Impacts of Industry 4.0 in Sustainable Food Manufacturing and Supply Chain

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Abstract: Integration of Sustainability and sustainable practices have been of paramount importance within most manufacturers' supply chain environment globally. Apart from the fact that every organisation now use this to improve on their Corporate Social Responsibility (CSR), this is also used as an opportunity to manage production and services within most firms efficiently. This sustainability is now a strategy adopted by most businesses to meet their customers' expectation considering the sustainable society awareness of which food manufacturing is not an exception. The use of several innovative strategies and incorporation of Industry 4.0 has been employed by some food manufacturers to meet up with this sustainability. This paper through a qualitative research study seeks to bridge the interconnection between Industry 4.0 and sustainable practices within food manufacturing supply chain.

Keywords: Food Manufacturing; Industry 4.0; Logistics; Supply Chain; Sustainability; Sustainable Production; Corporate Social Responsibility.

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1 Introduction

Sustainable practices in food manufacturing and supply chain are of paramount importance in Food and Beverage Manufacturing business considering the general orientation of sustainable society through the set "Sustainable Development Goals (SDGs)". Every organisation is working hard to ensure that the needed contributions to the achievement of these set goals are met while working to improve on their Corporate Social Responsibility (CSR). The challenge of "Sustainable food production and marketing has always needed to be addressed (Li, et al., 2014) this is necessary because of the population growth which leads to a daily increase in food demand. The food demand has tripled in the past 55 years (1950-2015) following the world population growth which has been predicted to keep growing (Govindan, 2017). This population growth will inevitably lead to depletion of more natural resources as production increases within the food industry. Environmental sustainability concern tends to grow more within food industry due to some factors and issues like food security, health and safety, food waste, fair trade, climate change, localism etc. (Li, et al., 2014).

Several researchers had been able to look into sustainability within the food industry considering the new and existing challenges associated with food safety, climate change, public health, localism, fair trade, food waste etc. and had come up with questions like, what are the ways to achieve and maintain best sustainable food manufacturing supply chain environment? What are the best strategies, regulations or technology could be adopted to mitigate sustainability problem within a food manufacturing environment? (Olga, 2012; Seuring & Müller, 2008a). Meanwhile, some researchers had also come up with some strategies and regulations that could be of use in attaining good sustainability level in food manufacturing one of which is Reg. 1305/15 by European parliament, "short supply chain in the food industry could help in sustainable agriculture through the reduction of transportation, thereby cutting down on CO_2 emissions" (Canfora, 2016). This Reg. 1305/15 by the European Parliament is a logistics regulation that could help in solving sustainability problems, but the impact of such regulations could be minute in the presence of many challenges encountered in the food industry sustainability process. Application of this strategy will only cover some part of the food manufacturing, supply chain and logistics but more strategies and planning would still need to be integrated into the production process for better sustainability. Integration of strategic innovations is required within any manufacturing supply chain environment for the best sustainability performance to be achieved (Long, et al., 2018). Such strategic innovations could be useful in food manufacturing and supply chain environments to achieve the best form of sustainable production and supply chain management.

Supply chain is a network of organisations that is responsible for the production and distribution of goods and services from the raw material state to the final consumer while supply chain management means merely an improved coordination of resources within and between various supply chain members (Mangan, et al., 2014; Ojo, et al., 2017). Meanwhile, the sustainable supply chain can be defined "as management of production process throughout the supply chain from the raw materials to customers and feedback with the improvement of the social, economic and environmental impacts in total considerations" (Seuring & Müller, 2008). However, to achieve sustainable food manufacturing and supply chain environment, good strategic innovation would be needed. Strategic innovation is an implementation of new ideas after combining resources and productive forces which are perceived through creative thinking to solve the identified problem or in improving an existing situation (Jelonek, 2015). This innovation as a strategy is paramount in food manufacturing, and supply chain environment in improving food security, food safety, and the needed sustainability associated with the triple bottom line (TBL), i.e. social, economic and environmental aspects within the food industry and therefore, should be considered throughout the entire supply chain. A few decades back, research has suggested that "strategic innovation in the food industry combines technology with socio-cultural innovation with the aim of improving consumer products and services" (Earle, 1997).

Meanwhile, in the face of sustainability awareness within the food industry, strategic innovation in food manufacturing is seen as one of the primary drivers for growth and the main aim of this is to make sure that good and healthy foods are produced efficiently and sustainably (Luque, et al., 2017). The integration of the new industrial revolution (Industry 4.0) also known as the smart factory (Wang, et al., 2016), has been identified as one of the latest strategic innovation in food manufacturing supply chain which supports the sustainable practices and this will go a long way to help in achieving the needed sustainability within the food industry (Luque, et al., 2017; Soto-Silva, et al., 2017). Implementation of Industry 4.0 within food manufacturing will be of high benefit to the food industry (Luque, et al., 2017); and this will also align with the achievement of the set sustainable development goals (SDGs). The new Industry 4.0 will also be able to address some of these identified issues like food safety, perishability, food wastage, food security control, demand predictions, competitive pressure etc. within the food manufacturing and supply chain environment.

This paper intends to review and analyse the overview of industry 4.0 with its evolution and essential components. Its adoption within the sustainable food production and supply chain environment. The critical role Industry 4.0 could play

in sustainable food production and supply chain environment has not been well exploited by literature and research. Therefore, this paper will further look into a case study of a food manufacturing firm that has adopted the use of Industry 4.0 in its operations and then analyses the entire potential impact of the integration of this Industry 4.0 within food manufacturing and supply chain environment. The case will be analysed and critically reviewed with the core findings to identify both the present and future opportunities and challenges associated with the integration of this technology in the food manufacturing and supply chain for sustainability. The paper further goes into discussion and conclusion looking into future research and development.

2 Literature Review

2.1 Overview of Industry 4.0

Smart factory is the known fourth industrial revolution (Industry 4.0) and remains the latest industrial revolution until this period. It combines automation and data exchange in a manufacturing technology environment. This industrial revolution was an idea conceived and initiated by the Germans and was initially given a public awareness in 2011 as part of the country's high-tech strategy intended to strengthening her industrial sector to meet up future production requirements (Hofmann & Rüsch, 2017; Mittermair, 2015). The combination of components like artificial intelligence, automation, robotics, internet of things (IoT), big data (BD), cloud computing (CC), enterprise resource planning (ERP), cyber-physical systems (CPS) etc. forms Industry 4.0 (Barreto, et al., 2017; Shirazi, 2018; Wollschlaeger, et al., 2017). This idea is to work on creating a smart manufacturing and supply chain environment within the industries for better efficiency and improved productivity and sustainability to meet the necessary need (Kamarul Bahrin, et al., 2016). Figure 1 highlights the journey so far on industrial revolutions and predictions of industrialisation based on trends and research.

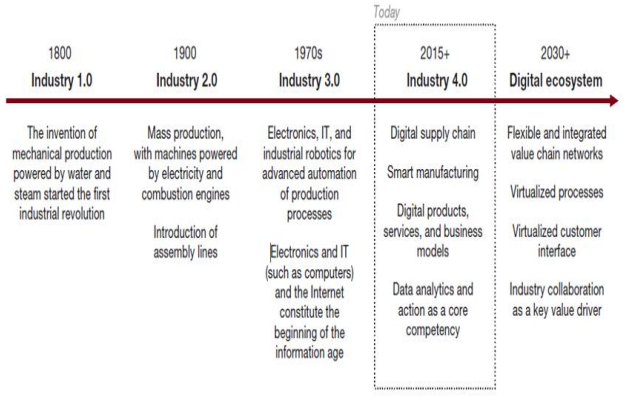

Figure 1: Evolution of Industry 4.0 (Berttram & Schrauf, 2016)

The First and early industrialisation started with the "Victorian One" in the late 18th Century when production moved from farming to factory production, this engaged the use of mechanical manufacturing equipment that was powered using steam engines (Barreto, et al., 2017; Berttram & Schrauf, 2016; Witkowski, 2017). The second industrial revolution started in the early 19th century and ran till the period of World War I with the introduction of mass production using conveyors and steel culminating powered by electricity and combustion engines (Barreto, et al., 2017; Berttram & Schrauf, 2016). Meanwhile, the third industrial revolution which sated in the late 90s migrated production from analogue mechanical technology to digital/automation technology engaging the combination of electronics and Information Technology (Barreto, et al., 2017; Berttram & Schrauf, 2016; Hofmann & Rüsch, 2017). The latest industry 4.0 which is the fourth industrial revolution started in the year 2011 which transforms manufacturing system and its supply chain into smart production using the advanced Information and Communication Technology (ICT) systems that would make production and its supply chain system more efficient, economical, flexible and environmental friendly (Berttram & Schrauf, 2016; Mittermair, 2015; Wang, et al., 2016).

The development and integration of this Industry 4.0 within industries will be a massive opportunity in attaining sustainability especially within manufacturing industries through the use of various information and communication technology (ICT) infrastructures (Stock & Seliger, 2016; Wang, et al., 2016; Witkowski, 2017). This industrial revolution's paradigm is outlined by three dimensions that include vertical integration, horizontal integration and end-to-end engineering across the entire product lifecycle (Stock & Seliger, 2016). Meanwhile, it is viewed through these three paradigms in micro perspective and macro perspective as highlighted in figure 2 with its essential components (Stock & Seliger, 2016). The vital elements of industry 4.0 include; (1) Cyber-Physical System (CPS) which comprises of different sets of networked agents and devices; it involves the coordination, integration, control and monitoring of physical and engineered system by computing and specific communication system (Barreto, et al., 2017). This system uses sensors, actuators, control processing units and other communication devices to integrate computer operations with the physical process in production for improved efficiency and better productivity. (2) Internet of Things (IoT) which is the system that deals with data exchange between materials world and the computers to enable and control better interaction of materials world with the computers making it smarter and more comfortable to improve production process (Barreto, et al., 2017; Hofmann & Rüsch, 2017; Witkowski, 2017). (3) Big Data (BD) deals with the analysis and management of advanced level data that cannot be handled with the use of traditional tools, it helps in quick and efficient management of data especially with the massive and rapid growth of databases through the integration of internet data sourcing (Kamarul Bahrin, et al., 2016). Meanwhile, considering the expanded database, Big Data is useful in logistic optimisation, quick and efficient management of data for better operational efficiency in production (Kamarul Bahrin, et al., 2016; Witkowski, 2017). (4) Automation and Intelligent Robotics is a crucial aspect of industry 4.0 especially within the

manufacturing sector; many robots had been developed and integrated into Industry 4.0 within manufacturing sectors to ultimately achieve the aspired smart factories (Kamarul Bahrin, et al., 2016). It plays a vital role in modern manufacturing by completing tasks intelligently with or without human intervention (Kamarul Bahrin, et al., 2016).

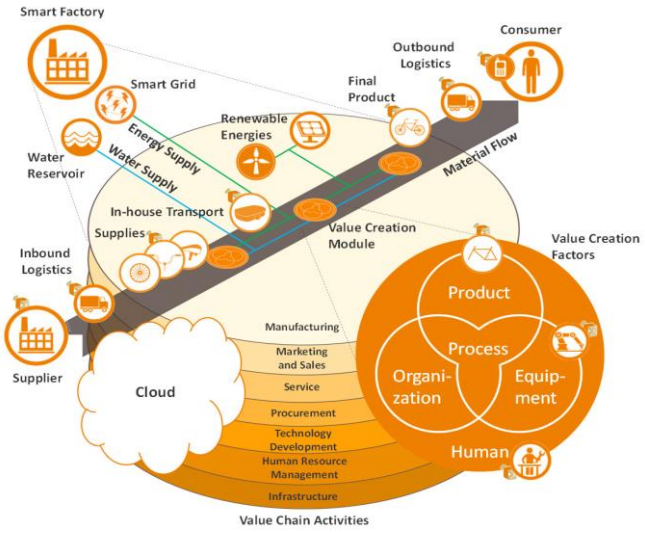

Figure 2: Micro Perspective of Industry 4.0 (Stock & Seliger, 2016.

(5) Cloud Computing is the part of Industry 4.0 that deals with computer resources or data storage through the use of the internet. It is a substitute for physical computer information storage using equipment like hard disk, or other data storage hardware. It merely means storing and accessing data and computer programs over the Internet instead of a computer's hard drive. This cloud computing remains one of the most crucial aspect of information security and transportation management systems in supply chain management within the purview of Industry 4.0 (Barreto, et al., 2017).

2.2 Overview of the Food and Beverage Manufacturing Industry

The food manufacturing industry is an essential part of every nations' economy considering its huge contributions to the world economy at large (Food and Agriculture Organization of the United Nations, 2016). This food industry remains an important aspect of most countries' health and economic well-being with its massive contribution to their GDP and employment generation for the majority of the populace. The food industry in the United Kingdom, for example, generates more than 400,000 jobs and remains the largest single employer of labour. It has the biggest manufacturing industry in the country with over 6,000 businesses with the worth of about €88 billion as of 2012 (Thomas, 2018). The growth of this industry has been continuous due to population growth and therefore, tends to be better and more prominent if well managed. The rapid world population growth has actively contributed to the growth of the food industry, and it has always added about 15% to the total manufacturing turnover especially in European economic sectors (Noya, et al., 2018).

Food processing and manufacturing can be described as a sequence of operations that takes place in the conversion of agricultural products into a finished food product that could be fit for consumption (Knoerzer, 2016). It involves the conversion of agricultural products into staple foods to be healthy and safe for human consumption. Examples of basic methods used in food processing include; sun drying, cooking, boiling, roasting, curing, fermentation, baking etc. Food processing and manufacturing come in about three different levels depending on the extent of manipulation or changes undergone before it is presented for consumption (Mahajan, et al., 2017). The history with proofs through the archaeological and ethnographic evidence concluded that first processed food was by a hunter-gather society where heat and boiling water were used to make vegetables, roots and meats palatable and better edible (Fellows, 2009). This was the start of food processing and manufacturing. However, as the need for food storage and preservation rises in these earlier centuries, this has sprung up ideas of food processing techniques were developed by the Egyptians in the 3000-1500 BC.

Meanwhile, methods like fermentation, milling, sun-drying, baking etc. and several other methods of processing grains and legumes were also developed in some parts of Asia and Europe in this early years with technological development and established regulations (Fellows, 2009). The need to preserve food for improved food security and safety has prompted further advancement in food processing and manufacturing techniques this has also stimulated the introduction of every various advanced technology in food manufacturing to improve on efficiency. The popularity of electrical technology in the early nineteen hundred revolutionised the food industry with the introduction new food processing machinery (Fellows, 2009) and this industry still follows the adoption of advanced technology and trends for improvement.

Technology advancement has been an essential part of real revolution and development in the food industry, and this industry has always relied on this for growth. It is, therefore, indispensable for the food industry to take advantage of any trend and advanced technology for improvement in processing and manufacturing. Although the initial reason for food processing and manufacturing is to convert food to staple form for better taste, edibility for it to be more palatable for consumption but the rights become enhanced as research and technology advance. The role and importance of science, technology and engineering in food processing are to conserve the supply of raw foods, protect against the further loss, and guarantee the food cultural relevance, nutritional value as well as the food safety (Olaoye, et al., 2014). Meanwhile, some of the reasons associated with food processing and manufacturing as analysed by (Fellows, 2009; Knoerzer, 2016; Olaoye, et al., 2014) include Preservation (shelf-life extension and value retention) safe for human consumption, improving cooking time, nutritional value improvement, improved handling, varieties and diversification, refined taste and quality,

enhanced value for health and safety purposes etc. However, technology advancement has helped achieve the purposes as mentioned earlier using several methods of food processing and manufacturing.

2.3 Industry 4.0 in Sustainable Food Manufacturing Supply Chain and Logistics

Every manufacturing environment is a sensitive one that needs attention at every step. However, supply chain and logistic is a critical aspect of every manufacturing; it is more important in a food manufacturing environment considering factors like food quality, food safety, food security etc. The complexity of the food supply chain had made logistics and supply chain management essential part of food manufacturing. Meanwhile, to achieve this, a good plan and a well-structured strategy are needed at every part of the supply chain especially to ensure food safety, good quality and quantity of food products (Soto-Silva, et al., 2017). Furthermore, as cumbersome as the food supply chain could be, integration of advanced technology has been helpful especially in the developed world. For instance, the operation of a cold supply chain management using different components of Industry 4.0 has gone a long way to ensuring a high level of food safety, quality and quantity. The cold supply chain is a logistics systems of handling agricultural produce in a regulated temperature environment from the point of harvest till it gets to the end users without losing the value of any form (Sharma & Pai, 2015). The evolution of industrialisation in food industry followed the trend in the general manufacturing industry and has now grown to the stage of food servicing where every part of the food supply chain is monitored and analysed with the help of advanced technology. Figure 3 further explained the four (4) stages of evolution in food production which include; 1. Farming, 2. Food Processing, 3. Food Processing and Packaging and 4. Food Manufacturing Supply Chain (Food Servicing).

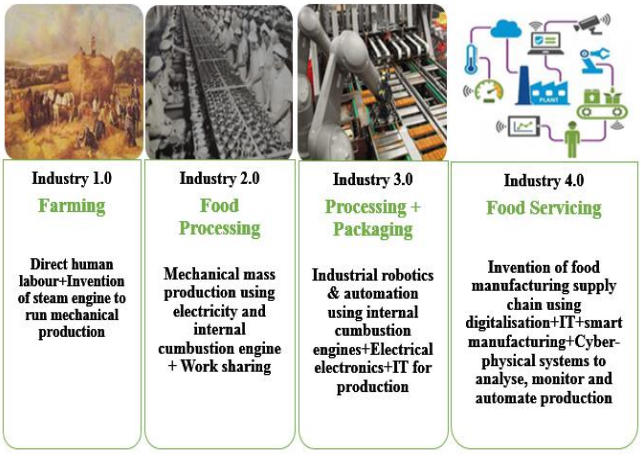

Figure 3: Industrial Revolution in Food Industry

However, there are some operations within the food manufacturing supply chain that work to ensure sustainable food production. Most of these operations now employ the use of advanced technology like industry 4.0 to achieve the sustainable food manufacturing supply chain and logistics. Technology like Industry 4.0 integrated into operations creates a smart manufacturing supply chain systems within sectors for better productivity and efficiency (Kamarul Bahrin, et al., 2016). The activities that are being influenced by this Industry 4.0 within the food industry include; Production order, production planning, Disposition and production as well as Delivery.

Production Order: This is the management and conversion of raw materials into finished products through the required information within the supply chain system (Saniuk, et al., 2013). Supply chain systems and procurement are paramount in food manufacturing, they form the basis of successful manufacturing and production order. These supply chain and procurement activities within food industry often require new tools, skills and processes at every point to find and secure the required sources of value that could improve competitive advantage (Doheny et al., 2017). A well-structured procumbent systems helps in effective management and expansion of most food companies' complex global supply chains. This could also be very useful in meeting consumers' preferences, managing risk, and cutting cost in production and also helps in effective business decision-making. This is the point at which information and material flow is highly needed for successful manufacturing and supply chain environments especially within food industry. The integration of some components of Industry 4.0 will be useful in both material and information flows within the food supply chain during the manufacturing process and beyond. It will make the Just-in-Time (JIT) systems that are necessary in food production more efficient and effective; this could align the production order with the actual consumptions (Hofmann & Rüsch, 2017). This integration could result to improved Information and Communication Technology (ICT) and improved Information Security System (ISS) which are paramount in good supply chain strategy, protection of information assets, sustainable manufacturing and logistics (Dubey, et al., 2017). However, for any organisation to improve its competitive advantage, high-level security on ICT structure is essential to exploit both software and human vulnerabilities (Barreto, et al., 2017).

Production Planning: This deals with striving to meet up with the customers' future demands (Hofmann & Rüsch, 2017). Proper adoption and implementation of Industry 4.0 paradigm in warehousing and material flow management will positively impact warehouse operations (Barreto, et al., 2017). Accurate prediction of products arrival could be achieved through enhancement of communication networks between transportation systems and the intelligent warehouse management system and also with the optimisation of the just-in-time and just-in-sequence delivery operations (Barreto, et al., 2017). The adoption of relevant environmental policies like EMAS or ISO could be useful (Olga, 2012); and these standards and procedures are communicated with the aid of several ICT systems. Strategic collaboration is also instrumental in production

planning, as it aids information circulation, improves access to innovative technology and helps in reduction of recycling and disposal costs within supply chain partners (Dubey, et al., 2017).

Disposition and Production: This entails meeting and delivery of customers' specifications and order requirements. These could best be achieved if the specifications and order requirements are promptly and well communicated to the producers. The integration of appropriate components of Industry 4.0 could help with this required real-time information which gives insight on how best customers' expectations could be met. This real-time information could be of great help in achieving sustainability and sustainable production through continuous improvement and new product development to meet the customers' expectations. New Product Development (NPD) is very useful in disposition and production; it is the innovation of new products to address identified problems of the existing products or upgrade for customers' satisfaction (Pinna, et al., 2018).

Delivery: This deals with the suppliers' distribution of products when and to where needed. It is important that the right materials should be delivered to the right place at the right time and in the right sequence if further processing is required (Hofmann & Rüsch, 2017). Integration of components of Industry 4.0 could positively influence production and logistics; the use of components like intelligent routing systems helps in just-in-sequence (JIS) and just-in-time (JIT) delivery for continuous production or to meet customers' immediate needs. Industrial ecology which involves the control of the used energy and materials ensuring a reduction in pollution and wastes in the logistic process (Boix, et al., 2015) is needed in logistics planning. The use of an alternative source of fuel, energy, logistics collaboration and reverse logistics could also be used in improving logistics for sustainability. This strategy would help in profit maximisation while greenhouse gas emission is controlled to the barest minimum for better sustainability and reduced global carbon footprint" (Dubey, et al., 2017). The integration of Industry 4.0 in transportation management system (TMS) through the application of Global Points System (GPS) and cloud computing technology to build its intelligent transportation system (ITS) will also be helpful as it improves communication within the transportation systems and the relevant supply chain partners (Hofmann & Rüsch, 2017). Internet of things (IoT) is another useful component of Industry 4.0 within transportation and logistics for proper monitoring of goods through vehicles' tracking, communication and data processing during material flow (Atzori, et al., 2010; Barreto, et al., 2017). Radio Frequency Identification (RFID) tags, barcodes, sensors etc. could also be useful for tracking and real-time monitoring of products flow with the aid of the Internet of Things (IoT). The Enterprise Resource Planning (ERP) systems and Networked Enterprises Systems (NES) are another part of Industry 4.0 that could be useful in achieving efficiency in quality control, safe delivery, marketing management, customers demand fulfilment and product tracing etc. (Shirazi, 2018). These systems/ tools also increase food security and safety.

3 Methodology

3.1 Research Approach

Industry 4.0 in food manufacturing is now becoming popular in the developed nations of the world, the literature review so far in this research has been able to conclude that much research has not been carried out in this aspect of sustainable food manufacturing and supply chain environment. Meanwhile, some analyses and literature have emphasised the importance of case study in hypothesis validations, research clarifications and model/framework development (Holweg & Helo, 2014; Sgarbossa & Russo, 2017). This research relied on in-depth interview within a chosen food manufacturing company to understand how the supply chain works and how best the application of Industry 4.0 has impacted sustainability within food manufacturing supply chain so far. The research took an explorative approach combining both primary and secondary research methods. The secondary aspect deals with the knowledge acquired from literature review while the fundamental element deals with the qualitative research which was performed through a preliminary case study to identify the research problems and proposed solutions to address them as well as fill in the identified research gaps in this area of study.

3.2 Case Selection and Data Collection

The process of selecting the case study was a comprehensive one with high scrutiny to ensure that the best sustainable food manufacturing and supply chain environment that has good integration of advanced technology is well captured. Meanwhile, with the little research that has been done within the European food industry, Andalusia food industry is identified as key in the Spanish economy, and it is of paramount importance in European economy considering its advantage and potentials (Luque, et al., 2017). Meanwhile, Spanish food and beverage industry is ranked as the fourth largest in Europe and ranked eighth in the world. However, this industry represents 16% of the total manufacturing industry in Spain with small and medium-sized enterprises representing about 96% of the total. The Spanish food and beverage industry is enormous and it directly employs 500,000 people with an average turnover of over €93million and directly employs almost half a million (Invest in Spain, 2017). Andalusia in Spain remains one of the Mediterranean coastal areas that take food production seriously; it is known for agricultural products including fruits and vegetables all year-round including winter with about 5,000 food and beverage manufacturing companies which is employing close to 220,000 people (Marsden, et al., 2000). Its food industry is strategic in enhancing both quality and quantity food production to support world food security, and it can also be an excellent source of employment generation (Luque, et al., 2017). It was, therefore, noted that if this kind of food

industry could be technologically improved, it will be a model for other food industry in the world. This improvement will influence and support sustainable food production which in turn helps the world sustainable development goal of environmental protection and the combat of food insecurity in the world. Hence, one of the strong reasons for considering case studies in Andalusia food industry zone in Spain.

This research carried out preliminary checks on some food industries in the Andalusia province of Spain sending out questionnaires and interview questions for reviews. The questionnaire responses and reports of the companies gave direction to the company that would be best for this research. The final selection of the company SG was made after the study and after many factors had been put into consideration. The information for this study was retrieved in three ways which include questionnaire, semi-structured interview and on-site/observation visits. All these were arranged within a month with four different visits. The first visit was for the questionnaires to be given with explanations given on it to the participants for better understanding. The second and third visits were arranged to complete the semi-structured interview while the last visit was for the on-site/observations with questions and answers session for some clarifications. The questionnaire and the interview questions were draft based on the previous information and acquired knowledge of sustainability and advanced technology in food supply chain environments. The face to face interview was arranged with some people at the management level within the SG Company. This is a company which is one of the biggest producers of Olive oil in Spain and one of the biggest exporter of olive oil in the world and exports olive oil to more than seventy (70) countries with an average of 1.4Billion Euro in total sales yearly (Company SG, 2016). The arranged semi-structured interview featured the key players within the company's supply chain, production and logistics activities which had earlier reviewed the questionnaire and prepared for the likely answers needed for the research progress and accuracy. The research was able to carry out semi-structured interviews for better interaction to get facts directly from the members of staff at the management level who are directly involved with the production process from the start of the supply chain till the end. The members of staff that were interviewed include the production director, two factory/production managers, two quality managers, warehouse manager and the finance manager of the SG in one of its manufacturing plant. Thereafter, there were on-site visits that gives room for direct observations with questions and answers sessions from the production and quality managers of the company. The research was also able to get both primary and secondary data sources with references to the company's sustainability reports. The research was able to combine these data sources, which were analysed through the case study methodology, comparing the reality within the industry with the reviewed literature to ascertain the practice and impact of Industry 4.0 within food manufacturing and supply chain environment. However, the research further looked into how best these practices could be matched up with literature requirements for best practices and results.

4 Result and Discussion

4.1 Result and Analysis

Sustainability is critical in company SG's operational strategy, this company is committed to this and has always been given regular attention and assessment to sustainability in every aspect of the company's operations. Sustainability assessment and report is done every year to monitor the company's progress while using this as an avenue to improve operational strategy and meeting the sustainability target. However, for this to be achieved, Company SG has employed the use of Industry 4.0 for sustainable production and logistics. Although, the full implementation of the new technology is not yet completed as the company is still working on the full incorporation of Big Data in its operations. Meanwhile, some other significant components of Industry 4.0 like the Internet of Things (IoT), Cloud Computing, Cyber-Physical Systems and Automation & intelligent robotics has been fully implemented and adopted to achieve sustainable manufacturing and supply chain environment. The integration of these components has proved a high level of sustainability so far considering the level of accuracy and consistency that has helped in waste reduction. The company through its operations as shown in Figure 4 has been able to effectively use the associated tools of Industry 4.0 at every stage of the manufacturing supply chain to achieve this great sustainable production and logistics. For instance, the raw material sourcing part of the company's production uses tools like the Internet of Things (IoT) and Cloud Computing to connect with processing/manufacturing, distribution and retailers through the production order, production planning and delivery operations for more effective demand and supply predictions. The quality control, traceability and monitoring of the raw materials are also made easy with the integration of this technology in the raw material sourcing and supply.

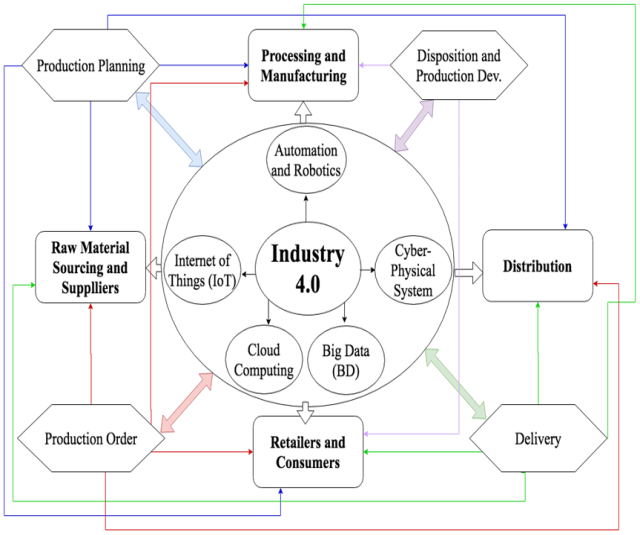

Figure 4: Industry 4.0 and Sustainable Manufacturing Supply Chain in SG's Operations (Ojo et al., 2018)

The red lines in figure 4 show the relationship/connection of the production order process to all the operations within the food manufacturing supply chain environments. This process uses some components of industry 4.0 to effectively connect with these operations to achieve order fulfilment which is the ultimate goal of production, especially within the food industry. The blue lines highlight the relationship of production planning and how it also connects to every part of the operations using components like the Internet of Things (IoT), Cloud computing, Robotics etc. to aid sustainable manufacturing in the production planning process. Meanwhile, the purple lines which show the relationship of disposition and production process which is connected to only the "processing and Manufacturing" and, Retailers and Consumers" operations. This uses tools like Big Data, Cloud Computing and Internet of Things (IoT) to strengthen the relationship within these two operations to promote satisfaction and sustainability. However, the green lines show the importance of delivery process in the supply chain systems as it connects with every operation within the cycle. The integration of these components of industry 4.0 in the process' activity promotes sustainable production successfully. Furthermore, the four active operations within the company's manufacturing supply chain environment also integrates the components of Industry 4.0 through different process to achieve sustainable production.

This integration also gives room for more effective communication within the supply chain especially for the best just-in-time (JIT) and just-in-sequence (JIS) production. The technology had supported better synchronisation between company SG and other outsourced companies involved raw materials sourcing and supply. This connection and sync has eased the stress associated with transportation and logistics and has indirectly helped in the mitigation of greenhouse gas emission. The processing and manufacturing part of the company SG which runs in two interconnected stages uses tools like automation, robotics, artificial intelligence, cyber-physical systems and Internet of Things (IoT) in its operations for improved efficiency and sustainable production. The process in the first stage of processing includes sorting, cleaning, grinding, weighing, testing, batching, centrifugation, refining etc.

Meanwhile, the other stage deals with bottling and labelling which is handled by an outsourcing firm that is synchronised with the phase one operations within the factory using advanced technology of industry 4.0 to ensure smooth just-in-sequence (JIS) production. This part of the supply chain connects with every other part of the supply chain through every operation that includes production order, production planning, disposition and product development as well as the delivery. The distribution and warehousing part of the supply chain of company SG is made smart and automated using a cyber-physical system, automation and robotics, artificial intelligence etc. to communicate directly with the production line (Processing and Manufacturing) for stock control and operations within the warehouse. Internet of Things (IoT) oriented equipment like Radio Frequency Identification (RFID), sensors and barcodes are used in delivery operations to get full information of stocks/products when sorting for shipping. The retail sales/customer part of the supply chain gets the finish products to consumers and uses some Industry 4.0 components like the Internet of Things (IoT), Cloud Computing and Big Data to obtain information about customers feedbacks and reactions to the products. This influences decisions in new product development, product improvement and demand predictions which helps to improve the overall customer satisfaction. This part of the supply chain uses Industry 4.0 technology to interact with other parts of the supply chain for better production, improved marketing and sales.

Furthermore, the company had to combine other sustainability approaches with these Industry 4.0 components to achieve a high level of sustainability. Examples of these approaches include; application/engagement of various environmental standards and certifications which is extended to the company's suppliers as one of the primary criteria used in suppliers selection, this is being communicated and monitored with the use of Industry 4.0 technology. Installation and the use of solar renewable energy are also one of the sustainability approaches within the production factory. The company through its production planning arrange and encourage the utilisation of recyclable containers to help in environmental pollution control. It is also working through strategic collaboration with the packaging material suppliers to produce lightweight containers with modifications of the shape to reduce the raw materials used in production as well as for better storage space, and this will also improve the recycling qualities. Awareness and Information are also being given to the consumers on how best the used containers could be disposed to help improve the recycling process.

4.2 Discussion and Future Research

The food industry has always been an innovative industry and strives to embrace the latest technology for product improvement. However, regular integration of any newest technology within this industry is essential especially for product improvement needed to achieve the best form of food safety. Meanwhile, the application of technology within the food industry is not limited to only the processing and manufacturing part of the supply chain but very useful in every part of the food manufacturing supply chain environment. Therefore, integration of new technology like Industry 4.0 starts from the point of harvest and all through the post-harvest until it gets to the final consumer. This full integration will have a full impact in food manufacturing supply chain system; every stage of the supply chain within the food industry will be able to share data and links with one another. The Internet of Things (IoT), Automation, Big Data, Cyber-physical Systems and Cloud computing which are the main components of the Industry 4.0 have been instrumental and effective in achieving greater efficiency within this food manufacturing supply chain system. The

accessible shared data has been beneficial at the earliest time possible during food manufacturing and distribution thereby making the supply chain super effective. Online platforms that give unlimited access to useful information for every member of the supply chain systems according to their jurisdictions; for instance, a platform for suppliers' information and feedback, accessible information to the manufacturing operations and distributions, consumers access to information and feedback. This platform improves the operations within food manufacturing supply chain environment where all these platforms are interconnected, updated and managed by the companies' supply chain management and operations team.

One of the most important things within food manufacturing supply chain is effective communication, and this could ultimately be achieved with the help and integration of latest technology comprising mostly of the Industry 4.0 components. However, the literature relates that sustainability and adoption of sustainable practices within any production and logistics could be very expensive to achieve, but the cost could be controlled with the joint efforts of the involved supply chain partners (Seuring & Müller, 2008a). Meanwhile, the case study had clearly shown that sustainability could be an adopted strategy to reduce the cost of production thereby maximising profit and one of the means to achieving this sustainability could be associated with the integration of latest technology within operations. Although it could seem expensive at the beginning, its advantages and useful cost control attribute will reflect within a short period.

However, the benefits and potential benefits associated with the use of latest technology in sustainable food manufacturing and supply chain environments as seen in the case study are so numerous and not limited to. (1) It helps in food quality control as all information needed to keep the manufacture products safe and also be of high quality is accessed when required and with high precision. (2) Improved shelf-life of the product as there has been a good plan in place through information for product control; there is good communication within the supply chain to control overproduction as well as produce the just-in-time (JIT) products needed on shelves. (3) Customers' demand prediction is always easy and helps in production control. The electronic traceability through the latest technology assists in tracking the food throughout the supply chain. (4) Supply chain integration is achieved with the fast connections of the supply chain partners/players and every part of operations involved in production through the use of the latest technologies imbibed in Industry 4.0 technology. (5) There are opportunities for product modifications and new product development to suit sustainability purposes. (6) Traceability is possible for easy food recall when needed for food safety standards. (7) Customers retention and loyalty are highly achieved as the customers' demands, and specifications are met as at when due, the requests and feedbacks are also got from the customers through the use of components of Industry 4.0 technology. (8) Mitigation of greenhouse gas emission like CO_2 in every aspect of operations. (9) It helps in effective environmental waste control. (10) It is also a great means of achieving good water and energy conservation which is paramount to environmental protection. The easy communication and access to information within the production cycle has given room to reduction in wastes and transportation which is the main contributing factor to emission.

5 Conclusion

Sustainability and sustainable production is crucial within every manufacturing sector at this period of global warming and climate change. The food industry is not an exception to this and hence, the reason to investigate the best approach that could guarantee the needed sustainable food manufacturing supply chain environment. This approach should be good enough to address the sustainability problems of economic, social and environment during production. However, it is advantageous to ensure sustainability at every operational stage and also at every aspect of the supply chain to make the operations more efficient. This research has contributed theoretically through literature reviews and findings and even in practice through the conducted case study and analysis. Meanwhile, considering both the theoretical and practical aspects, this research and other earlier studies had been able to suggest that integration of innovations and new technology in operations could have a significant impact in achieving a more suitable and sustainable manufacturing and supply chain environment.

The analysed case study has been able to suggest that proper integration of the latest technology like Industry 4.0 within food manufacturing supply chain environment could improve operational efficiency and promote sustainable production and supply chain systems. The study was also able to point out the present and future opportunities and challenges associated with the integration of this new technology. For instance, the prospect of New Product Development (NPD) and rebranding, more product varieties, and functional energy conservation. Meanwhile, during operations, high precision in demand and supply is achievable, better food quality, lead time reduction, accurate food traceability and quick recall and most importantly the environmental control and protection. Despite these advantages, there could be constraints that include employee redundancy, high cost of implementation, data security risk etc. but these challenges could be strategically addressed.

This paper is a part of an extensive research that is looking into the development of a framework that will support sustainable production within the food industry. A comparative approach is necessary where further research and case studies will still be conducted in other part of the world within food industry to further investigate their sustainable food manufacturing supply chain environment and how this could be improved globally. The future research will also investigate the level of advanced technology involvement in food manufacturing and supply chain environment within the emergent nations to support

sustainable production and logistics. This will give room for a universal framework design that could be effective in improving sustainability and efficient techno-economic performance within food industry worldwide.

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