Impacts of Industry 4.0 within Sustainable Production and Logistics in Food Manufacturing

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ABSTRACT

Sustainability and sustainable practices has been the focus of importance for both manufacturers and customers within the global markets. Every manufacturer and supplier within the Supply Chain environments now strive hard to ensure they are part of this sustainable development goal to achieve better results and fulfil their Corporate Social Responsibility (CSR) principles. This is done mostly by business owners to meet up with customers' expectation of sustainable society, including that of the food manufacturers and other small suppliers. They need to work hard and think of innovative strategies that could be employed to meet up with this popular challenge of sustainable society. This paper reviews current literature studies to analyse food processing suppliers who have adopted new technological advances and that of Industry 4.0 practices to achieve and fulfil better sustainable practices within their production and logistics activities in their supply chains. Through this research study we aim to bridge the interconnection between Industry 4.0 and that of sustainability practices within food manufacturing environments.

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

1. INTRODUCTION

Sustainable food production and logistics is one of the most relevant and desirable action in food industry at this period of set "Sustainable Development Goal". Every industry is working hard to contribute to the achievement of this set goal in order to improve their Corporate Social Responsibility (CSR). "Sustainable food production and marketing has always been a global challenge that needs to be addressed (Li, et al., 2014), this is due to the fact that food demand will always increase on daily basis as a result of the population growth. Record has it that "food demand has trippled in the past 55 years (1950-2015) following the world population growth" (Govindan, 2017). This demand increase will therefore result to continual increase in the quantity of natural resources used in production and through the entire suppy chain system within the food industry. Meanwhile, several issues like food security, health and saftey, food waste, fair trade,, climate change, localism etc. in food industry grow concern daily about environmental sustainability in the sector (Li, et al., 2014). There had been questions like how best food

production and logistics can be made sustainable with these existing and developing challenges associated with population explosion, localism, climate change, public health, food saftey, food waste, fair trade among others? How can the tripple bottom line (TBL) of sustainability (i.e Social, Environmental and Economic) be met with the challenges in the industy? What type of regulations, strategies or technology could be adopted or put in place to solve this problem? (Olga, 2012); (Seuring & Müller, 2008a). Meanwhile, as suggested by Reg 1305/15, "short supply chain in food industry could help in sustainable agriculture through reduction of transportation, thereby cutting down on CO2 emissions" (Canfora, 2016). This logistics regulation can actually help but there is little to what it can do in resolving the many challenges within food industry. It could only be used to cover a little part of the food industry or its supply chain but more logistics planning would still be needed for better sustainability. Sustainability must be integrated into any manufacturing supply chain innovative strategy to attain and maximise the business sustainability performance (Long, et al., 2018). These innovations could be used in business practices within food industry to achieve sustainable supply chain management and sustainable development goal.

Sustainable supply chain can be defined "as management of production process throughout the supply chain from the raw materials to customers and feedback with improvement of the social, economic and environmental impacts in total considerations" (Seuring & Müller, 2008). Meanwhile, innovation can said to be the implementation of new ideas after combining resources and productive forces perceived through creative thinking to solve a specific problem or improve on existing situation (Jelonek, 2015). This is a very important tool in food industry to improve on food safety, food security as well as improving on the triple bottom line (TBL) of sustainability i.e. social, economic and environmental situation within the industry's supply chain. Innovation strategy should be considered throughout the entire supply chain in the food industry for improvement, it should start from the point of harvest or raw material sourcing, processing or manufacturing and throughout the entire distribution network till it gets to final consumer. Early research concluded that "Innovation in food industry combines technological with social and cultural innovation with the aim of improving consumer products and services" (Earle, 1997). However, food industry innovation strategy at this period of sustainable development goal for environmental and human protection should emphasise more on the environmental aspect which will in turn strengthen the social and economic aspect of the industry. Food industry innovation strategy should not only be directed totally at technology changes in the food industry but the social and environmental changes also need to be considered to ensure production of food that satisfies the nutritional, personal and social needs of the consumers (Earle, 1997).

In the food business, innovation is seen as the main driver for growth and the main aim of this is to make sure that good and healthy foods are produced in an efficient, effective and sustainable way (Luque, et al., 2017). Application of the Industry 4.0 as one of the newest innovation in food manufacturing supply chain which supports the sustainable practices will go a long way to help in achieving all these within the food industry. Implementation of this Industry 4.0 within food manufacturing will be of high benefit to the food industry (Luque, et al., 2017); this will surely support the sustainable development goal which every industry is striving to achieve. Industry 4.0 that is also known as smart factory will be able to address a lot of these identified issue like food safety, food security control, perishability, competitive pressure, difficulty in demand predictions etc. within the food manufacturing settings. The digital technology imbibed in in Industry 4.0 like Internet of Things (IoT), big data, automation, intelligent robotics, additive manufacturing etc. will be more than enough tool in addressing most of the associated problems in food manufacturing and supply chain and this could go a long way to improve productiohn and marketing in the food industry.

2. LITERATURE REVIEW

2.1 Overview of Industry 4.0

Industry 4.0 (smart factory) is the known fourth industrial revolution; it is the combination of current automation and data exchange in manufacturing technology. Industry 4.0 was first publicly introduced in the year 2011 as part of German high tech strategy to be used in strenthening the industrial sector in future preparation for the sector to meet its production requirements (Mittermair, 2015). The combined use of industry automation, robotics, internet of things (IoT), big data (BD), cloud computing (CC), enterprise resource planning (ERP) cyber physical systems (CPS)concepts and some other forms of advanced information technology systems forms the Industry 4.0 (Wollschlaeger, et al., 2017); (Shirazi, 2018); (Barreto, et al., 2017). Intergration of these is belived to improve effeciency, productivity and sustanability.Meanwhile, the "Victorian One" started industrialisation in the 19th Century when production was moved from farming to factory production, this was referred to as the first industrial revolution where the use of mechanical manufacturing equipment powered by the steam engine was introduced and dominant (Barreto, et al., 2017); (Witkowski, 2017). The second industrial revolution ran from around the 1850s till the period of World War I and this began with the introduction of conveyor, steel culminating in the early electrification of factories and the first spouts of mass production (Hofmann & Rüsch, 2017); (Witkowski, 2017); (Barreto, et al., 2017). However, the third industrial revolution is the change from analogue mechanical technology to digital technology of automation which combined the use of electronic and Information and Communication Technology (Barreto, et al., 2017) (Hofmann & Rüsch, 2017). This has been in use until the advent of the latest Industry 4.0. The Industry 4.0 concept is introduced to transform manufacturing system and its supply chain into smart production with the aid of advanced Information and Communication Technology (ICT) systems that would make both the supply chain and production system more economical, flexible and environmental friendly (Mittermair, 2015) (Wang, et al., 2016).

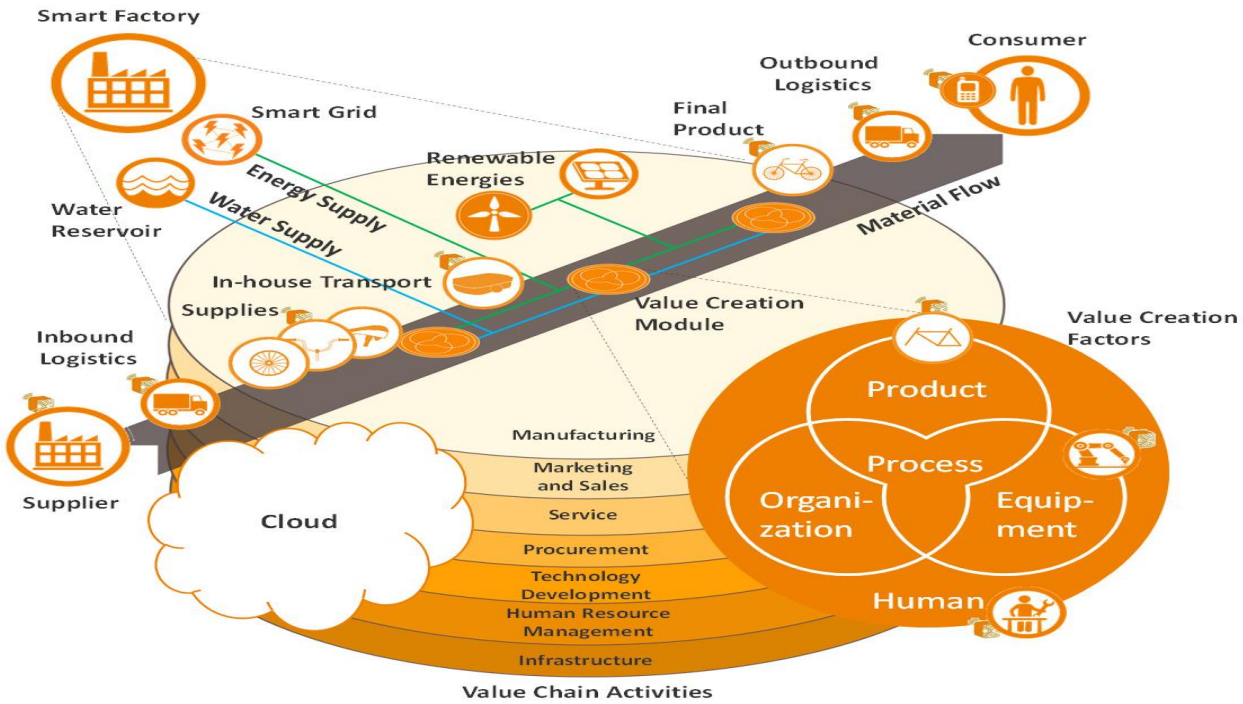

Figure 1: Micro Perspective of Industry 4.0 (Stock & Seliger, 2016)

The development towards Industry 4.0 will be a huge opportunity in attaining sustainable manufacturing within industries through the use of various information and communication technology (ICT) infrastructures (Stock & Seliger, 2016); (Wang, et al., 2016); (Witkowski, 2017). The Industry 4.0 paradigm is outilined by three dimensions that includes vertical intergration, horizontal integration and end-to-end engineering across the entire product lifecycle (Stock & Seliger, 2016). Meanwhile, Industry 4.0 is viewed through these three paradigms in micro perspective and macro perspective (Stock & Seliger, 2016). These two perspectives shows the essential components, uses and impacts of Industry 4.0 with Fig 1 highlighting the overview of the micro perspective of Industry 4.0 with its vertical, horizontal and end-to-end integration within smart factories.

2.2 Overview of Food Processing and Manufacturing Industry

The food processing and manufacturing industry is an important aspect of every countries' economy with its immense contribution to the world economy (Food and Agriculture Organization of the United Nations, 2016). This industry is paramount to most nations' health and economic wellbeing as it contributes a lot to most countries' manufacturing GDP and creates employment opportunity to majority of the population in the world. In the United Kingdom for instance, it remains the largest single employer with over 400,000 employee with the biggest manufacturing industry of over 6,000 businesses worth about EUR 88 billion as at 2012 (Thomas, 2018) and the industry kept growing on daily basis as the population grows. However, this industry grows at a very fast rate due to the rapid increase in the world population (Ojo, et al., 2017) and it always contributes about 15% to the total manufacturing turnover especially in European economic sectors (Noya, et al., 2018). Most of the consumable food products undergo processing one way or the other and as a result contributing to the manufacturing turnover seen as economic asset especially with the national gross added value (Noya, et al., 2018).

The history as indicated by the archaeological and ethnographic evidences has it that the first food processing was done when a hunter-gather societies used heat and boiling water to make roots, vegetables and meats more palatable and edible (Fellows, 2009). Meanwhile, as the need for food storage and preservation arise as far back as 3000-1500 BC, some food processing techniques were developed by the Egyptians which include sun drying, fermentation, milling, baking etc. Several other method 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). Food processing and manufacturing keep advancing as the technology develops, as safety regulations spring up and as human needs grow. The advancement of food processing and manufacturing has been prompted by the need to preserve food to improve food security, this has also stimulates the introduction of every latest technology into food manufacturing for better efficiency. It was stated that widespread introduction of electricity for example revolutionised the food industry in the early nineteen hundred which prompted production of some new food processing machinery (Fellows, 2009). This is still in practice as the technology improves, food processing and manufacturing industry adopts the trending technology for improvement in food industry. Food processing and manufacturing can be described as a sequence of operations that takes place in conversion of agricultural products into finished food product that could be fit for consumption (Knoerzer, 2016). It involves conversion of agricultural products into staple foods to be fit 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 comes in about three different levels depending on the extent of manipulation or change undergone before it is presented for consumption (Mahajan, et al., 2017).

Technology advancement has been playing vital role in the food industry for a long time and the industry has always relied on it for growth; that is why it is important for food industry to key into any trending technology for improvement in processing and manufacturing. The initial reason for food processing and manufacturing is to convert it to staple form for it to be edible and more palatable for consumption but the reasons becomes enhanced as research and technology advance. The role and importance of science, technology and engineering in food processing is to conserve the supply of raw foods, protect against further loss, and guarantee the food cultural relevance, nutritional value and the safety (Olaoye, et al., 2014). Meanwhile, some of the reasons for food processing and manufacturing as analysed by (Olaoye, et al., 2014); (Knoerzer, 2016); (Fellows, 2009) include Preservation (shelf-life extension and value retention) safe for human consumption, improving cooking time, nutritional value improvement, improved handling, varieties and diversification, improved taste and quality, improved value for health and safety purposes etc. There are several methods of food processing and manufacturing to achieve the aforementioned purposes and more of this methods spring up every day as the technology advances (Ojo, et al., 2017).

2.3 Industry 4.0 in Food Industry's Sustainable Production and Logistics

Production Order: Production order is key in manufacturing as it manages the conversion of purchased materials or requested supplies into manufactured products through required information within the supply chain (Saniuk, et al., 2013). Information flow is of paramount importance in sustainable manufacturing; it is however more essential in food manufacturing because of the perishability factors involved for human health and safety. Integration of Industry 4.0 will be highly useful in both material and information flows within food supply chain throughout manufacturing process and beyond. It will make the Just-in-Time (JIT) systems that is necessary in food production more efficient and effective and it will also "align the production order with the actual consumptions" (Hofmann & Rüsch, 2017). Therefore, production order relies and requires good information and communication technology (ICT) structure and good information security systems through Industry 4.0 for desire results. **Improved Information and communication Technology** is an important aspect of sustainable production and logistics and "it is interesting to know that enabling technologies contribute immensely to the strategic framework formulation of a suitable and sustainable production within most supply chains" (Dubey, et al., 2017). Several strategic information that support sustainable manufacturing are been accessed using the Information and Communication Technology (ICT) systems. This has resulted to great improvement and achievement in the set sustainable supply chain management strategy, sustainable manufacturing, production and logistics. **Improved Information Security System** is also very paramount in any organisation to protect the information assets. The amount of data that is being shared and dealt with by organisations on daily basis with various third parties access need protection. This is of high importance to a successful business organisation to improve its competitive advantage and it is good to know that the security of the IT and computer structures is necessary not only to exploit software vulnerabilities but to exploit human vulnerabilities (Barreto, et al., 2017). This is definitely an important aspect of a successful production order within any food manufacturing and supply chain.

Production Planning: Production planning has to do with working towards meeting up with future demands of the customers (Hofmann & Rüsch, 2017). Meanwhile, putting economic, social and environmental factors into consideration during production is highly important for an organisation to run a sustainable production. Incorporation of several Industry 4.0 components like cloud computing, internet of things, internet of services, cyber physical systems, auto-ID

technologies etc. ensures the smooth material flows and smart warehousing. The integration of environmental conservation using various standards communicated and enforced through the use of applied ICT tools could also impact sustainable production and logistics. **Green and Smart Warehousing Operations** is important in any manufacturing supply chain system and is needed in almost every line of the chain. A lot of waste is generated through food manufacturing supply chain of which could be associated with loss through energy, water, packaging, food perishables etc. Energy efficient technologies in warehouse operations could be needed for sustainability in warehousing, storage minimisation, energy minimisation and continuous use of green and renewable energy sources could also be very useful in food manufacturing green warehousing. Proper adoption and implementation of Industry 4.0 paradigm in warehousing management will surely have positive impact on the way warehouse works (Barreto, et al., 2017). This could enhanced communication network between transportation systems and the intelligent warehouse management system which in turn enable optimisation of just-in-time and just-in-sequence delivery with accurate prediction of product arrival (Barreto, et al., 2017). This overall process coordinates the inventory, storage space and product movement to and from the right locations at the right time within production. **Environmental Conservation** is also an important driver in sustainable production and logistics as it supports sustainable development within food manufacturing environment. The adoption of relevant environmental policies like EMAS or ISO 140001 in every part of manufacturing process and the supply chain could be of help in environmental conservation and this could promote sustainability and sustainable development (Olga, 2012). The environmental standards and policies are being communicated with the help of several Information and Communication Technology (ICT) Systems and applications. **Strategic Collaboration** is very useful in any manufacturing environment, it aids information circulation and improves access to innovative technology needed for sustainable development in manufacturing process and within supply chain partners. This strategic collaboration could also help in the process of reducing recycling cost as well as disposal costs (Dubey, et al., 2017). The integration of collaborative environmental planning and furcating systems within the supply chain members goes a long way to improve manufacturing, logistics and supply chain system.

Disposition and Production deals with meeting the consumers or buyers specifications and order requirements. The use of various Industry 4.0 components could help with real time information required from the customers which gives insight on how best to meet their expectations. This will however help in improving the production planning, lead time reduction as well as better end product for the consumers. This could also give room for sustainability and sustainable production through continuous improvement and new product development to meet the customers' expectations. **Continuous Improvement** plan is always needed in disposition and production to meet up with the customers' needs and expectations. This process gives opportunity for production to be made green considering products and production modifications and this gives opportunity for every aspect of the supply chain and production to be modified and made sustainable. **New product Development** is the innovation of new products to address identified problems of the existing products or updating for customer satisfaction (Pinna, et al., 2018). This is mostly planned with the feedback from the consumers and the advancement in technology and trends. New product development in terms of "green product design is one of the major drivers in organisations' sustainable manufacturing and supply chain management" (Dubey, et al., 2017) as it takes every latest sustainability measure into consideration.

Delivery: This has to do with distribution of products to wherever and whenever they are needed. Every supplier is committed to delivering of the right materials to the right place at the right time and also in the right sequence if the product requires further processing (Hofmann &

Rüsch, 2017). The use of several Industry 4.0 components impacts production and logistics with introduction of intelligent routing systems that helps in just-in-sequence (JIS) and just-in-time (JIT) delivery for continuous production or to meet customers' immediate needs, telematics unit that helps in location tracking and general product information during transportation. **Logistics Improvement and Optimisation** is significant in food manufacturing and Sustainable Food Supply Chain Management (SFSCM) and it is highly recommended. Every aspect of supply chain in food manufacturing is paramount and therefore the logistics should be efficient and effective to prevent the food from spoilage and contamination. Industrial ecology which involves the control of the used energy and materials ensuring reduction in pollution and wastes in logistic process (Boix, et al., 2015) is needed in logistics planning. The use of alternative source of fuel, energy, logistics collaboration and reverse logistics could also be used in improving logistics for sustainability; the use of "energy efficient logistics could significantly 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) helps as it improves communication the transportation systems to the relevant supply chain partners (Hofmann & Rüsch, 2017). The internet of things (IoT) is now very useful in transportation and logistics within industries as it is now used in enhancing capabilities in vehicles' tracking, communication and data processing for proper monitoring (Barreto, et al., 2017); (Atzori, et al., 2010). The help of enterprise resouce planning (ERP) systems and networked enterprises (NEs) could help in achieving flexibility in quality control, safe delivery, marketing management, customers demand fulfillmentand product tracing (Shirazi, 2018). Tracking and real-time monitoring of products' movement can now be achieved throughout the entire supply chain i.e. from the raw material sourcing, manufacturing and distribution with the aid of sensors, barcodes, and Radio Frequency Identification (RFID) tags with the incorporation of the internet of things (IoT).

3.0 METHODOLOGY

3.1 Research Approach

Industry 4.0 is novel in food manufacturing and it has been noted that much research has not been done in this aspect of food manufacturing and supply chain sustainability. 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. This research took an explorative approach combining the earlier little knowledge acquired from literature review done and the qualitative research which was performed through 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. Case studies can be very useful in understanding and developing new theories and hypothesis (Sgarbossa & Russo, 2017); (Holweg & Helo, 2014); this will therefore be an important aspect of this research.

3.2 Case Selection and Data Collection

The case selection process was a comprehensive one to capture the best sustainable food manufacturing and supply chain with the integration of the new technology Industry 4.0. Meanwhile, little research work has been done on this within Europe food industry but not in-depth. Andalusia food industry is key in Spanish economy and very important in the entire Europe

with its economic advantage and potentials (Luque, et al., 2017). Andalusia remain one of the Mediterranean coast area that that takes food production seriously, it is known for agricultural production including fruits and vegetables all year-round including winter (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 a very good source of employment generation (Luque, et al., 2017). It was therefore noted that this kind of food industry could be technologically improved, it will be a model for other food industry in the world and it will go a long way to support sustainable food production which in turn supports 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 a preliminary checks on some food industries in Andalusia province of Spain sending out questionnaires and interview questions for reviews. A comprehensive face to face interview was finally arranged with Sovena Group which is one of the biggest producers of Olive oil in Spain and one of the biggest exporter of olive oil in the world. The company exports olive oil to more than seventy (70) countries with the average of 1.4Billion Euro in total sales yearly. The interview featured the key players within the company's supply chain, production and logistics activities who 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 form the people that are directly involved with the production process from the start of the supply chain till the end. The people that were involved in the interview include factory manager, quality manager and the financial manager of the Sovena group in its Brenes (Seville) manufacturing plant. The research was 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 and these data 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 one of the main element of Sovena Group strategy and this has always been given regular attention and assessment. Sustainability assessment and report is being done yearly to monitor the company's progress and also to improve on the strategy considering meeting the sustainability target. However, for this to be achieved, Sovena group has employed the use of Industry 4.0 for sustainable production and logistics. Although, the full implementation of the new technology is not yet achieved as the company is still working on full incorporation of Big Data in its operations. Meanwhile, other major component of Industry 4.0 like Internet of Things (IoT), Cloud Computing, Cyber-Physical Systems and Automation & intelligent robotics has been fully implemented and adopted to achieve sustainable production and logistics. This 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 2 has been able to effectively use the associated tools of Industry 4.0 at every stage of the supply chain to achieve this great sustainable production and logistics. Furthermore, the company had combine other sustainability approach with these Industry 4.0 components to achieve high level of sustainability. Examples of these approach include; application /engagement of various environmental standards and certifications which is extended to the company's suppliers as one of the major 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 is 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 light weight 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 is also been given to the consumers on how best the used containers could be disposed to help improve the recycling process.

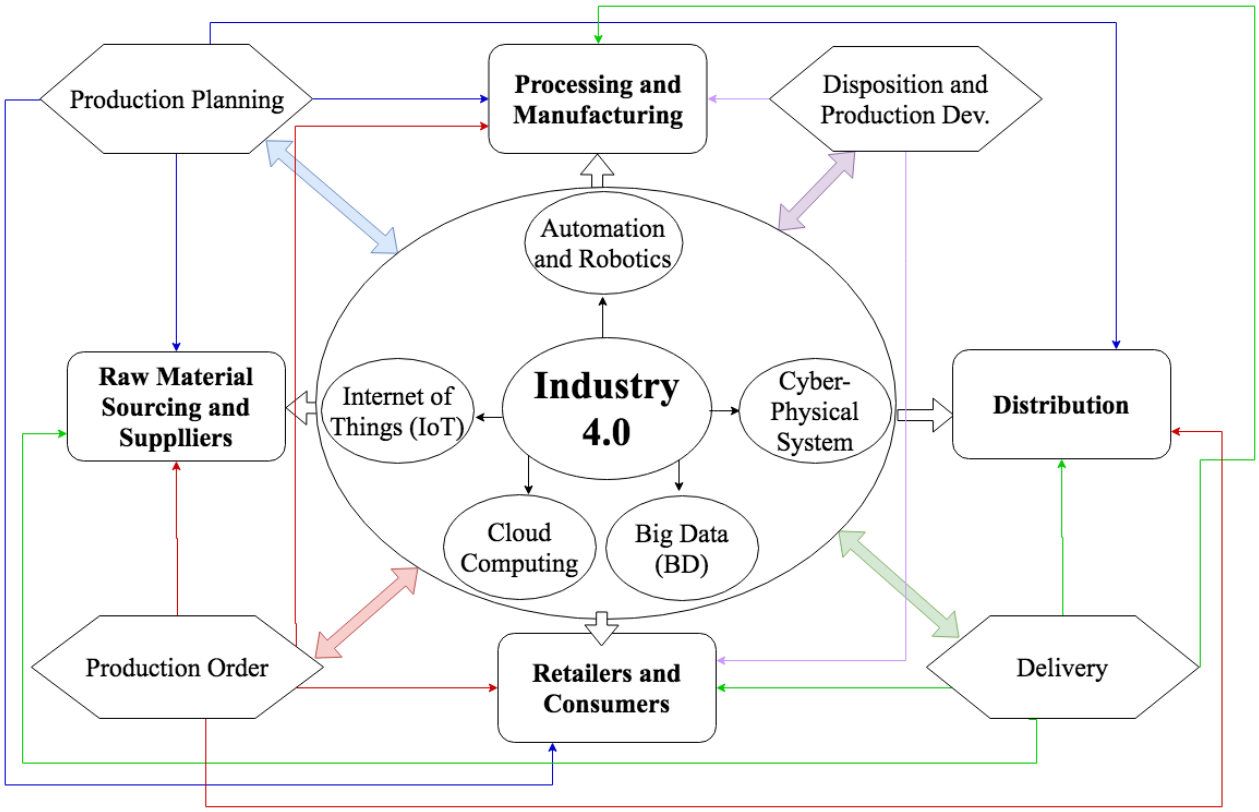

Figure 2: Sustainable Production and Logistics Framework

4.2 Discussion and Literature Findings

The food industry has always been an innovative industry and the industry always strive to embrace latest technology for product improvement. The integration of the new technology in the industry for product improvement is very essential as the industry usually works on achieving the best form of food safety at all times. Technology introduction in food industry is not always limited to only the production line (Manufacturing) but also very important in logistics and the entire supply chain system of the industry. Therefore, integration of Industry 4.0 starts from the point of harvest in the farm and runs through the processing aspect, to the distributions till it finally gets to the consumers' table. This will have complete impact in food manufacturing supply chain system; every stage of this supply chain within 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 component of the Industry 4.0 has gone a long way to help in achieving greater efficiency within this food manufacturing supply chain system. The accessible shared data has been very useful at the earliest time possible during food

production and distribution thereby making the supply chain super effective. Online platforms that gives 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, accessed information to the manufacturing operations and distributions, consumers access to information and feedback 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 a strategy that could be adopted to reduce cost of production thereby maximising profit. Although, it could seem expensive at the beginning but its advantages and effective cost control attribute will reflect within a short period of time. 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 needed 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 very easy and helps in production control; electronic traceability through the latest technology assists in tracking of the food throughout the supply chain. (4) Supply chain integration is achieved with the swift 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 is highly achieved as the customers' demands and specifications are met as at when due with the requests and feedbacks got from the customers through the use of components of Industry 4.0 technology.

5 CONCLUSION

Conclusively, the full integration of Industry 4.0 within food manufacturing will go a long way to help in predictions of customers demand at any time for production management which will in turn help in waste management. It will be useful in identifying consumers' wants and priorities at earliest time as well as consumers' feedback. This will help in better plans in the distribution network and better flow of information and instructions within the entire supply chain systems. This will give room for new product development (NPD), rebranding and repackaging of products to suit consumers use according to their requirements. More varieties of product could be created with consumers' feedback at the needed time. It will also help in the consumer support for sustainability and a great tool for customers' retention. It will be helpful in the aspect of energy conservation as much time will be saved and precision will also be high during production process. This will also contribute to the reduction in lead time which translates to improvement in shelf-life as it makes the products get to the market and consumers' table at the earliest possible time for fresher and better food quality. Finally, this will be very effective in food recall and traceability process. Digitalised food manufacturing supply chain system with great integration of

Industry 4.0 will be able to easily track, trace and recall products in case of emergency or incidents of food contamination. This will go a long way to prevent contaminated food from getting to market or quick withdraw of such contaminated food from the shelves in no time to minimise the risk of human consumption as well as protecting the image and integrity of the affected company.

The research is a preliminary case study research that considered sustainable food production within the develop nations of the world. Further research will be carried out through some case studies in some emergent nations of the world to see how sustainable production and logistics looks within food manufacturing in these emergent nations. Then a balance point could be met to have a common framework that could be applicable and used as standard for general sustainable food production and logistics. 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 the sustainable production and logistics.

6. REFERENCES

Atzori, L., Lera, A. & Motabito, G., 2010. The Internet of Things: A survey. *Computer Networks,* 54(15), pp. 2787-2805.

Barreto, L., Amaral, A. & Pereira, T., 2017. Industry 4.0 implications in logistics: an overview. *Procedia Manufacturing,* Volume 13, pp. 1245-1252.

Boix, M., Montastruc, L., Azzaro-Pantel, C. & Domenech, S., 2015. Optimization methods applied to the design of eco-industrial parks: a literature review. *Journal of Cleaner Production,* Volume 87, pp. 303-317.

Canfora, I., 2016. Is the Short Food Supply Chain an Efficient Solution for Sustainability in Food Market?. *Agriculture and Agricultural Science Procedia,* Volume 8, pp. 402-407.

Dubey, R. et al., 2017. Sustainable supply chain management: framework and further research directions. *Journal of Cleaner Production,* Volume 142, pp. 1119-1130.

Earle, M. D., 1997. Innovation in the Food Industry; Review. *Trends in Food Science & Technology,* Volume 8, pp. 166-175.

Food and Agriculture Organization of the United Nations, 2016. *Climate change and food security: Risk and Responses.* s.l.:s.n.

Govindan, K., 2017. Sustainable consumption and production in the food supply chain: A conceptual framework. *International Journal of Production Economics.*

Hofmann, E. & Rüsch, M., 2017. Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry,* Volume 89, pp. 23-34.

Holweg, M. & Helo, P., 2014. Defining value chain architectures: Linking strategic value creation to operational supply chain design. *International Journal of Production Economics,* Volume 147, pp. 230-238.

Jelonek, D., 2015. The Role of Open Innovations in the Development of e-Entrepreneurship. *Procedia Computer Science,* Volume 65, pp. 1013-1022.

Knoerzer, K., 2016. Food Process Engineering. *Reference Module in Food Science,* pp. 1-5.

Li, D., Wang, X., Chan, H. K. & Manzini, R., 2014. Editorial: Sustainable Food Supply Chain Management. *International Journal of Production Economics,* Volume 152, pp. 1-8.

Long, T. B., Looijen, A. & Blok, V., 2018. Critical success factors for the transition to business models for sustainability in the food and beverage industry in the Netherlands. *Journal of Cleaner Production,* Volume 175, pp. 82-95.

Luque, A., Peralta, M. E., de las Heras, A. & Córdoba, A., 2017. State of the Industry 4.0 in the Andalusian food sector. *Procedia Manufacturing,* Volume 13, pp. 1199-1205.

Mahajan, R., Garg, S. & Sharma, P. B., 2017. Processed food supply chain: a framework for literature review. *Journal of Advances in Management Research,* 14(1), pp. 91-109.

Mangan, J., Lalwani, C., Butcher, T. & Javadpour, R., 2014. *Global logistics and supply chain management.* 1 ed. Chichester: Wiley.

Marsden, T., Banks, J. & Bristow, G., 2000. Food Supply Chain Approaches: Exploring their Role in Rural Development. *Sociologia Ruralis,* 40(4), pp. 424-438.
Mittermair, M., 2015. Industry 4.0 initiatives. *SMT: Surf. mt. Technol.*, 30(3), pp. 58-63.
Noya, L. I. et al., 2018. An environmental evaluation of food supply chain using life cycle assessment: A case study on gluten free biscuit products. *Journal of Cleaner Production,* Volume 170, pp. 451-461.
Ojo, O. O., Shah, S. & Coutroubis, A., 2017. *An Overview of Sustainable Practices in Food Processing Supply Chain Environments.* Singapore, IEEE International Conference on Industrial Engineering and Engineering Management.
Olaoye, A. O., Idowu, O. A. & Lawrence, G. I., 2014. Certain roles of the food scientist in ameliorating. *ISABB Journal of Food and Agricultural Sciences,* 4(1), pp. 13-19.
Olga, C., 2012. Sustainable supply chain management: Theoretical literature overview. *Sweden: International Institute for Industrial Environmental Economics, Lund University.*
Pinna, C. et al., 2018. Effect of product lifecycle management on new product development performances: Evidence from the food industry. *Computers in Industry,* Volume 100, pp. 184-195.
Saniuk, A., Witkowski, K. & Saniuk, S., 2013. *Management of production orders in metalworking production.* METAL 2013 - 22nd International Conference on Metallurgy and Materials, s.n.
Seuring, S. & Müller, M., 2008a. Core issues in sustainable supply chain management - a Delphi study. *Business Strategy and the Environment,* 17(8), pp. 455-466.
Seuring, S. & Müller, M., 2008. From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production,* 16(15), pp. 1699-1710.
Sgarbossa, F. & Russo, I., 2017. A proactive model in sustainable food supply chain: Insight from a case study. *International Journal of Production Economics,* Volume 183, pp. 596-606.
Sharma, S. & Pai, S. S., 2015. Analysis of operating effectiveness of a cold chain model using Bayesian networks. *Business Process Management Journal,* 21(4), pp. 722-742.
Shirazi, B., 2018. Towards a sustainable interoperability in food industry small & medium networked enterprises: Distributed service-oriented enterprise resources planning. *Journal of Cleaner Production,* Volume 181, pp. 109-122.
Soto-Silva, W. E., González-Araya, M. C., Oliva-Fernández, M. A. & Plà-Aragonés, L. M., 2017. Optimizing fresh food logistics for processing: Application for a large Chilean apple supply chain. *Computers and Electronics in Agriculture,* Volume 136, pp. 42-57.
Stock, T. & Seliger, G., 2016. Opportunities of Sustainable Manufacturing in Industry 4.0. *Procedia CIRP,* Volume 40, pp. 536-541.
Suryaningrat, I. B., 2016. Raw Material Procurement on Agroindustrial Supply Chain Management: A Case Survey of Fruit Processing Industries in Indonesia. *Agriculture and Agricultural Science Procedia,* Volume 9, pp. 253-257.
Thomas, N., 2018. *UK Food Industry Overview.* [Online] Available at: http://www.limeconsultancy.net/wp-content/uploads/2015/01/UK_Food_Industry_Overview_-_15.03.13.pdf
Vorst, J. G. v. d., Da Silva, C. A. & Trienekens, J. H., 2007. *Agro-industry supply chain management: concepts and applications.* 1 ed. Rome: FAO.
Wang, S., Wan, J., Li, D. & Zhang, C., 2016. Implementing Smart Factory of Industrie 4.0: An Outlook. *International Journal of Distributed Sensor Networks,* 12(1), p. 3159805.
Witkowski, K., 2017. Internet of Things, Big Data, Industry 4.0 – Innovative Solutions in Logistics and Supply Chains Management. *Procedia Engineering,* Volume 182, pp. 763-769.
Wollschlaeger, M., Sauter, T. & Jasperneite, J., 2017. The Future of Industrial Communication: Automation Networks in the Era of the Internet of Things and Industry 4.0. *IEEE Industrial Electronics Magazine,* 11(1), pp. 17-27.