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Internet of Things (IoT) enabled Food Technologies: A systematic review approach

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***Abstract*—**Information and communication technology provide tremendous services to all the sectors including food technologies. On the other hand, this world fighting against hunger, food wastes, and nutrition-less food. There are much more technologies increase not only the profitability but also quality and production rate. IoT technologies use by the food technologies in many countries for food safety, transportation, packaging, temperature monitoring, nutrition analysis, and find the defective foods using IoT devices and applications via smart phones and computers in real time. This study mainly focused on IoT in food technologies in terms of the food production, security issues and possible solutions for those issues. For that, a systematic literature review was conducted and analyzed using qualitative method. Findings confirmed that, IoT and relevant technologies positively provide its full support to increase the demand and quality of food production process. Meanwhile, data privacy issues and provide immediate technical solutions were the major security issues faced by those IoT devices and application. In addition to that, none of the articles found conducted in Sri Lanka related to this study and none of the studies found related to IoT, Food technology Food-destroying robes. Apart from these all, this study suggested developing IoT systems and applications based on cloud computing to drive away from the food-destroying robes. Finally, it is planning to conduct a statistical analysis to find the expectations of food scientists, food production industrialists, and farmers. This paper purely based on past research works from famous Journals and conferences.

***Keywords*—**IoT, Food technology, Security issues, systematic review, ICT

I. Introduction

A. Internet of Things (IoT)

IoT is an emerging technology advancement in this era, which can help create a bigger leap ahead in the Information and Communication Technology (ICT) sectors in the in the existing and future. IoT is the extension of networking and web technologies into the physical realm via sensors, actuators, and digital devices for the betterment of automation services (Miorandi *et al*., 2012). IoT-enabled devices are used in all sectors and industries such as transport, healthcare, farming, commerce, tourism, food production, education, and engineering. While the number of connected objects to the wireless devices increase, data provided by those objects also increase, which may increase the quality and reliability of the results of those collected data, all these processes could happen without human intervention (Torğul *et al*., 2016). All these collected data send to the cloud storage by the connected devices. Cloud Computing (CC) providing unlimited, on-demand storage, and donkey years (Botta *et al*., 2015; Rojas, 2015). This IoT and CC combination creates a superhighway that enables possibilities to integrate any sectors with ICT to increase productivity and efficiency without human interaction. The following figure 1 illustrated the theoretical diagram of IoT.

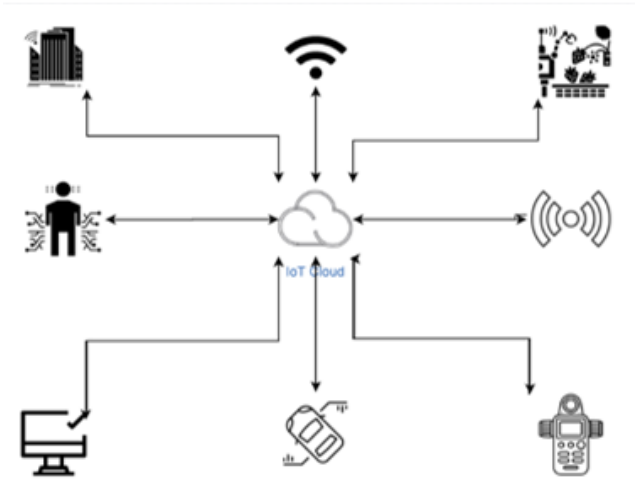

Figure 1: Theoretical diagram of IoT

B. Food Technology (FT)

This earthmoving toward hunger and poverty but the FT concepts fight against these matters like the speed breaker

to avoid this situation. In that sense, FT plays a major role in the food production process (FPP); such as production, preservation, quality control, and research and development are the main part of that. Nutrition analysis, quality control, maintenance are the best manufacturing practices in the food industries (Meghwal *et al*., 2016). Food industries are the key factor to decide the country's economic growth. Therefore, profit from these industries mainly depends on the quality of the foods. But, on the other hands, profitability depends on increase the labor productivity (Thenabadu M *et al*., 2020). As discussed previously, good standards of any food depend on those 4 factors. people are giving priority to healthy foods rather not only than taste food products (Hsieh Ofori, 2007). These quality deciding factors are developing mainly with the help of human assistance, and partially digitalized types of machinery. But, food productions could be affected as these industries mainly depends on human, which is because of manual food development procedures.

Therefore, food production industries expecting automatic machinery to reduce the human effort within less duration, which could develop different types of food production without losing its qualities to increase the customer. Food safety can be increased by the ICT-enabled traceability systems (Setboonsarng *et al*., 2009). ICT provides a significant role in user-friendliness, easy access, cost-effectiveness, and security in the FPP (Mahant *et al*., 2002). The advancement of ICT applications introduces multiple technologies to increase efficiencies such as IoT, CC, drone, and artificial intelligence (AI). These technologies working in various steps during the FPP; such as nutrition analysis, quality control, packing, supply chain, and food safety. IoT enabled systems food distribution can help to automate food supply chain process during the process (Bhushan *et al*., 2016)(Accorsi *et al*., 2017). Meanwhile, food safety and its freshness can be monitored with mobile based IoT application in real time (Witjaksono *et al*., 2018). And, an IoT based application used to analyze the food ingredients and that uses sensors for food nutrition quantification (Sundaravadivel *et al*., 2018). Similarly, sensor technologies are used in AI-based packing (Popa *et al*., 2019). Computerized systems used in food industries to check weight and find leakages of the foods that goes down the line (Srivastava *et al*., 2015). But, all the technologies using by the food industries are require more development in terms of safety and supply process. Furthermore, majority of the conducted researches related to IoT and Food science till today were not provide required development steps in food technologies.

Furthermore, IoT can be implemented with agriculture. Precision agriculture is known as one sustainable, ecological, and gainful approach to progress agriculture yields and quality, and will eventually come true with the further execution of IoT practices in agriculture (Ruan, Jiang, *et al*., 2019). In addition to that cloud computing can be accommodated with IoT to make sure the quality and sustainability of smart agriculture (Rojas, 2015).

There were hundreds of research and development works conducted and still counting the numbers. In that sense, this study focusing on finding the better solution to improve the food technology (FT) via IoT based on existing studies. This study discussed many emerging technologies in the respect of food technologies and agriculture that are leading to smart agriculture or the smart food industry, especially related to IoT. In addition to that, cyber security and privacy issues of IoT also have been discussed. Therefore, a systematic literature review was used to collect the required data. Recently published papers were collected from various indexing databases in different perspectives such as used technologies, developed IoT applications, and security concerns separately in terms of food technology and agriculture. The following section explained the methodology used for the systematic literature review. And the final part concludes the study with limitations of the study and future works.

II. Methodology

This is study was focus on services of IoT on FT. We were used a systematic literature review to collect the required data, and these collected data were analyzed using qualitative research methods. A review of literature is the process of developing the questions, finding the relevant studies, assessing the quality of the studies, briefing the proof, and discuss the findings from the previously conducted scientific studies to formulate a new concept (K. S. Khan *et al*., 2003). Meanwhile, the qualitative research method is a way to collect the required data from interviews, observations, and previous studies (Mahant *et al*., 2002).

A. Criteria for Study Selection

There were 56 articles selected from 274 downloaded research papers, where these articles were downloaded from various publications such as international research conferences, peer reviewed journals, and book chapters. These articles were searched using the keywords Internet of Things, IoT, food, food sciences, food technology, food safety, food nutrition, and food production using the Boolean terms AND, and OR. Furthermore, majority of the articles were sort listed based on the following criteria;

1) Papers published in high index publishers and digital libraries
2) Published after 2015
3) Only full papers
4) Free accessible research papers

Furthermore, figure 1 represents the classification diagram for the systematic literature review.

B. Development of Research Questions

The following research questions were developed according to the above mentioned review process.

Finally, finding of these research questions were summarized; those summary information were analyzed to come up with new conclusions to the food production process via IoT. In addition to that, limitations and future research problems also identified and suggested to the upcoming research works.

Table I: Developed research questions

S. No	Research Questions	Motivation
RQ1	What are the most suitable IoT technology, devices, and Application to implement with Food production?	With less human efforts Increase the productivity within a short period of time and finding the new food product if possible.
RQ2	How the IoT devices, application and technologies help in FT?	Understanding how IoT provide services to the FPP.
RQ3	What are the security issues existing in the IoT devices, technologies and applications?	Find and suggest the way to reduce or remove the security issues in IoT devices or IoT applications that are affecting the FPP.

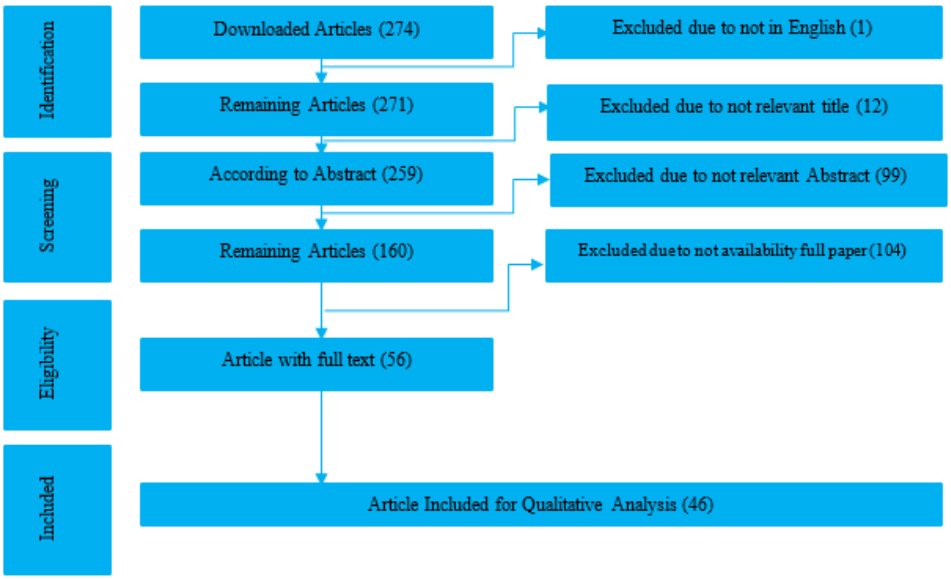

Figure 2: Classification diagram of Research Articles

III. Review of Literature

A group of experts developed an IoT-based system to assist food packaging and Transportation in real-time using the Internet, sensors, RFID, and smart devices that can help to reduce foodborne illness and food traceability during transportation (Maksimović *et al*., 2015). Further, A concept has proposed to develop an IoT architecture based on a Software-defined Network (SDN) and cyber physical system to develop different food products with good nutrition and healthy against the increase of the population in the smart cities (Ordoñez-García *et al*., 2017). Likewise, An IoT system based on magnetic induction (MI) was developed for the fresh food supply to monitor food waste, food transportation, and tracking the food contaminant (Pal Kant, 2011). and, an IoT retrofitting approach to reduce the production expenses and maintain the quality of the food products with the help of industry 4.0, AWS lambda and sensors (Panda *et al*., 2019). Meanwhile, another system was proposed based on IoT, Block chain, and deep learning that was help to the end users to verify the food products before consume to confirm the origin and supply chain of the relevant food; furthermore, this system help to keep track of proper temperature and supply tracks of the food products (P. W. Khan *et al*., 2020). Similarly, the error ratio of food traceability in supply chain process can be reduced by using IoT based system based on block chain and fuzzy technologies compared to traditional way (Tsang *et al*., 2019). In addition this, authors have suggested for the development of smart systems especially using IoT for the food production for the safety, transportation, nutrition, quality control, and cost effective (Ramundo *et al*., 2016). Likewise, a bibliometric analysis was confirmed that IoT technologies strongly involved in food safety and its quality over a decade with the help of RFID, sensors, and internet (Bouzembrak *et al*., 2019). As well as, IoT help positively supports food quality monitoring, traceability, and smart packaging (Ben-Daya *et al*., 2020). Further, it was mentioned in a study that IoT in agriculture increases food safety and reduction of food wastage (Brewster *et al*., 2017).

IV. IoT devices, application and technologies help in food technology

IoT can be used in Agriculture via cloud-based to provide services to the farmers about cultivation time, find the diseases, and solution to those diseases (S.Balamurugan , N.Divyabharathi, K.Jayashruthi, M.Bowiya, 2016); this was supported by (Jaiganesh *et al*., 2017) conducted in India. And also, It was proved that soil conditions can be monitored using pH and soil moisture sensors based on IoT based system using LoRa technology via mobile and computer

interfaces, where this system was provide positive results for star fruit plantations (Rachmani Zulkifli, 2018). Furthermore, a review was saying that the majority of the food farming IoT systems focusing on management systems mainly developed on cloud and big data technologies (Navarro *et al*., 2020). Meanwhile, IoT systems used in fresh agriculture products in terms of monitor the food's freshness, food security, and building management of those food products to increase the supply chain integration level (Yu Gu Tiaobin Jing, 2011). A mobile app based on IoT architecture was developed to assist farmers in real time to reduce watermelon related disease based on expert's answers (Hubei, 2016). Similarly, a low-cost respirometer was developed based on open source software which can use to measure the CO_2 concentration, pressure, and temperature and this system showed positive results for the fruit and vegetables placed in the system (González-buesa Salvador, 2019). Furthermore, Agricultural industries could reach more region directly to the consumers with the help of IoT based on cloud computing (Patil *et al*., 2012).

A study was developed an architectural framework for IoT based system for the food and agriculture which provided valuable assist to the those sectors by conducted some case studies in European IoF 2020, agricultural sub sectors, conventional and organic farming (Verdouw *et al*., 2019). Analogously, IoT systems in food production and logistics could be developed with very low-cost RFID-based sensors used for the short-distance wireless sensor data records (Arnaud Costa, 2020). Likewise, another low implementation cost IoT system was developed based on RFID and QR code which used to track not only individual food items but also the whole supply chain; further, this system mainly used to prepackaged the foods (Li *et al*., 2017).

A research based development created a sensor based IoT system to manage the restaurant food waste (RFW) that includes generation, collection, transportation, and disposal of the food wastes; and this work was provided positive feedback on RFW management processes (Wen *et al*., 2018). Likewise, Food waste throughout the entire food production process could be reduced using IoT based monitoring system with the help of dynamic shelf-life prediction based on the kinetic Arrhenius model (Ostojic *et al*., 2017). Similarly, Another study has investigated and believed that food safety through IoT was significantly possible in a Chinese restaurant (Yun Gu *et al*., 2012). Further, a smart food security system architecture has been proposed that could be developed based on big data and IoT, which helps to create food safety information and carry out the information on the monitor and analyze the collected data where it assists to realize monitoring from food source to the final consumer (Parvin *et al*., 2019). Similarly, Block chain technologies implemented IoT devices were proposed to increase food safety during the food supply chain (Lin *et al*., 2018). Furthermore, an IoT based food waste maintenance system was developed for a pilot study and the result confirmed that the developed system significantly reduce the food wastage (Hong *et al*., 2014).

A study urged to use of cloud storage to maintain food quality such as humidity and temperature that can maintain the quality of the raw food via mobile or computing devices in real-time using internet connectivity (Mallik *et al*., 2018). As well, a low-cost MQ5 gas sensor was used to developed an IoT based intelligent system to find expired foods or altered food packs; further, the system can be used via smartphone to monitor the stored food products (Popa *et al*., 2019).

A research paper suggested implementing a system combining QR-code with the internet which can be used to increase the information volume of some food product and present it visually to the consumers about the antioxidant capacity of blended juices and enriched bakery products (Nilova *et al*., 2019).

A. Security Issues in IoT

There were several common issues and attacks outlined in the IoT systems such as forgery, location privacy, cannot stand with server impersonates resynchronization, data integrity, server spoofing, and backward traceability forward traceability problem (Tewari Gupta, 2020). Data security was the highest priority among the IoT-enabled devices since the device manufacturer might have the connection over the smart devices which uses temperature sensors for monitoring food transport as those IoT-enabled devices work with the support of internet connectivity (Astill *et al*., 2019; Liao *et al*., 2020). In addition to this, Data management and swift support for the technical problem are another set of issues facing by IoT-enabled food technologies (Ruan, Wang, *et al*., 2019). As well, study discussed major security issues that arise in IoT which may affect smart farming such as Daniel of service attack, malware infection, jamming attack, misinformation, false data injection, data leakage, supply chain attack, and cyber-terrorism (Gupta *et al*., 2020). Meanwhile, Data integrity and authentication are also issues happening in the IoT during data transfer from a node to another node, which could happen in the smart farming process (Dennis *et al*., 2014). Similarly, technical challenges in the block chain technology used in the IoT traceability system used in the food supply chain (Feng *et al*., 2020).

V. Conclusion

A country's economic growth depends on many factors, in that sense food production is the core part of that. However, a stand-alone human resource only is not enough to develop the required amount of food with higher quality nutrition. Therefore, this study aimed at how technologies assist the food industries to achieve the produce the required amount of food, food safety, nutrition maintenance, food supply chain, and food transportation. On that basis, this study focused on how IoT provides services for food technology.

This article was developed based on a systematic review and analyzed using qualitative statistical analysis, further, it was concluding according to the developed research questions.

A. Most suitable IoT technology, devices, and Application to implement with Food production

From the review of the literature, it was confirmed that IoT provides valuable services to the food industries, such as developing new kind of food products with the expected level of nutrition, food packaging, real-time monitoring of the food's temperature, moisture, traceability of transportation, finding the defective foods, reducing diseases during the farming, and reducing the food wastages. In addition to these positive achievements, it was also proved that those IoT systems can be developed at minimum cost with higher efficiency. Where these IoT applications and systems were done with many trending technologies but IoT, RFID and Block chain were the major among all of these, due to their security and data transfer rate.

B. Security issues existing in the IoT devices, technologies and applications

Although, there were some negative consequences also rising, majorly Data Privacy issues and quickest technical assistance during a device or system failure. But, these issues can be reduced by stopping to share private keys with others (Zhao *et al*., 2019), develop big data analytics, try to develop any low-cost IoT-based security monitoring systems, discuss cyber risk management frameworks (Gupta *et al*., 2020), implement devices users identification authentication (Dennis *et al*., 2014), reduce third-party access, frequently updated virus malware software, implement block chain technology throughout the full food processing, and increase the security of the login procedure by implementing 2 step verification methods.

C. Limitations, Recommendation and Future work

Since this study was conducted in Sri Lanka and based on systematic review, but there were no studies found based in Sri Lanka about IoT and food technology. And also, none of the studies found related to IoT, Food technology Food-destroying robes. Furthermore, none of studies were found which provided stable solutions to the IoT security issues. This review article strongly suggested to develop an IoT systems and applications based on cloud computing to drive away the food-destroying robes, that should be further used to provide require information to find a permanent solution to stop the food-destroying robes based on cloud analysis. Finally, we authors planning to conduct an analysis among the food scientists, food production industrialist and farmers about their expectations about IoT devices and applications.

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