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CIRCULAR ECONOMY AND FOOD PRODUCTION SYSTEMS: TRACING LINKAGES AND EXPLORING SYNERGIES

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Abstract

Food production systems have been in the spotlight for a sustainable conversion due to their environmental, economic, and social impacts. On the other hand, the concept of circular economy has been promoted as a promising alternative for various production systems. By decomposing the agri-food supply chain to its core components, i.e. primary production, food processing and distribution, certain interventions may be assessed through the lens of circular economy. In this paper we focus on the stages of food processing and manufacturing in order to analyze how the application of circular economy perspectives in closing material loops contributes towards minimizing the economic and environmental impacts of food production systems, in opposition to the widely applied linear economy model. Moreover, we explore from a managerial perspective the new technological advancements for waste minimization and valorization and critically discuss the new business models that emerge, along with the redefined value chains.

Key words*: food production system, circular economy, food processing, food manufacturing, value chain*

INTRODUCTION

Due to the perishability of food products, food supply chains can be considered of high importance and perplexity. The world population continues to grow and food production increases with a high cost by putting pressure on the natural milieu. On the other hand, 1.3 billion tons of food are annually lost or wasted, which accounts for 1/3 of all food produced for human consumption [5 , 3].

As mentioned in the UN 2030 Agenda, the goal is “to ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality”.

Food normally has a short life cycle; therefore the objective should be about preventing food loss and waste and eventually finding new ways to use surplus food (for human consumption or as animal feed) [21].

In addition it is important for food products to reach the right customer, at the right time, with the right quality, within suitable shelf life and in the right way in order to sustain competitiveness [19, 16].

This brings to the spotlight another matter for the evolution of the food supply chain where both sustainable consumption and sustainable production are essential conditions for sustainable development [2]. According to the United Nations, both combined means “doing more and better with less”. Keeping in mind that customers’ demands are the focal point of supply chains, customers are particularly interested for the safety of food products while concerns such as food security, damages and quality constitute a significant problem worldwide [16].

Dora et al. (2020) mention that food losses and wastes can be attributed to four main factors [3]:

-Over production, which is a major issue in developed economies. In particular, cosmetic defects are the main reason for losses at production and manufacturing.

-Poor forecasting, which is affected by many factors, such as seasonality, the weather and marketing instruments.
-Technical inefficiency in operations such as farming, storage, and transportation.
-Consumer behavior, which is shopping habits and nutritional attitudes.

The analysis of these factors will definitely assist reaching educated decisions and improving the sustainability and resilience of food production systems.

In this paper we focus on the stages of food processing and manufacturing in order to analyze how the application of circular economy perspectives in closing material loops contributes towards minimizing the economic and environmental impacts of food production systems, in opposition to the widely applied linear economy model. Moreover, we explore from a managerial perspective the new technological advancements for waste minimization and valorization and critically discuss the new business models that emerge, along with the redefined value chains.

MATERIALS AND METHODS

For the scope of this paper, we used relevant bibliography which deals with the emerging paradigm of circular economy and its application in food manufacturing. The approaches discussed in these papers formed the basis for identifying potential interventions in food production systems that serve the purposes of circular economy.

The societal needs and demands are rapidly evolving and set the ground for:
-the development of new policies and regulations for producers
-the need for transparency across the food supply chain, where the consumer knows exactly how the product was handled from farm to fork
-new improved techniques in food manufacturing with stable final food products that meet consumers' expectations during manufacturing by applying sustainable production techniques, and
-ways to make the information associated with the above flows accessible to stakeholders.

Towards this end, circular economy is an emerging paradigm which strives to modify human and organizational behavior and practice patterns. Circular economy aims at improving the way organizations are producing goods [1]. It aims to preserve the value of products and materials and to reduce waste and consumption of resources based on a thinking that prevents waste, uses products until the end of their useful life cycle, and extends its usability through end-of-life product repurposing by application of the 6Rs (Recover, Reduce, Reuse, Remanufacture, Redesign, Recycle) [21]. The innovation and technological development can ultimately contribute to sustainable development and corresponding value creation in products, processes and systems [4]. As Närvänen et al. (2020) mention, circular economy is a regenerative and restorative approach aiming to extend the value and usability of resources as long as possible and contribute to the objectives of sustainable development, especially with respects to our commitments to future generations [14].

Circular economy and sustainable manufacturing are sometimes interchangeably used in the academic literature. There is, however, a major distinction between them: circular economy is a generic model of the entire economy, while sustainable manufacturing is ipso facto limited to manufacturing. Therefore, the latter is an approach which promotes circular economy [4].

There are great possibilities to the matter of circular economy in food manufacturing by incorporating new technologies that would minimize unsustainable handling and innovations on how food by-products can be used as input materials. There is big potential in Data and IT that needs to be explored in order to support the food supply chain procedures towards circular economy implementation. Food manufacturing by-products, due to their nature are free of dangerous contaminants and hold great concentrations of nutrients and chemical compounds which renders them as valuable resources.

RESULTS AND DISCUSSIONS

Food manufacturing is the link between agricultural production and the customer. The agri-food supply chain can be divided in the following consecutive stages, the first one being supply of raw materials followed by production, processing, packaging and finally storage of a final product before being channeled into retail distribution or wholesale [17]. This long chain is in short mentioned using the phrase “from farm to fork”. In a production system, even the simplest process can add up to unsustainability and therefore it is a necessity for a transition to a more sustainable production by reforming the stages of the supply chain by exploring new solutions and implementing existing successful methods. In the sequel we focus on specific dimensions of food production systems which can be directly linked with circular economy, namely Industry 4.0, food waste valorization and packaging.

Industry 4.0

In order to explain transition in sustainable manufacturing model products, processes and systems should be reconsidered and undergo a sustainable conversion with a goal to increase value and bring economic growth to an industry [4].

Industry 4.0 applications hold great potential towards the circular economy model. The ways to incorporate technologies such as Internet of Things (IoT), Big Data Analytics and Blockchain Technologies in food manufacturing is a field that is currently under research. Achieving a sustainable food supply chain is very complex matter given the limited life and abundance of raw materials and of final products, compared to simpler supply chains where processes are easier to keep a track of. This complexity raises the levels of uncertainty to the risks related to food production and generates questions and concerns about how possible is a sustainable transition in the economic, environmental and social performance of this sector [11].

The key drivers of digitalization of the supply chain process are increasing the flexibility and speed of response of the industrial/logistics systems, as well as improving the strength and flexibility of the agricultural food supply chain. In addition, to meet the quality standards requirements of large chain and food retailers, there is a demand for food companies to use recognized quality management and traceability systems. Investing in digital technology also promotes automation of access to a new range of operators, data management, and management tools [11].

A literature review by Enyoghasi & Badurdeen (2021) presents that the interest is shifting towards the identification of potential opportunities for a conversion towards sustainable manufacturing and incorporation of circular economy through Industry 4.0 technologies in general [4]. There is major limitation of frameworks and models presented that lack to emphasize on the current methods of the sustainability methods of assessment such as the total lifecycle or the 6R-based approach for example. Also, none of the studies collectively considers the benefits or opportunities offered through Industry 4.0 for product, process, and system level especially in food supply chains.

Implementing Life Cycle Assessment (LCA) and collecting reliable data is a significant challenge due to the complexities such as incorporating input and output monitoring or quantification at multiple stages of the supply chain. Blockchain technology provides a rich solution to overcome the challenge of sustainable supply chain management. Its use in combination with IoT and Big Data Analytics and Visualization can help organizations achieve operational excellence in LCA operations and improve the supply chain stability [22].

Jagtap et al. (2021) studied ways on how to have higher resource efficiency in food manufacturing and proposed the integration of the IoT to reduce losses in the food supply chain. They suggested adopting an integrated resource management of the food production systems using digital technologies in order to obtain detailed data, which could be depending on resource use and waste generation not only by looking broadly at the whole production, but focusing at a more specific part of the production that being a specific process or even a piece of the equipment [6].

Food waste valorisation

The food sector is considered inefficient due to the large amount of food waste and the amount of energy and water resources consumed. This problem extends more if we consider stricter regulations and the increasing costs associated with the processes of disposing and the treatment of food waste, carbon emissions and wastewater generation. As a result, efficient use of resources is a major factor to sustainable food systems [6]. Finding more efficient ways to manage waste is stated as the challenges identified by the 2030 Agenda for Sustainable Development of the United Nations. This state of wastage contradicts the current state of increasing number of people suffering from malnutrition as well as the depletion of natural resources. Key solutions focusing on the conversion of output materials into useful products are discussed.

There are concepts such as waste biorefineries that have the potential of producing green energy as well as work under a state of zero waste production technologies. This is a motivation for industries to develop products which are friendlier to the environment, that have lower carbon footprint and minimum water consumption. Therefore, in order to meet the goals of the circular economy, waste biorefineries must be able to generate stable market-related products or products that can be used in power industries. The development of these industry plants is highly relevant to increase the value of local raw materials, make the process economically sustainable and contribute to the development of a certain region [20].

Another great example is discussed by Jiménez-Castro et al. (2020) on possible uses of orange peels. This specific food waste was studied as a potential substrate in order to produce different types of bioenergy related products such as biogas, bio-ethanol bioelectricity etc. but also flavonoids for pharmaceutical use by applying a variety of treatments [7].

A study was conducted by Naziri et al. (2014) about the possible was to valorize the agri-food by-products generated in agriculture related businesses and waste from Central Macedonia (Greece) in order to explore potential resources of compounds that could be used as alternatives in food manufacturing [15]. In this specific geographical area, there are three major industry categories: production of olive-oil, wine production and rice production. In olive oil industry by-products are being further analyzed in order to produce carotenoids and bioactive compounds. In wine industry by products are being processed in order to produce squalene and bioactive phenolic compounds from the seeds, bioactive phenolic compounds are also found in rice hulls. All of these products can be used as additives for the production of other products and hold a great position on creating a link between industries while implementing the zero-waste concept in order to minimize waste and close material loops.

Kandyliari et al. (2020) did a research on fish by-products as a possible lipid source. Several types of lipids were found in by-products, but they also found some very important proteins that have the potential to be used in new product development as a source of lipids and protein nutrients and is an example of applying circular economy in practice [10].

In any case, several approaches such as LCA may be used by industries to support deviations from the waste hierarchy, which is the term used in bibliography to describe the steps a company should follow in waste management plan: prevention, minimization, reuse, recycling, energy recovery and disposal. By reviewing a small number of studies, the awareness of the complexity in the abundance of food manufacturing output materials rises and demonstrates the great potential of a transition into the circular economy model.

Packaging

The circular economy model can also create a complex output of materials, but in this case, this complexity leaves fertile ground for sustainable growth since there is space for the development of several new applications.

At the moment, there is a growing concern on the large amounts of plastics that are being generated worldwide since about 80% of these are not being recycled or otherwise re-used. This is a reason of high level of pollution. Big manufacturing companies are committing towards shifts in their processes to reduce the use of plastic packaging, but this shift does not imply their elimination or that this conversion has a beneficial effect on other indices (CO_2, water, etc.) important for the assessment of the sustainability of the company suggesting that circular models are the most beneficial.

On the other hand, science community is working towards creating solutions on this problem suggesting bioplastics, which hold the characteristic of biodegradability and/or are produced using renewable resources, to make up a sustainable solution for traditional plastic materials used in packaging of products [8].

Kakadellis & Harris (2020) conducted a thorough review and found that bioplastics offered the advantage of blocking biodegradable waste from ending up in landfills or being incinerated by channeling them into ‘greener’ streams [9]. Those greener streams are composting and anaerobic digestion which are important methods of implementing the concept of circular economy. Biodegradable bioplastics should be encouraged as a replacement to traditional plastics especially in cases where recycling is not an option. These cases are the multi-layered plastics or highly contaminated by food residues plastic materials. Creating functional solutions by setting the polymer preference and by designing the right packaging. Still there are circumstances where bioplastics do not provide the appropriate characteristics and properties to preserve food products and extend their shelf-life.

Interesting ongoing research on waste leaves from tea waste processed in order to produce bio plastic films [12] or waste from seed oil production which until now has been used as animal feed, is now a material of interest to be used as a resource in bioplastics production (Mirpoor et al., 2021) with the possibility to be utilized also as food packaging material [13].

The concept of bioplastic has been gaining ground on for their beneficial environmental possibilities but in their study (Scarpi et al., 2020) researched the antecedents of consumers’ willingness to alternate their choices towards food waste bioplastic products [18].

Consumers value different characteristics of the products to be more important, those being the quality of the product, the cost of the product rather than their sustainability characteristics which can be for example the implementation of resource management on natural resources, indices such as water consumption or carbon emissions or the handling of the product after or near the expiration date. All of these parameters make switching to sustainable products a very delicate and complex matter for the economy of the food manufacturing industry and is a representation of how strong the interconnection between economy, environment and social aspect of sustainability are.

Taking into consideration current trends in consumers’ diets and lifestyle habits such as veganism, is an index of how consumers are transitioning into a sustainable way of life. Even though currently this is a small group of consumers, the rest of the consumers that are not following or are even opposed to this lifestyle are not necessarily eager to even examine such alternatives let alone adopting them.

Our primary motivation in this paper was to identify the potential of incorporating the concept of circular economy in food production systems. Circular economy is a concept that is strongly working its way to enter industries since all parties, policy makers, industries and consumers are realizing its significance. All pillars of sustainable development may be affected and in all cases cost-benefit analyses have to be conducted.

Food manufacturing contains an abundance of industries, each one with a certain process/system which makes it very complex matter to approach. The abundance of raw materials, manufacturing techniques and by-products leaves ground for a great variety of interventions. Further analysis of the matter in order to unravel this complex subject and reach solutions on how and at what extent the concept of closing material loops has been effectively implemented is of great importance.

Consumers are the driving force of the market and they affect the trends in the food sector by increasing demands on diet habits, lifestyle, and production characteristics as well as transparency and green strategies applied along production. More extensive research on how this possibly affects the concept of circular economy will be valuable.

Currently it seems that the focus is on specific applications such being waste valorization, by-product valorization, biorefineries and a switch towards biomaterials. There is space for further and broader research and development to generate more nodes which can be part of a circular economy system, by developing new products, by implementing new technologies and by creating synergies across sectors. Moreover, supply chain optimization could further enhance this objective.

Packaging has a vital role for most of the final products of a food manufacturing industry, but trends like zero plastics in consumers' behavior could even suggest a zero-packaging mentality with forcing change in companies and setting the ground for further development of sustainable innovations in the field of food packaging.

Data have been drilling their way into manufacturing, but there is still enough space for evolution in the field of food production and manufacturing but also across the whole agri-food supply chain. Until now data analysis had a different approach in food manufacturing focusing more on bringing quality or presenting the consumer with details about the product in hand which is of course essential but at this crucial state of the planet it is of major importance to include additional dimensions.

The circular economy model is getting well-established, but it should also be evolved in the context of Industry 4.0. The IoT, and the Big Data Analytics hold great potential towards the optimization of manufacturing processes and towards a production with higher efficiency.

CONCLUSIONS

Nevertheless, agri-food supply chains are not always easy to cluster and employ the same set of approaches, tools, and technologies. It is clear that there are many researched solutions from several fields proposing methods which can change food manufacturing. Multiple factors such as different geographical regions or consumers' willingness to change, for example, can even have an effect on how this matter is approached and on what is considered most important between economic, environmental and the social aspect of sustainability making it a multifaceted issue. This is a determinant in the case interventions which aim to circular economy objectives. However, collaborative approaches and the systematic sharing of knowledge and experience may be the catalysts towards this transition. What currently needs to be done is for further actions to be taken from stakeholders in order to create links between these fields. A significant number of studies have been conducted and now what needs to be done is to combine the obtained knowledge and implement it in ways that can have an effect on the current state of food supply chains.

Despite the fact that the incorporation of these technological techniques are still costly procedures for food manufacturers, the 2030 Agenda towards sustainable development is a sufficient motive for stakeholders to take action.

REFERENCES

[1]Barros, M. V., Salvador, R., Francisco, A. C. De., 2020, Mapping of research lines on circular economy practices in agriculture: From waste to energy. Renewable and Sustainable Energy Reviews, 131, 109958.

[2]Coderoni, S., Angela, M., 2020, Sustainable consumption in the circular economy. An analysis of

consumers' purchase intentions for waste-to-value food. Journal of Cleaner Production, 252, 119870.

[3]Dora, M., Biswas, S., Choudhury, S., Nayak, R., Irani, Z., Bank, W., Sheffield, S., 2020, A system-wide interdisciplinary conceptual framework for food loss and waste mitigation strategies in the supply chain. Industrial Marketing Management, 93, 492-508.

[4]Enyoghasi, C., Badurdeen, F., 2021, Industry 4.0 for sustainable manufacturing: Opportunities at the product, process, and system levels. Resources, Conservation and Recycling, 166, 105362.

[5]FAO, 2015, July 22, Food loss and waste facts. http://www.fao.org/resources/infographics/infographics-details/en/c/317265/, Accessed on January 13th, 2021.

[6]Jagtap, S., Garcia-Garcia, G., Rahimifard, S., 2021, Optimisation of the resource efficiency of food manufacturing via the Internet of Things. Computers in Industry, 127, 103397.

[7]Jiménez-Castro, M. P., Buller, L. S., Sganzerla, W. G., Forster-Carneiro, T., 2020, Bioenergy production from orange industrial waste: a case study. Biofuels, Bioproducts and Biorefining, 14(6), 1239-1253.

[8]Jõgi, K., Bhat, R., 2020, Valorization of food processing wastes and by-products for bioplastic production. Sustainable Chemistry and Pharmacy, 18, 100326.

[9]Kakadellis, S., Harris, Z. M., 2020, Don't scrap the waste: The need for broader system boundaries in bioplastic food packaging life-cycle assessment: A critical review. Journal of Cleaner Production, 274, 122831.

[10]Kandyliari, A., Mallouchos, A., Papandroulakis, N., Golla, J. P., Lam, T. T., Sakellari, A., Karavoltsos, S., 2020, Nutrient Composition and Fatty Acid and Protein Profiles of Selected Fish By-Products, Foods 2020, 9(2), 190.

[11]Lezoche, M., Panetto, H., Kacprzyk, J., Hernandez, J. E., Alemany Díaz, M. M. E., 2020, Agri-food 4.0: A survey of the Supply Chains and Technologies for the Future Agriculture. Computers in Industry, 117, 103187.

[12]Liu, M., Arshadi, M., Javi, F., Lawrence, P., Davachi, S. M., Abbaspourrad, A., 2020, Green and facile preparation of hydrophobic bioplastics from tea waste. Journal of Cleaner Production, 276, 123353.

[13]Mirpoor, S. F., Giosafatto, C. V. L., Porta, R., 2021, Biorefining of seed oil cakes as industrial co-streams for production of innovative bioplastics. A review. Trends in Food Science and Technology, 109, 259-270.

[14]Närvänen, E., Mattila, M., Mesiranta, N., 2020, Institutional work in food waste reduction: Start-ups' role in moving towards a circular economy. Industrial Marketing Management, 93, 605-616.

[15]Naziri, E., Nenadis, N., Mantzouridou, F. T., Tsimidou, M. Z., 2014, Valorization of the major agrifood industrial by-products and waste from Central Macedonia (Greece) for the recovery of compounds for food applications. Food Research International, 65, Part C, 350-358.

[16]Parashar, S., Sood, G., Agrawal, N., 2020, Modelling the enablers of food supply chain for reduction in carbon footprint. Journal of Cleaner Production, 275, 122932.

[17]Saetta, S., Caldarelli, V., Saetta, S., Caldarelli, V., 2020, How to increase the sustainability of the agri-food supply chain through innovations in 4.0 perspective: a first case study analysis. Procedia Manufacturing, 42(2020), 333-336.

[18]Scarpi, D., Russo, I., Confente, I., Hazen, B., 2020, Individual antecedents to consumer intention to switch to food waste bioplastic products: A configuration analysis. Industrial Marketing Management, 93, 578-590.

[19]Singh, P. J., Power, D., 2009, The nature and effectiveness of collaboration between firms, their customers and suppliers: a supply chain perspective. Supply Chain Management, 14(3), 189-200,

[20]Trevisan Weber, C., Ferreira Trierweiler, L., Trierweiler, J. O., 2020, Food waste biorefinery advocating circular economy: Bioethanol and distilled beverage from sweet potato. Journal of Cleaner Production, 268, 121788.

[21]Wilts, H., Schinkel, J., Koop, C., 2020, Chapter 2-Effectiveness and Efficiency of Food-waste prevention policies, circular economy and food industry. Food Industry Wastes (2nd. Ed.). Assessment and Recuperation of Commodities, 2020, 19-35,

[22]Zhang, A., Zhong, R. Y., Farooque, M., Kang, K., Venkatesh, V. G., 2020, Blockchain-based life cycle assessment: An implementation framework and system architecture. Resources, Conservation and Recycling, 152, 104512.