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The Effects of Industry 4.0 on the Food and Beverage Industry

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Abstract
Production and technology are the two concepts which have a significant relationship with each other. The food and beverage industry is a broad industry where raw materials, semi-finished and finished foodstuffs are processed, packaged and distributed. In order to understand the effects of Industry 4.0 on the food and beverage industry; the issues of digitalization, interaction and future factories are examined in accordance with the relevant literature. The present study discusses the big data in the food and beverage industry, cloud computing, visual technologies, cyber-physical systems, 3D printers, and the ways of using smart factories. Based on a review of previous research studies, this study also offers specific recommendations for both practitioners and future research.

Keywords
Industrial revolution, Industry 4.0, Components of industry 4.0, Food and beverage industry, Kitchen practices

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Introduction

In line with the developments within the field of artificial intelligence such as three-dimensional (3D) printers robotics and bio-, nano- and, space technology; Industry 4.0 is defined as a smart production age that allows any being or object, alive or not to interact with each other through an internet connection (Aksoy, 2017). With the involvement of Cyber-Physical Systems during production, it will be possible to make an improvement within the production process, which is customized, eco-friendly and has good visual perception skills (Bulut & Akçacı, 2017). Industry 4.0 includes Internet of Things (IoT), Cyber-physical systems, big data and cloud computing, visual technologies (Augmented Reality/Virtual Reality/ Computer Vision), cybersecurity, additive manufacturing, advanced robotic systems, automation and control systems.

The Industry 4.0 revolution continues to influence almost all industries in several ways. It, for instance, had a significant influence on the food and beverage industry, which is a mass-production type. The food industry benefits from technological resources in order to meet the nutritional needs of the world population in accordance with human health, food safety and food legislation. For a long time, technology has been used in several stages of food and beverage production such as transportation, processing, packaging and storage of food products. On the other hand, through social media, consumers are aware of the fact that new food trends have been constantly emerging in the world. This situation, therefore, results in an added pressure on the food industry. The food industry can reduce the severity of this pressure by taking advantage of using the aforementioned technological resources.

In the relevant literature, it has been observed that there are a few comprehensive studies (Luque et al. 2017) examining the effect of all the technological innovations provided by Industry 4.0 on the food and beverage industry. The present study focuses on the effects of technological innovations such as big data, cloud computing, visual technologies (augmented reality/ virtual reality/ computer vision), Internet of Things (IoT), Cyber-physical systems, additive manufacturing, advanced robotic systems automation and control systems on the food and beverage industry.

The present study consists of two parts. The first part discusses the current and potential impacts of Industry 4.0 on the food and beverage industry in accordance with the relevant literature. In the second part, the current and potential situation of Industry 4.0 in the food and beverage industry is examined. Finally, recommendations for future studies are made so that technological innovations can be used commonly in several stages of food and beverage production.

The Effects of Industry 4.0 on the Food and Beverage Industry

Food industry is a multi-dimensional, complex and challenging sector due to the manufacturing of raw materials, semi-finished products and finished products. Moreover, the term 'food industry' refers to the companies that produce, process, manufacture, sell and serve food, beverages and dietary supplements (Luque et al. 2017).

With the development of the commercial kitchen, for many years mass-production techniques have been used in food and beverage companies (Okumus & Cetin, 2019; White, Barreda, and Hein, 2019). However, it is perceived that mass-production is not enough in terms of both the food service business and the customers. Thus, the concept of "industrial kitchen" has emerged (Aktaş & Özdemir, 2007). It, hereby, refers to an innovative approach that combines the best features of mass-production and customer orientation. The industrial kitchen is based on three principles as follows; intensive customer focus, increase in production and new production technologies (Bradford, 1997; cited from, Aktaş & Özdemir, 2007). In the 21st century, it has become an important issue to cope with the negative effects of the food industry such as perishable products, food safety, production of waste and food packages in the environment (Luque et al., 2017). The technological advantages provided by Industry 4.0 and the role they have and will have in the future in food industry are as follows (Luque et al., 2017):

- Internet of Things (IoT), Artificial Intelligent and Big Data
- Microencapsulation and nanoencapsulation for the next generation ingredient design
- Chemical images for quality control and food security
- Bacteriophages; new biological methods for food security
- Pressure as a tool for food process transformation
- Proteomics
- Active packaging, the skin of the 21st century food

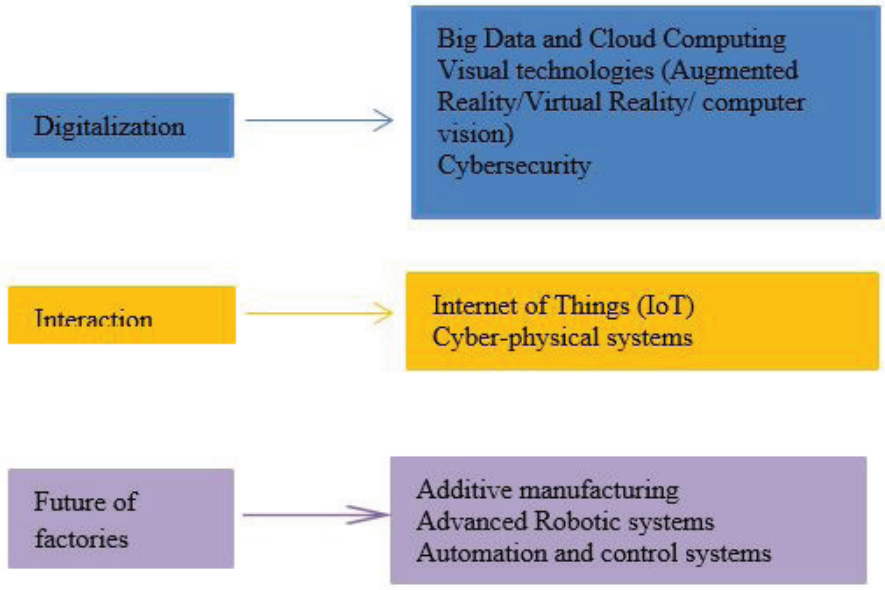

Figure 1. Industry 4.0 Leading Technologies (Source: adapted from Tübitak, 2016, cited from Aksoy, 2017)

In order to examine the effects of Industry 4.0 on the food and beverage industry, technological developments, digitalization, interaction and future factories within the scope of Industry 4.0 are illustrated in Figure 2. Firstly, digitalization, involves technological developments related to big data and cloud computing, virtualization and cyber security. Secondly, interaction refers to technological developments regarding the IoT and Cyber-physical systems. Finally, the future of factories consists of technological developments related to additive manufacturing, advanced robotic systems and automation and control systems.

Digitalization

Big Data and Cloud Computing

Because of the use of the internet and social media tools, access to information and problems of redundant and false information has consequently increased. The big data concept has made it possible to access and store real and reliable information more easily. Big data, respectively, involves a large number of information sources such as web server logs, internet statistics, information from social media posts, microblogs, climate and other similar sensors, and call records from GSM operators (EBSO, 2015).

There is no need to download the data obtained by the cloud technology. Web-based applications (for instance, iCloud, Google Drive, Yandex Disk, and Dropbox) provide online storage services for users. This technology allows people to access information stored in the cloud from any place or device as long as you are connected to the internet. Cloud technology obviates the need for an individual or corporate user to physically keep hard disks (Aksoy, 2017).

In the food and beverage industry, cloud computing is also used in agricultural activities such as production planning (Hori et al., 2010; TongKe, 2013), operational planning (Hori et al., 2010), various management strategies for different growing processes of essential plants (TongKe, 2013), reliable data sharing between administrators and employees (Hori et al., 2010), and tracing systems for agriculture lands and products (Hori et al., 2010; TongKe, 2013). In addition, cloud computing makes it possible for people to recognize foods by displaying their images on their devices (Duan et al., 2013). In this system, the user only needs to take a picture with his device and then upload it to the server. Afterwards, the system processes the picture and eventually sends feedback to the user accordingly.

Big Data allows machinery failure prediction, anticipation of maintenance operations, improving process optimization, and identifying the client consumption patterns (Luque et al., 2017). The large amount of data obtained by using radio frequency identification, wireless communication, automatic control, and the information sensing techniques of IoT are handled with agricultural information cloud computing (TongKe, 2013). In the new smart industries, information is stored on the cloud instead of the computers or servers of the company (Luque et al., 2017).

Visual technologies (Augmented Reality/ Virtual Reality/ Computer vision)

Augmented reality (AR) is the visualization of digital media generated by computers with audio, video, graphic or GPS data in a graphical environment that can affect the senses of people (Bulut & Akçacı, 2017). This concept is about changing and increasing reality with the use of a computer. The user can interact with the information around himself thanks to the developing augmented reality technology. When using this technology, artificial information and elements related to the environment are compatible with the real world (EBSO, 2015).

Today, restaurants try to differentiate the experience of consumers by applying technological innovations in the restaurant atmosphere. Inamo soho restaurant, for instance, allows its customers to have a unique experience while eating their food. This restaurant, besides eating, provides its customers an opportunity to play games in rooms, drink or sing. Inamo soho restaurant, therefore, creates a fun and interactive atmosphere where people can eat and have a good time at the same time. To illustrate

another example, IEAT is an interactive table that includes augmented reality. IEAT table provides a variety of augmented reality technology facilities such as ordering, playing, decorating the table surface and communicating (for other examples see Margetis et al., 2013).

Cyber Security

The role of cybersecurity is essential in Industry 4.0. In accordance with the discussions so far, there are several technological systems and many industrial objects related to interchanging information that are able to control production systems. Thus, adequate protection measures need to be taken to prevent attacks that could change the correct operation of factories with a consequent potential for economic risk. (Luque et al., 2017). Cyber security ensures that data security is kept under control. Otherwise, having regularly active devices on the internet might cause data loss and severe problems in information security (Bulut & Akçacı, 2017). Today, cyber security is an important issue since sharing information among animate and inanimate objects is spectacularly rapid.

Interaction

Internet of Things (IoT)

Zanella et.al., (2014) define IoT as a recent communication paradigm that conceives a near future, in which the objects that we use every day will be supplied with microcontrollers, transceivers for digital communication, and appropriate protocol stacks that will make them able to interact with each another and with the users, becoming an integral part of the Internet. Whitmore et.al., (2015) claim that IoT devices will be ubiquitous, context-aware and will enable ambient intelligence. IoT, additionally, can not only save people and organizations time and money, but also help improve decision making skills and outcomes in a wide range of application areas (Whitmore et.al., 2015).

Human-computer interaction (HCI) activated by IoT assists people's kitchen practices. For example, technological cutting boards can sense the weight of various foods processed on it while cutting during meal preparation (Kranz et al., 2010). Also , by analyzing the force and torque changes that occur when users are chopping food, the blade feature can determine the type of food to be chopped (see for example Kranz et al., 2010). IoT controls the food supply chain through effective information processes. It requires equipping machines and industrial objects with sensor systems and electronics with embedded software and connectivity. This, accordingly, allows the objects to collect and exchange the data using the internet infrastructure. (Luque et al., 2017). Numerous examples exist, including...

Cyber-physical systems

Cyber-physical systems make physical machines much more intelligent by being integrated with cyber technology (EBSO, 2015). RFID (Radiofrequency Identification) technology is a working form of a cyber-physical system (Selek, 2015 cited in Aksoy, 2017) that facilitates automatic identification of items using radio waves (Nambiar, 2009). In factory production, radio frequency identifier labels, which are one of the most essential elements of Industry 4.0, are attached on products, for example, soap bottles. These labels, in fact, have the feature of transferring information such as color, size, and the volume of the bottle into the machine. Through the use of these labels, the smart machines then classify and identify the bottles according to their determined features and fill the bottles with soap according to their color. This system, ultimately, makes it possible to store the information of a product that has been transferred via radio signals to the digital platform since the beginning of its production process. RFID technology also has advantages in the physical production field and production processes.

RFID technology has remarkable advantages for the food and beverage industry. Firstly, as it can identify the quality information of products, RFID technology stores the data of the manufacturing methods and transfer period of the products and classifies them accordingly. Secondly, RFID is quite beneficial for wholesalers, vendors and retailers as they can check the supply chain of each product with it. In addition, consumers can check the supply chain of each product using the RFID readers through their web and smartphone applications. Finally, the collected data can be used by research institutions (Costa et al., 2013). Abad et al., (2009) have reported that RFID systems offer significant advantages for its users. They, for instance, offer more memory and can be reused rather than being disposed of. There is also no need for human participation or a physical tag to read the labels on the product.

RFID technology enables the sharing of information among manufacturers, vendors and consumers in the food industry. Therefore, this information exchange creates mutual trust in the supply chain. Moreover, RFID technology facilitates safe food production with objective data provided in the production area.

The Future of Factories

Additive manufacturing and 3D printing

3D printing is known as a process of “additive manufacturing” or slowly building layer upon layer in the food industry. The printer needs to be working well with food such as sugar, starches, and/or proteins. Printing food, basically, involves carefully layering tiny semi-liquefied food particles on top of each other to create novel processed foods (Lam et al., 2012, cited from, Lin, 2015). Techniques in 3D printing

food can be divided into three techniques as follows: bio-driven (meats), bottom-up (uncommon source such as algae and insects), and mixed insect powders with other printable food (cheese et.) and it can make delicious ingredients. Insect powder can be an alternative protein resource for addressing the global food shortage crisis (Sun et al., 2015). Top-down researchers look to develop additive manufacturing techniques that use traditional edible materials, such as chocolate, dough, and vegetable puree as base ingredients (Lipton et al., 2015). Besides this, available printing materials can be considered as a process of natively printable materials, non-printable traditional food materials, alternative ingredients, and post-processing.

In the food industry, FOODINI appliances can be observed within the scope of 3D. FOODINI is a 3D food printer + IoT) new-generation kitchen appliance that makes cooking better with fresh, real ingredients. FOODINI is the first 3D printer to print all types of foods from savory to sweet using fresh and real ingredients. 3D printers can be used to cook using ingredients such as chocolate, icing, hydrogel, cheese, hummus, pastry dough, butter, jelly, starch and granulated sugar (Izdebska & Tryznowska, 2016). On the other hand, 3D printers cannot be used to print traditional food materials containing meat, rice, vegetables and fruits. However, the author of the study highlights that these 'non-printable' foods are added to materials such as hydrocolloids (Sun et al., 2015), xanthan gum, and gelatin and can be processed in 3D printers (Izdebska, & Tryznowska, 2016).

3D food printing technology can be good for consumer-produced foods at home, small-scale food production and industrial scale food production (Lipton et al., 2015). This technology can make production more efficient and decrease manufacturing cost for customized food products fabrication (Sun et al., 2015). Additionally, 3D food printers can be quite advantageous for food production topics such as various food decoration, geometric complexity, developed recipes (Lipton et al., 2015), personalized food production (Lin, 2015; Lipton et al., 2015; Sun et al., 2015; Lille et al., 2018), customized food design, customized food supply chain (Sun et al., 2015), saving time, preventing food waste (Izdebska, & Tryznowska, 2016)., enhancement of manufacturer's skills (Lipton et al., 2015; Sun et al. 2015). Moreover, it is easier to, transport of prepacked cartridges to distant locations since prepacked cartridges (mashed food is filled into the cartridges and printed in 3D food printers.) can stay fresh longer than fresh fruits and vegetables (Lin, 2015).

So, On the other hand, Lipton et al., (2015) discuss that most of the 3D printer food stock has an extremely limited shelf life. However, current 3D printing technology is limited due to reasons such as cost, time (Lin, 2015), and more importantly it is a food process that is practiced slowly compared to other techniques (Lipton et al., 2015).

Advanced Robotic systems, Automation and Control Systems

Iqbal et al. (2017) discuss that earlier use of robots in the food industry was restricted to packaging of food and palletizing in dairy, beverages, chocolates and food tins. Nowadays, robots are used in numerous areas of the food industry such as seeding, spraying water, harvesting, cutting, processing and packaging of food products (Sun, 2016 cited from Iqbal et al., 2017), meat processing and automatic quality detection of final bakery products. In addition, bottles are automatically cleaned, counted, filled and arranged on a conveyer belt with the help of robotic machines (Saravacos and Kostaropoulos, 2016 cited in Iqbal et al., 2017). The benefits of robots to the food industry can be illustrated as follows: kinematics, dynamics, control, hygiene, productivity and worker safety (Iqbal et al., 2017). Specifically, Iqbal et al., (2017) assert that picking and placing, packing and palletizing are the steps where robots serve especially well.

One of the most important areas where transformation takes place in Industry 4.0 is the factories equipped with smart technology. These factories are also described as dark factories (lights out) since there are no people working in them. At the beginning of these factories' existence, the major areas of use the production areas in which people are exposed to dangerous working conditions such as high temperatures, heavy weights, and toxic gases (Aksoy, 2017).

In recent studies, it has been revealed that robot chefs are able to make basic recipes such as cookies (Bollini et al., 2011), and pancakes (Betzz et al., 2011). These studies particularly reveal that robot chefs can perform daily kitchen actions such as pouring, mixing, placing and cooking. In addition, Japan has developed the idea of robots serving customers (Iqbal et al., 2017).

These days, people benefit from robots in the food and beverage industry in fields such as washing, extracting, cutting, processing and packaging of food and beverage products. Robot chefs or service robots that can be considered as advanced technological innovations are not yet widely used in the food and beverage industry since these innovations are currently only in the prototype stage of development.

Conclusion

The purpose of the present study was to address the effects of technological innovations in Industry 4.0 on the food and beverage industry. In accordance with the existing relevant literature, the study revealed that Industry 4.0 provides technological innovations as follows; cloud computing, visual technologies, cyber security, IoT cyber-physical systems, 3D printers and smart factories.

Big data technology enables the determination and storage of safe and real information. Big data also helps to predict the malfunction of machines that are used in the food and beverage industry and check their maintenance. Moreover, it effectively improves the production process and specifies the profiles for the consumers. Cloud computing is a technology system that helps to store the collected big data. Thanks to this technology, computer storage space or hard disk space is not required, and data storage and access is possible via online networks from anywhere that has internet connection. The present study has also discovered that consumers within the food and beverage industry benefit from the cloud computing system when figuring out the features of the foods in the agricultural practices. This technology, especially, provides a fast and safe method of information sharing among employers and customers.

Within the scope of augmented reality technology, restaurants can use smart tables in their workplaces. On these tables, customers experience several activities such as ordering, table decorating, getting information about the food, sharing instant posts on social media and playing games. As a consequence of these tables are required to recognize the foods that the customers eat or detect to what extent they would impact the socialization level of the customers with the other people next to themselves.

IoT is defined as the communication of things using the internet and managing actions autonomously (EBSO, 2015). This technological development decreases the costs of food production as well as increasing time efficiency. Especially within kitchen production areas, human-computer interaction helps people with the cutting process thanks to the smart cutting boards and the knives attached to them. However, it can be observed that this innovation is a prototype study at this time.

Radio Frequency Identification (RFID) labels are involved within cyber-physical systems. RFID technology allows factories to produce foods and beverages with different features on the same production line. It, in addition, makes it possible for manufacturers to produce safe foods and beverages as it provides them with data about the production, storage and transfer of foods and beverages. As it provides consumers with information about the product as well, it allows them to check the supply chain. However, due to technical and economical obstacles, the use of this technology becomes restricted.

3D food printers help to prepare the final products using ingredients such as chocolate, cream, cheese, hummus, dough, butter, jelly, starch and granulated sugar as wished. Within the existing related literature, there have been numerous studies and debates regarding 3D food printers. For instance, whereas the manufacturers of FOODINI brand asserts production of any kind of fresh and real ingredients, from sweet to salty, can be performed/achieved by 3D printers, Izdebska & Tryznowska (2016) state that meat, rice, vegetables and fruits are counted as the ingredients which

cannot be printed by 3D printers. They also claim that it is possible to process these ingredients with additives such as xanthan gum or gelatin. It is believed that 3D printers will increase the production power, decrease costs, enable customized food production, and manufacture geometric food shapes easily with the help of these machines. Lin (2015) asserts that food that is prepared and packaged in prepacked cartridges is more appropriate for transportation across long distances since they have longer shelf lives than fresh fruits and vegetables. On the other hand, Lipton et al. (2015) state that most of the food stock that is produced with 3D printers has a limited shelf life. In the food and beverage industry, 3D printers are not very common due to their cost and the long process required for printing food products.

In factories that produce food and beverages, machines and robots are used efficiently in the stages such as shelling, washing, processing, packaging and counting. The technological innovations brought to this industry by Industry 4.0 such as big data, cloud computing, IoT, human-computer interaction, RFID technology, and 3D printers form the basis of smart factories. It can be considered that within these factories there will be a quantitative decrease yet qualitative increase in staff number. Nowadays, robot chefs and service robots that can make recipes are in the phase trial.

In the food and beverage industry, there is a need for investment to make the technological innovations provided by Industry 4.0 more common. Investor workplaces need to be informed about the technological innovations as well. In addition to bringing the technological innovations into the production areas, there is also a need for staff that are qualified enough to understand and use these innovations. Appropriate courses, particularly, need to be added to the curriculum in order to provide necessary training for the staff to be employed in the food production area. In this way, young people will be both using the technological innovations within the production area and closely following recent technological developments in the world thanks to the awareness they gain in the training. For further recommendations, researchers can conduct studies focusing on the experience and perceptions of the employees on the technological innovations provided by Industry 4.0 in the food and beverage industry. Another study can examine the advantages and disadvantages of these innovations for the food and beverage industry.

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