

Applications and Opportunities for Internet-based Technologies in the Food Industry

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Abstract— In the modern world, information technology (IT) has been incorporated in most development activities. The food production industry is one of the recent industries to embrace IT in their major daily operations. This study discusses applications and opportunities for Internet-based technologies in the food industry and highlights state-of-the-art technologies and trends in the field. These technologies are mainly classified into Radio Frequency Identification (RFID) for supply chain management, quality and safety monitoring, e-commerce, robotics, Wireless Sensor Networks (WSN), and Geographic Information Systems (GIS). Since all emerging technologies are coupled with challenges, the study addresses both challenges and benefits of incorporating IT in the food industry. Safety and quality of food products is a vital issue in the context of the food industry. As a result, this paper discusses how IT can be integrated to enhance the safety and quality of food products. The paper concludes by arguing that awareness be raised within the agro-food industry on the importance of the adoption of Internet-based technologies as a critical success factor in the twenty-first century.

Keywords- food industry; information technology; Internet; RFID; e-commerce.

I. INTRODUCTION

Information technology (IT) is one of the individual forces that has contributed to globalization and advancement of life standards. These advancements have been occurring rapidly due to the rate of innovation from the IT industry. Significant incorporation of IT in most of the developmental activities is proof of the spread and importance of this technology [1]. IT has been globally incorporated in construction industries, production, manufacturing, healthcare, education, information management, security, and food and agricultural production. However, IT has been embraced at different levels by the fields mentioned above. Information management ranks as the most advanced field concerning use of IT [2]. On the other hand, agriculture ranks as the least innovative field as far as incorporation of IT is concerned. Other fields of production besides agriculture and food obtain maximum potential production from their fields due to highly incorporated IT systems [3]. Unfortunately, agriculture and food production does not extract its maximum potential because of its low level of IT incorporation. Most of the yield available in the agricultural sector is retrieved from small and medium sized enterprises (SME). Therefore, high scale production firms from the food

and agriculture production industry are not constructive parties in the business [4]. SME are characterized by either low or medium financial capacity. This financial background is not able to fully fund state-of-the-art technologies such as radio frequency identification (RFID), wireless sensor networks (WSN), and integration to e-commerce. These technologies are available for application by the food and agriculture industry, and once incorporated, agricultural and food production would be able to maximize its potential [5]-[7].

The rest of this paper is organized as follows. Section II summarizes a review of literature. Section III discusses the use of important and available Internet-based technologies in the food industry. Section IV discusses in finer detail, the aim of the paper. Section V includes an acknowledgement and conclusions.

II. LITERATURE REVIEW

Currently, food and agricultural production has incorporated IT to a significant degree. Unfortunately, there still exist technical challenges that have resulted in the industry incurring losses and gaining a bad reputation. These technical challenges can be corrected through application of the mentioned technologies [8]. IT is signified by techniques that result in faster, efficient production with minimal human effort. Agricultural production is an economic activity that is more dependent on human input relative to machine input than other activities. This does not mean that technologies to minimize human effort and input in the industry are absent. Technologies that can result in reduction of human input exist in the industry, but the prevailing challenge is the cost of operation. As initially stated, SMEs comprise robust producers in the industry and lack sufficient capital to sustain these technologies [9]. IT applications relevant to the field of agriculture require high initial capital, but are cost effective. Areas within the field of agricultural production that can incorporate IT include; supply chains, harvest, standardization, marketing, soil fertility, and yield prediction [10]. These areas can be improved by the following technologies: RFID, WSN, GIS, robotics control, and e-commerce. These technologies are applied in the agricultural and food production industry to fulfill different objectives. These technologies utilize networks for communication. However, some technologies such as RFID have more than one application in the industry. It can be used in supply chain management and also in traceability for standardization [11].

III. AVAILABLE TECHNOLOGIES

A. RFID Technology

This technology uses radio frequency to identify or retrieve information from production. It operates using the same mechanism as barcodes with magnetic strips [12]. Instead, of a barcode, RFID uses microchips that are embedded on the product of interest. RFID has two main advantages over barcodes. In the case of a barcode, it has to be on the line of sight of the barcode reader for information to be obtained from it. RFID is advantageous because the chip and the reader do not have to be on a line of sight to retrieve information from the chip, because the chip produces specific radio frequencies. The other advantage of RFID is that the chip is more reliable than the barcode [9]. This is because validity of barcodes is ruined once the code is scratched or removed. RFID microchips are not easily removed because they are not attached to the surface of the product.

RFID technology can be used in supply chain management and standardization. Food quality has been the cause of controversy in the food industry. Food that has not been properly stored has higher chances of going bad and once food has attained this status, it can become toxic. Food toxicity is dangerous as it can result in complex health disorders or even death. Therefore, a compromise on the quality of food is likely to ruin the reputations of the supplier and manufacturer, and this translates into losses [4]. RFID enables the user to establish the amount and type of ingredients contained in the food product. In addition, it also provides the time elapsed from the time of manufacture to the time of first use. This information is imperative to both the retailer and the consumer. Cases of food poisoning as a result of consuming expired food or allergic substances would be substantially reduced.

The other core challenge in the food production and agriculture industry is supply chain management. Some food products are essential for humans, but their production is unique in specific regions. Therefore, a comprehensive supply chain should be established so as to benefit both the manufacturer and consumer. The supply chain involves the food transit process from harvest, to processing, to distribution to the retailer [13]. Food undergoes this process before reaching the end user. Despite the extensive route, which is undergone before a product's use, monetary value has to be established. This means that the end user is not overcharged and the manufacturer is not underpaid [14]. RFID technology establishes an infrastructure that tracks a food product's location and ingredients, thus enhancing reliability of the end product. Farmers, specifically involved in food production, have been discouraged from expanding their investment due to limited profit from their enterprise. Previously, middle-men have benefited more than either the farmer or the consumer, minimizing profits to these constituents. Currently, with the employment of RFID, profits and satisfaction have improved because the supply chain of the goods has been bolstered by the technology. RFID technology has to be applied from the point of production (farmer) to the consumer. This reduces the bulk

cost that could have been incurred by the distributor or supplier [15]. Wal-Mart is among the supply companies that have encouraged manufacturers to incorporate RFID to increase their profits. They encourage manufacturers through financing part of the RFID implementation. This practice is prevailing in most developing countries, as SMEs are financed to increase agricultural food production performance in the international market.

B. Information technologies applied in food quality and safety monitoring

Poor performance in the food industry is due to loss of trust between food distribution companies and the end user. This is as a result of food contamination and poisoning. In China, profits in the food industry have declined by 50 percent as a result of contaminated food. This shows the sensitive nature of the food industry as a single flaw has the potential to bring down the whole industry. In addition, China's food production is also mainly extracted from small scale investors. This means the sector is not fully exploited. One of the technologies that the country has embraced to enhance the status of the food supply is RFID food packaging. This technology uses RFID to identify the ingredients and the inventory of food products [16]. It utilizes disposable biosensors that produce an antigen-antibody reaction to identify any bacterial cells in the food product. When bacteria thrive in an enclosed food product, the result is a bio-chemical reaction that would either make the food product stale or poisonous. Therefore, this technology helps the food industry upgrade their monitoring systems, and the quality and safety of food products is enhanced. As a result, IT has aided in the restoration of trust between consumers and manufacturers. Furthermore, since the introduction of RFID food packaging, the number of health issues associated with food poisoning or food quality has declined by more than 50 percent [12]. RFID technology also has an additional use as biosensors used in the tags containing inventory information that can be used in supply chain management. Traceability of food products from the farmer to the consumer is the other main concern in the food production industry. Effective supply management is a barrier that prevents SMEs from maximizing their potential. RFID detection technology poses a remedy to this barrier; RFID stores ingredients, destination, and the appropriate geographic location of products [16]. This helps the food industry realize their market extent and as a result increase or reduce their production where necessary, thus minimizing losses. This technology enables rapid detection of poisons or derailed quality of finished food products. It also enables automatic identification of food products along a supply chain.

C. E-commerce

Internet technologies within the context of e-commerce have provided a more interactive market that enhances communication between manufacturers and consumers. This can be accomplished through existing social networking sites such as Facebook and Twitter. Manufacturers append their

social networking websites on containers of food products so that in case of a complaint or compliment, the user can directly communicate with the food company [17]. When there is a reliable communication pathway between service or good providers and the end user, performance of the product is likely to be high. This is relative to a scenario where there is no elaborate communication between the user and manufacturer. IT provides better database management systems that portray the accurate needs of consumers. E-commerce expands the food market as the Internet is able to establish new consumers from regions where a specific food product has not yet been sold. E-commerce serves to benefit SMEs more because of their otherwise insufficient capital to market their food products. E-commerce is cheaper than hiring a marketing firm. This system requires less than five users to conduct online marketing and thus is affordable for SMEs [18]. As a result, SMEs can access a larger market without seeking additional financial assistance to facilitate marketing. Therefore, Internet technologies ensure development of a more reliable supply chain, higher quality food products, and a larger market for food products.

The disadvantage of Internet technology among SMEs is that the business owners and staff have to undergo training so that they can understand computer systems [19]. This is an additional cost that a small scale investor aims to reduce by all means necessary. IT exposes SMEs to Internet hazards such as hacking and fraud, which can cause huge losses to investors.

D. Robotics technology

Immense human input, which is visible in the food production industry, can be replaced by machines as a result of IT. Human input is hindered by fatigue and non-uniform output. Opposed to human input, machine input as a result of IT, is both uniform and reliable. In addition, it is faster and produces more profit than human input. Robotics is applied in land preparation, planting, and weeding [19]. A series of corporative IT devices can sufficiently handle agricultural production leaving human application to solely play an oversight role. A combine harvester is one of the machines that has replaced human involvement in harvesting activity (see Figure 1). In cases where the machine has been used, there has been a greater than 100 percent advantage in yield compared to regions where human effort was used in harvesting. This prevailed in areas with the same size and climatic conditions.

E. WSN technology applications

WSN differ from RFID in that it is able to integrate with other network devices in the field while an RFID tag can only be read with the RFID tag reader. WSNs comprise of Wi-Fi, Bluetooth, and ZigBee. The latter two operate within the Industrial Scientific and Medical (ISM) band of 2.4 GHz, which provides license-free operations, enormous spectrum allocation, and global compatibility. Other devices deployed on a farm to aid agricultural activities [20]. WSN technology



Figure 1. Diagram showing robotic harvesters

is used in this industry for monitoring and surveillance of crops within a farm. However, weather variation is the sole challenge that affects performance of WSN in the agriculture industry. The technology utilizes radio frequencies that can be interfered with by weather conditions [21]-[23]. The technology is used in maintenance and monitoring of farmlands. This is achieved through installation of sensors and cameras on the field. These devices are linked to the control station on the farm via the mentioned wireless technology. Monitoring fields enables identification of severe conditions on the soil and weather. With this information, farmers make comprehensive decisions concerning planting activities. Wireless technology also enables pest control and irrigation activities that are essential when pursuing maximum yield. Sensors deployed on the soil are able to determine moisture content of the soil. When soil moisture content is below the minimum, the information is transferred to the control that commands the irrigator to sprinkle the soil. Phytophthora is a disease that affects potatoes and is influenced by temperature and humidity conditions. Between 868MHz and 916MHz, motes can be used in determining moisture content on air and temperature [24]. Extreme temperatures can be reflected and relayed to the control station which initiates spray of pesticides.

F. GIS applications

A GIS uses unique colors and shades of colors to represent different atmospheric and soil conditions. It also uses the same set of unique colors to depict different terrains and ground cover. They utilize satellites to obtain aerial images of the Earth's surface. These satellites exist exclusively for GISs as the colors of objects and surfaces are different from ordinary depiction and representation. For instance, a water body would appear blue from ordinary satellites, whereas a GIS satellite depicts water bodies in dark. Food production and agriculture is governed by atmospheric conditions and soil fertility. Globally, farmers' yields are affected by changes in weather and climate. This is because of poor decisions that are dependent on farm activities [25]. For instance, harvesting time is signified by dry weather and medium to high temperatures. Therefore, when a farmer harvests during other atmospheric conditions, the resultant yield will be low. Through GIS technology farmers have been able to obtain atmospheric conditions in

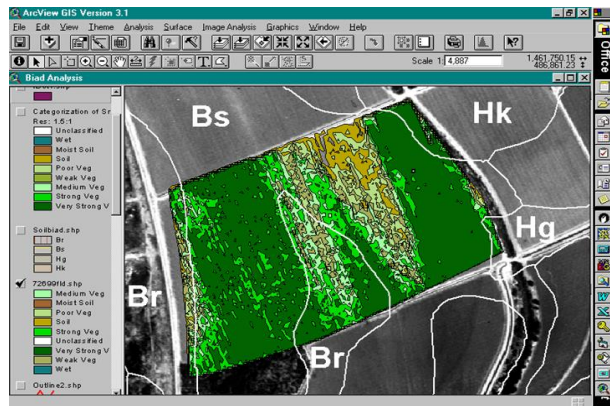


Figure 2. Diagram of remote-sensed image of the soil (GIS image)

real-time that have enabled them to conduct farming activities appropriately. GIS images are specific to natural, physical features. As a result, farmers or investors are able to locate ideal regions that will favor their agricultural investments. Planting on the wrong soil will result in lower yield and losses. Analyzing a soil using the naked eye does not necessarily yield an accurate description of the soil's composition [26]. Therefore, advanced methods induced by IT would result in better land use, thus maximizing yield from the food production and agricultural industry (see Figure 2).

IV. DISCUSSION

The primary goal of IT incorporation in the food industry is to foster food security and extract maximum sustainable yield. Once the primary role has been fulfilled, there are numerous secondary goals that IT ensures are effectively addressed. They include: processing, distribution, marketing, and storage [27]. IT, through the technologies previously discussed, fulfills each of these goals successfully. RFID ensures comprehensive results from supply management, which constitutes a secondary goal of the industry [26]. Regions that have incorporated RFID in their supply chains receive more revenue from the agriculture and food production industry than regions that have not applied RFID technology [29]. Similarly, regions that have incorporated WSN practice sustainable farming on a larger scale than in regions where the technology has not been applied. After production, the other barrier to extracting maximum potential from agriculture is the marketing of harvested goods. Large scale producers in farming have extensive marketing strategies that cover almost ninety percent of their produce. On the other hand, SMEs in agricultural and food production lack elaborate marketing avenues that can ensure intake of their products in the market. The first obstacle is the cost, which is a requirement for establishing an elaborate marketing network. The other obstacle is technology. Technology now offers a solution to its initial problem in that the Internet has contributed positively towards establishing global villages. Farmers are able to establish first person contact between the manufacturer and the user or processing firm. For instance, the Kenyan association of coffee growers has established a direct link to coffee

processing firms in England and the United States. This ensures farmers obtain maximum compensation for their products, and therefore represents an appropriate motivation for farmers to expand their farms. As a result, the potential of food and agricultural production is optimized.

Food investors who have embraced robotics and e-commerce receive more income from the food industry than food investors not aware of the technology or those who have shunned it. Consequently, in countries where these practices have been encouraged and are prevailing at significant levels have a better economy than in countries where IT application is limited.

Another added value of internet-based technologies in the agro-food industry is the improvement of efficiency and reactivity from real-time management of supply chains from farm to fork [30]. From a "food miles" point of view, this could result in a reduction in greenhouse gas emissions and in the carbon footprint, e.g., decrease of transport kilometers or empty vehicles, less waste, and better decay management.

The digital divide is a challenge that might hinder the applicability of the technologies discussed in this paper. Digital divide is mainly the gap between those with and those without access to ICT technologies and/or skills necessary to take advantage of ICT services. In addition, there is a widening gap between the urban and rural sectors on utilizing advanced and emerging technologies [31]. To overcome this, measures should be taken to strengthen informatics in the agro-food industry by fostering the development of national information capacity and new databases, linking national and international databases, and adding value to information to facilitate utilizing them at various levels. Also, innovative ways of combining ICT-based information sources (such as agro-food information systems) with traditional ones should be considered.

V. CONCLUSION

This paper gives an overview of major IT-based technologies and their impact on the food industry. It presents how selected fields of application can make a considerable contribution to food industry both in increasing efficiency and making data more available and easily managed. It discusses how these technologies can be integrated to enhance safety and quality of food products and provide advantages such as mobility, transparency and autonomy. The example technologies are mainly built on networked devices or utilize networks for communication. However, much additional work still should be done for a large scale integrated communication and scalable coordination throughout the agro-food networks.

The paper also highlights that there is great opportunity for internet-based applications in developing countries. However, in most developing countries, strategies should be employed to overcome technical and societal barriers that can hinder further development of these technologies in agro-food sector. Therefore, it is a mandate of the ministry of agriculture and/or other governmental authorities to ensure IT techniques are being used in the food and agriculture sector to boost production and create an extensive market for the produced goods.

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