy supply chain | The primary findings demonstrated that implementing ICTs (information and communication technologies) has a favorable effect on capacity and, as a consequence, increases the effectiveness of the dairy supply chain. | Mohammadi et al (2012) |

**Conclusion**

ICT applications in the food industries are expanding swiftly as a potential technology to achieve green and sustainable advancements. This paper covered in depth the advantages of current ICT trends for supply chain, food waste, food quality, and food safety. Digitalization and automation are anticipated to improve the mutually beneficial interaction between farmers, the food processing industry, and consumers through the application of strategic frameworks. ICT technologies are well-established in many industries, but the food processing industries have not yet embraced the technology required for complete automation, improved production capacity, and cleaner production with minimum waste via the control measures supplied by the data. It is important to look at the economic, environmental, and social sustainability of ICT-based technologies, especially in the context of food processing firms and the supply chain.

**References**

2017 *FAO. Strategic work of FAO for sustainable food and agriculture*

2017 *FAO. The future of food and agriculture: trends and challenges* ISBN978-92-5-109551-5

2018 *UNEP. Sustainable food systems programme* http:// web.unep.org/10yfp/programmes/sustainable-food- systems-programme

Alafeef, M., Moitra, P., Pan, D., 2020. Nano-enabled sensing approaches for pathogenic bacterial detection. Biosens. Bioelectron. 165, 112276. https://doi. org/10.1016/j.bios.2020.112276.

Alfian, G., Rhee, J., Ahn, H., Lee, J., Farooq, U., Ijaz, M.F., Syaekhoni, M.A., 2017. Integration of RFID, wireless sensor networks, and data mining in an epedigree food traceability system. J. Food Eng. 212, 65–75. <https://doi.org/10.1016/j.jfoodeng.2017.05.008>

Alfian, G., Syafrudin, M., Fitriyani, N. L., Rhee, J., Ma’arif, M. R., & Riadi, I. (2020). Traceability system using IoT and forecasting model for food supply chain. *In 2020 International Conference on Decision* *Aid Sciences and Application (DASA)* (pp. 903-907). IEEE

Allahyari M, Atashi M, Dunn E 2018 *JAFI* **19** <https://doi.org/10.1080/10496505.2017.1363654>

Balamurugan, S., Ayyasamy, A., and Joseph, K. S. (2020) “Iot based supply chain traceability using enhanced naive bayes approach for scheming the food safety issues.” International Journal of Scientific and Technology Research 9 (3): 1184-1192.

Beker, I., Delić, M., Milisavljević, S., Gošnik, D., Ostojić, G., and Stankovski, S. (2016) “Can IoT be used to mitigate food supply chain risk.” International Journal of Industrial Engineering and Management 7 (1): 43-48.

Bharucha, J. (2018). Tackling the challenges of reducing and managing food waste in Mumbai restaurants. *British Food Journal*, *120*(3), 639–649. doi:10.1108/BFJ-06-2017-0324

Bravi, L., Murmura, F., Savelli, E., & Vigano, E. (2019). Motivations and actions to prevent food waste among young Italian consumers. *Sustainability*, *11*(4), 1–23. doi:10.3390/su11041110

Caro, M.P.; Ali, M.S.; Vecchio, M.; Giaffreda, R. Blockchain-based traceability in Agri-Food supply chain management: A practical implementation. In Proceedings of the 2018 IoT Vertical and Topical Summit on Agriculture-Tuscany (IOT Tuscany), Tuscany, Italy, 8–9 May 2018; Institute of Electrical and Electronics Engineers Inc.: Piscataway, NJ, USA, 2018; pp. 1–4.

Chauhan, C., Dhir, A., Akram, M. U., & Salo, J. (2021). Food loss and waste in food supply chains. A systematic literature review and framework development approach. *Journal of Cleaner Production*, 295, 126438.

Cheruvu, P., Kapa, S., Mahalik, N.P., 2008. Recent advances in food processing and packaging technology. International Journal of Automation and Control, Inderscience Publications 2 (4), 418–435.

Cho, H. W., Jo, G. H., and Song, Y. J. (2017) “New IoT Technology for Food Shelf Life Management.” Advanced Science Letters 23(10): 10346-1034.

Ellis, S., Morris, H. D., & Santagate, J. (2015). IoT-enabled analytic applications revolutionize supply chain planning and execution. International Data Corporation (IDC) White Paper, 13.

Feng, Y., Xie, L., Chen, Q., Zheng, L.R., 2015. Low-cost printed chipless RFID humidity sensor tag for intelligent packaging. IEEE Sensors J. 15 (6), 3201–3208. <https://doi.org/10.1109/JSEN.2014.2385154>.

Gallo, A., Accorsi, R., Goh, A., Hsiao, H., Manzini, R., 2021. A traceability-support system to control safety and sustainability indicators in food distribution. Food Control 124, 107866. <https://doi.org/10.1016/j.foodcont.2021.107866>

Garver K (2018) 6 examples of artifcial intelligence in the food industry. Retrieved from https://foodindustryexecutive.com/6- examples-of-artificial-intelligence-in-the-food-industry/.

Grecuccio, J., Giusto, E., Fiori, F., and Rebaudengo, M. (2020) “Combining blockchain and iot: Food-chain traceability and beyond.” Energies 13(15) : 3820.

Industry 4.0: blockchain technology implementation opportunities and impediments from the

Jagtap, S., Bhatt, C., Thik, J., and Rahimifard, S. (2019) “Monitoring potato waste in food manufacturing using image processing and internet of things approach.” Sustainability 11(11): 3173.

Kayikci, Y., Subramanian, N., Dora, M., & Bhatia, M. S. (2020). Food supply chain in the era of

Khan, P. W., Byun, Y. C., & Park, N. (2020). IoT-blockchain enabled optimized provenance system for food industry 4.0 using advanced deep learning. *Sensors, 20*(10), 2990.

Kumar, A., Jain, S., and Yadav, D. (2020) “A novel simulation-annealing enabled ranking and scaling statistical simulation constrained optimization algorithm for Internet-of-things (IoTs)” Smart and Sustainable Built Environment.

Kumar, A., Singh, R. K., & Modgil, S. (2019). Exploring the relationship between ICT, SCM practices and organizational performance in agri-food supply chain. *Benchmarking*, 1463–5771. doi:10.1108/BIJ-11-2019-0500

Liegeard, J., Manning, L., 2020. Use of intelligent applications to reduce household food waste. Crit. Rev. Food Sci. Nutr. 60 (6), 1048–1061. https://doi. org/10.1080/10408398.2018.1556580.

Ma, Z., Yin, T., Gui, T., Wang, Z., Sun, X., Li, C., Guo, Y., 2018. Design and application of electronic tongue system for orange juice quality detection using internet of things. IFAC-PapersOnLine 51 (17), 437–442. <https://doi.org/10.1016/j.ifacol.2018.08.182>.

Mahalik, N.P., 2014. Advances in packaging methods, processes, and systems. International Journal of Challenges, Multidisciplinary Digital Publication Institute (MDPI) Publishing, 5 (2), 374–389. <http://dx.doi.org/10.3390/challe5020374>.

Maksimović, M., Vujović, V., and Omanović-Miklić, E. (2015) “Application of internet of things in food packaging and transportation.” International Journal of Sustainable Agricultural Management and Informatics 1 (4): 333-350.

Manning, L., 2018. Systems for sustainability and transparency of food supply chains. In: Sustainable Food Systems From Agriculture to Industry. Elsevier, pp. 153–187, <https://doi.org/10.1016/b978-0-12-811935-8.00005-6>.

Maroli, A., Narwane, V. S., & Gardas, B. B. (2021). “Applications of IoT for achieving sustainability in agricultural sector: A comprehensive review.” Journal of Environmental Management 298: 113488.

Mavridou, E., Vrochidou, E., Papakostas, G.A., Pachidis, T., Kaburlasos, V.G., 2019. Machine vision systems in precision agriculture for crop farming. J. Imaging. <https://doi.org/10.3390/jimaging5120089>.

Mohammadi, A., Sahrakar, M., & Yazdani, H. R. (2012). Investigating the effects of information technology on the capabilities and performance of the supply chain of dairy companies in Fars province. *African Journal* *of Business Management*, *6*(3), 933–945. doi:10.5897/AJBM11.1417

Moudoud, H., Cherkaoui, S., & Khoukhi, L. (2019, September). An IoT blockchain architecture using oracles and smart contracts: The use-case of a food supply chain. *In 2019 IEEE 30th Annual International Symposium* *on Personal, Indoor and Mobile Radio Communications (PIMRC)* (pp. 1-6). IEEE.

Nayal, K., Raut, R., Balkrishna, P. P., Narkhede, E., Kazancoglu, Y., & Narwane, Y. (2021). Exploring the role of artificial intelligence in managing agricultural supply chain risk to counter the impacts of the COVID-19 pandemic. *International Journal of Logistics Management*. Advance online publication. doi:10.1108/IJLM-12-2020-0493

Pal, A., & Kant, K. (2020). Smart sensing, communication, and control in perishable food supply chain. ACM Transactions on Sensor Networks (TOSN), 16(1), 1-41.

Pang, Z., Chen, J., Zhang, Z., Chen, Q., Zheng, L., 2010. Global fresh food tracking service enabled by wide area wireless sensor network. In: 2010 IEEE Sensors Applications Symposium, SAS 2010 – Proceedings, pp. 6–9, <https://doi.org/10.1109/SAS.2010.5439425>.

Qiao, S., Zhu, H., Zheng, L., Ding, J., 2017. Intelligent refrigerator based on internet of things. In: Proceedings – 2017 IEEE International Conference on Computational Science and Engineering and IEEE/IFIP International Conference on Embedded and Ubiquitous Computing, CSE and EUC 2017. vol. 2, pp. 406–409, <https://doi.org/10.1109/CSE-EUC.2017.262>

Rajakumar, G., Ananth Kumar, T., Samuel, T.S.A., Kumaran, E.M., 2018. IoT Based Milk Monitoring System for Detection of Milk Adulteration.

Ranasinghe, D.C.,Falkner, N.J.G., Chao,P., Hao,W.,2013. Wireless Sensing Platform for Remote Monitoring and Control of Wine Fermentation. IEEE.

Reddy, K. H. K., Luhach, A. K., Pradhan, B., Dash, J. K., and Roy, D. S. (2020) “A genetic algorithm for energy efficient fog layer resource management in context-aware smart cities.” Sustainable Cities and Society 63: 102428.

Rejeb, A., Rejeb, K., Zailani, S., Treiblmaier, H., Hand, K.J., 2021. Integrating the Internet of Things in the halal food supply chain: a systematic literature review and research agenda. Internet Things 13, 100361. <https://doi.org/10.1016/j.iot.2021.100361>.

Reynolds, C., Goucher, L., Quested, T., Bromley, S., Gillick, S., Wells, V.K., Evans, D., Koh, L.,

Carlsson Kanyama, A., Katzeff, C., Svenfelt, A˚ ., Jackson, P., 2019. Review: consumption-stage food waste reduction interventions – what works and how to design better interventions. Food Policy 83, 7– 27. <https://doi.org/10.1016/j.foodpol.2019.01.009>.

Schmitz, A., Kennedy, P. L., & Schmitz, T. G. (2017). World Agricultural Resources and Food Security: International Food Security. Emerald Group Publishing.

Sebastin, J. Artificial Intelligence: a real opportunity in food industry. Food Quality and Safety. 2018.. Available from <https://www.foodqualityandsafety.com>.

Sharma Sagar (2019) How artifcial intelligence is revolutionizing food processing business? Retrieved from: https://towar dsdatascience.com/how-artificial-intelligence-is-revolutionizingfood-processing-business-d2a6440c03Cite Reference.60

Sheahan, M., & Barrett, C. B. (2017). Review: Food loss and waste in Sub-Saharan Africa. *Food Policy*, *70*, 1–12. doi:10.1016/j.foodpol.2017.03.012 PMID:28839345

Shweta, A.S., 2017. Intelligent refrigerator using artificial intelligence. In: Proceedings of 2017 11th International Conference on Intelligent Systems and Control, ISCO 2017, pp. 464–468, <https://doi.org/10.1109/ISCO.2017.7856036>.

Sooryanarayana, P. S., and Mudhol, Mahesh V. Communication Technology: Itís Impact on Library and Information Science. Delhi: Ess Ess, 2000. pp. 23-25.

Spaargaren G, Oosterveer P, Loeber A 2013 *Sustainability transitions in food consumption, retail and production* pp 1–30 http://doi.org/10.4324/ 9780203135921

Tian, F. A supply chain traceability system for food safety based on HACCP, blockchain & Internet of things. In Proceedings of the 14th International Conference on Services Systems and Services Management, ICSSSM 2017—Proceedings, Dalian, China, 16–18 June 2017; IEEE: Piscataway, NJ, USA, 2017.

Tian, F. An agri-food supply chain traceability system for China based on RFID & blockchain technology. In Proceedings of the 2016 13th International Conference on Service Systems and Service Management (ICSSSM), Kunming, China, 24–26 June 2016; IEEE: Piscataway, NJ, USA, 2016; pp. 1–6.

Utermohlen K (2019) 4 Applications of artifcial intelligence in the food industry, Retrived from [https://heartbeat.fritz.ai/4- applications-of-artificial-intelligence-ai-in-the-food-industrye742d7c02948](https://heartbeat.fritz.ai/4-%20applications-of-artificial-intelligence-ai-in-the-food-industrye742d7c02948)

Verdouw,C.N.,Wolfert,J.,Beulens, A.J.M., Rialland, A., 2016. Virtualization of food supply chains with the internet of things. J. Food Eng. 176, 128136. <https://doi.org/10.1016/j.jfoodeng.2015.11.009>.

Wang, N., Zhang, N., Wang, M., 2006. Wireless sensors in agriculture and food industry – recent development and future perspective. Comput. Electron. Agric. 50 (1), 1–14. <https://doi.org/10.1016/j.compag.2005.09.003>