Sustainability of Food Production and Consumption in the Food Supply Chain

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Abstract

The United Nations' second Sustainable Development Goal (SDG 12) is to ensure sustainable production and consumption patterns. How can circular economy principles assist in building sustainable food systems? Since food systems inextricably interweave socio-economic business models with physical infrastructure assets, engineered assets deployed throughout the supply chain of food systems should be managed to conform to the precepts of a circular economy and the sustainability paradigm. This paper reviews (i) strategies that can enhance sustainable food systems through circular economy precepts and (ii) supports the second goal of sustainable production.

The study indicates that existing infrastructure and assets must be managed to enable the incorporation of reverse logistics processes to introduce circular economy imperatives into food systems towards the achievement of sustainable development goals. Future work may focus on tracking the supply chain of food systems and examining the challenges of conforming to circular economy precepts and SDG 12.

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1. Introduction

1.1. Background

Poverty, hunger, malnutrition, poor diet, climate change, land and ecosystem degradation, greenhouse gas emissions, water scarcity and biodiversity loss are caused by how we produce, distribute, and consume food (FAO, 2014), that is to say, food systems. Although enough food is currently produced, many households face food insecurity and undernourishment, although obesity through overnutrition is also evident (WHO, 2017). Approximately one-third of the global food supply set for human consumption is annually lost or wasted, constituting nearly 8% of worldwide greenhouse gas emissions and an approximate financial loss of 1 trillion US dollars (FAO, 2019). While comprehensive data remains limited, these losses and wastage wield significant ramifications.

Despite generating sufficient food to nourish 10 million individuals, the global food system has thus far failed, leaving 8.9% (690 billion) of the population undernourished, 25% (approximately 2 billion) grappling with varying degrees of food insecurity, 21% (144 million) of children stunted, and 7% (47 million) of children wasted due to dietary insufficiencies in their own and their family's nutritional intake (Stroosnijder et.al., 2022) this is evident particular in African countries. There is a need to produce nutritious food safely and to secure jobs to address poverty in Africa. Therefore, there is a need to move towards more sustainable food systems that will promote the achievement of the targets set out in the Paris Agreement.

Food systems must deliver food and nutrition security for present and future generations at the global, national, local, and household levels. Creating sustainable food systems requires moving from an agriculture-centered system to a more holistic approach. The twelfth Sustainable Development Goal (SDG 12), as adopted by the General Assembly of the United Nations in 2015, is to (i) achieve sustainable management and efficient use of natural resources (ii) reduce global food waste, food losses along production and supply chains, and post-harvest losses (iii) reduce wastes throughout their life cycle into air, water and soil (iv) reduce waste generation through prevention, reduction, recycling and reuse by adopting sustainable practices (v) support developing countries to strengthen their scientific and technological capabilities to encourage more sustainable patterns of consumption and production.

1.2. Problem Statement

The introduction and management of proper food systems are therefore imperative. In recent years, circular economies have gained prominence in a bid to enhance sustainability practices. In food systems, the focus is on managing nutrients, reducing food waste through the reuse of food, using by-products, and managing surpluses of food. Blockchain technology may be very useful in tracking nutrient value and the safety of food and may also be useful in tracking the conditions of assets and changes in the status of assets (Hatzivasilis, et al., 2021). In this paper, it is argued that the proper management of information and logistics systems within food systems must take place so that the principles of a circular economy can be entrenched with a view to achieving sustainable development goals. The aim of this paper is to review strategies that can enhance sustainable food systems and their deployment across the food supply chain using circular economy strategies that can influence production and consumption patterns.

1.3. Research objective

To investigate and identify strategies that can enhance the deployment of circular economy practices in food systems across the supply chain, with a focus on influencing production and consumption patterns to achieve sustainable development goals.

2. Literature Review

2.1 Food systems

Sustainable food systems require fair access to production opportunities and inputs and a balanced distribution of production costs, goods, and services as-sociated with resource use (El Bilali et al., 2019). Food systems are multidisciplinary in nature and are constantly developing and changing. Food systems are influenced by geography, demography, urbanisation, globalisation, socioeconomic factors, income, marketing, consumer attitude, religion, and culture (Kearney, 2010). What is a food system and how they affect diet and nutrition? A food system is defined by the High-Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security as including “all the elements (environment, people, inputs, processes, infrastructure, institutions) and activities that relate to the pre-production, production, processing, distribution, preparation, and consumption of food and the outputs of these activities, including socioeconomic and environmental outcomes” (Branca et al., 2019).

Population growth, globalisation, urbanisation, and climate change, economic drivers, trade, environmental concerns, and international policies affect food systems and may create preferences to produce particular types of food, while rural development, urban planning, and

transport policies influence which types of food reaches which consumers and at what price the food is made available (Branca et al., 2019).

It is crucial to keep track of the dynamic information related to food systems that can inform decision-making within the food supply chain. In this context, information and data related to food systems can become assets that must be managed. Collecting data along food supply chains is a complex process because of inconsistencies, different geographic scales, dissimilar measurement standards and diverse sampling strategies and because very little real-time data is available (Marshall et al., 2021). Considering the need to better manage food systems, these mismatched data sets create inefficiencies and gaps.

There is a disconnect between food production and consumption in food systems, and current distribution and consumption behaviours in the supply chain are not sustainable. This disconnect leads to food losses and food waste, which have received increased attention owing to global targets within the SDGs, particularly SDG 12. Food waste arises from different role players throughout the food supply chain, from farming and food processing to retail and consumption by the end user. This problem is not only a waste of resources, but also has significant environmental, social, and economic impacts.

According to the United Nations Food and Agriculture Organisation (FAO, 2019), approximately one-third of the food produced globally for human consumption is wasted each year. This amount of waste is equivalent to around 1.3 billion tonnes of food, which is enough to feed the world's hungry population several times over (Vilariño et al., 2017). In addition to the wasted food, the resources used to produce this food, such as water, energy, and land, are also wasted. This has a significant impact on the environment, as food production is a major contributor to greenhouse gas emissions, deforestation, and water scarcity (Rohini et al., 2020). The methane gas produced at landfills by food thrown out as waste further aggravates climate change and global warming. According to FAO, the carbon footprint of global food waste is about 8% of all greenhouse gas emissions caused by humans. For every kilo of food produced, 4.5 kilos of CO_2 are released into the atmosphere (FAO, 2015).

Food waste also has significant social and economic impacts. The FAO estimates that the economic loss from food waste is around $940 billion per year (Principato & Principato, 2018:3). This is a significant loss of income for farmers, food processors, and retailers. In addition, food waste contributes to food insecurity, as it means that there is less food available for those who are in need. Food waste often results in higher food prices, as the resources used

to produce food are wasted and therefore cannot be used to produce more food, resulting in higher food prices (de Gorter et al., 2021).

In developing countries, food waste often occurs at the production stage, due to lack of infrastructure and poor transportation systems (Rohini et al., 2020). In South Africa millions of rands are lost in food waste which are caused by the power cuts (load shedding) (Gernetzky, 2023) as the country battles with shortages of electricity supply. Food waste is an issue of social justice, as it disproportionately affects low-income communities and those living in developing countries particularly the most marginalised and vulnerable groups. This means that food is wasted before it even reaches consumers. Therefore, the production and logistics processes are crucial in securing food safety and the preservation of food.

Consumer dietary behaviours and consumption patterns are influenced by personal considerations (culture, knowledge, skills, dietary preferences, and food preparation time), to economic (cost of food or its availability), available information about food, marketing (labelling, advertisements, media campaigns) and policies (Branca et al., 2019). In developed countries, food waste often occurs at the consumption stage, due to overconsumption, and lack of awareness of the problem. This means that consumers waste food that could have been used to feed those in need. It is necessary to educate consumers to become more waste averse. Furthermore, it can also help to improve the reputation of a company, as consumers are becoming increasingly conscious of the environmental impact of products and companies that fail to manage their waste effectively may risk losing customers (Fidlerová, Makyšová, Sklenárová, & Bajdor, 2021).

Responsible consumption is defined as the use of goods and services that meet the basic needs of the present without compromising the ability of future generations to meet their own needs (Lubowiecki-Vikuk et al., 2021). To ensure responsible consumption by consumers, a multi-faceted approach is needed, which includes education, awareness-raising, and the provision of sustainable alternatives. There should be more effective communication and education about food waste, so that consumers are aware of the problem and can take steps to reduce their own food waste. This can be achieved by providing consumers with information on the environmental and social impacts of their consumption choices. For example, consumers should be made aware of the environmental impact of products such as single-use plastic and the social impact of products that are produced through exploitation of workers. Furthermore, consumers should be provided with information on how to make more sustainable consumption

choices, such as buying products that are produced locally or that have been produced using environmentally friendly methods (Welch & Southerton, 2019).

This can be achieved by providing consumers with a wider range of sustainable products, such as organic foods, fair trade products, and products that have been produced using environmentally friendly methods. consumer behaviour is shaped by the availability, accessibility, and price of products. Furthermore, governments and businesses can support sustainable production by providing incentives for sustainable production and by implementing policies that support sustainable production. This can be achieved through policies that support sustainable production, such as tax breaks for sustainable producers, and by providing financial incentives for consumers who make sustainable consumption choices (Lubowiecki-Vikuk et al., 2021).

The food wastage is due to the lack of proper management, finances, and technical capabilities in harvesting methods, storage and cooling, processing, packaging, infrastructure, and marketing systems (Cattaneo et al., 2021). Heavy rains in KwaZulu Natal, South Africa had created many potholes that affect road transportation and deliveries, affecting the livelihoods of farmers in that area (Ngwenya, 2023). Food waste reduction can be achieved through a variety of measures such as: improving supply chain coordination, reducing overproduction, and encouraging more efficient use of resources. On the other hand, food waste should be seen not as only waste but as a valuable resource. This can be achieved through the use of innovative technologies such as anaerobic digestion and composting, which can convert food waste into useful products such as biogas and fertilizer. Food industry needs to produce innovative products by using food waste materials (Lin et al, 2019). The wasted food can be converted into value added products through circular economy applications that can increase the nutritional value to reduce the malnutrition percentage at local, regional, national and global level.

2.2 The food supply chain

Modern communities require legitimate and sustainable systems that do not compromise the well-being of people. Food supply chains are saliently obliged to create eco-friendly environmental systems that integrate environmental practices into product development and operational processes and that extend value creation while moving away from cradle-to-grave mindsets towards cradle-to-cradle approaches. Agriculture is no longer the primary activity in food supply chains as processing, packaging, distribution, warehousing, and retail activities have expanded in jobs and income generation. The food supply chain extends across various

interlinked functions, activities and stakeholders as demonstrated in Figure 1, that also forms part of food systems.

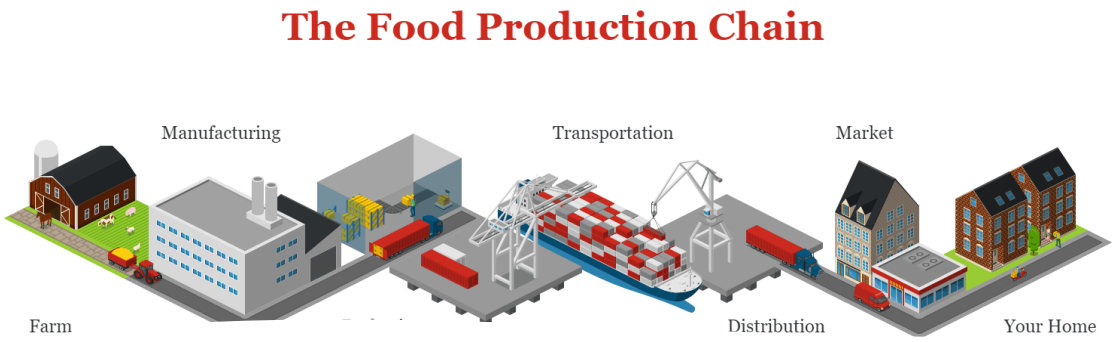

Figure 1: The Food production chain
Icograms.com

The development of environmentally sustainable food supply chains begins when local firms collaborate with their suppliers and/or customers to improve the environmental performance of their products, services, processes, and supply chains. This includes the advancement of the underlying packaging processes, along with designs that support recycling and low new material usage. In essence, supply chains need to pursue sustainability on different levels, that is, eco-friendly processes for the environment, the protection of primary inputs and the creation of a competitive advantage to secure their long-term existence. Lean supply chain management (SCM) has evolved into sustainable SCM, where the focus shifted from mitigating damage towards creating value through strategic partnerships (Su-dusinghe and Seuring, 2021).

Food supply chain stakeholders include governmental and non-governmental institutions, academics, service institutions, community groups, individuals, and private sector investors. According to Christopher (1998: 5), supply chain management (SCM) is 'the management of upstream and down-stream relationships with suppliers and customers to deliver superior custom-er value at less cost to the supply chain as a whole'. To enhance the agility of supply chains, their interconnectedness has been promoted in recent years.

2.3 Circular economy

Agricultural production is responsible for about 30% of greenhouse gas emissions (Fassio and Tecco, 2019:3). The economic value of wasted food and the estimated environmental and societal costs of this waste worldwide amount to 2 600 billion dollars annually (FAO, 2014).

A circular economy is aimed at curbing emissions into the environment by optimising existing systems using renewable energy sources and systems thinking and by reorganising flows of materials and energy through reuse, repair, refurbishing and re-cycling strategies (Jurgilevich, et al., 2016). Value can be created whereby waste can be resold into the food system for reuse, redistribution, and recycling. Food that is fit for purpose can be redistributed for consumption, waste can be recycled into additional products (e.g., manufacturing fabric for clothes, production of biogas), recycling as manure that becomes input into farming practices. In addition, extra work can be created for additional earnings.

Current food systems predominantly use the take-produce-consume-discard linear economic model. The circular economy approach aims to keep resources in use for as long as possible, extract the maximum value from them, and then recover and regenerate them (Hobson, 2021). A circular economy in food systems implies reducing the amount of waste generated in the food supply chain by making provision for the re-use of food, using by-products and food waste as inputs into farming and other practices by means of recycling and changing diets toward more diverse and more efficient food patterns. The reorganisation that is required in the food supply chain is reflected in Figure 2.

Figure 2: Circular economy in the food supply chain. Fassio and Tecco, 2019

Figure 2 demonstrates that what traditionally is deemed to be waste can become input resources and raw materials into existing food cycles. Raw materials are transformed into products before they are distributed to businesses and consumers for use in other manufacturing processes or consumption. It is also possible to use food waste as inputs into processes that produce biofuel

and bio-products (Girotto et al., 2015) as well as nylon, recovered cotton and leather substitutes that can be used to produce clothing (Provin and de Aguiar Dutra, 2021). Discarded corn cobs, beetroot skins, sugarcane, and potato skins can be used as alternatives to plastic. Agriculture, as inputs into the food supply chain, can introduce agroforestry practices, regenerative methods of farming, and the use of organic fertilisers that are generated from food waste.

However, existing infrastructure that produce, transport and distribute food will need to be used to collect and redistribute food waste and therefore also form part of the food system. Technologies, equipment and other assets used in farming processes and their inability to perform optimally can lead to food losses and food waste. In January 2023, it was reported in South Africa that more than 40 000 chickens had died due to variations in voltage that damaged equipment and pumps during electricity load shedding that resulted in the air conditioning shutting down (Gernetzky, 2023a) while another farmer had to discard of nearly 12000 litres of milk as a result of failing electricity that led to the burnout of farm equipment (Gernetzky, 2023b). In addition to loss of income for farmers, job losses may occur, and the situation may also lead to food insecurity. In Tanzania, it was reported that 50% of the fresh tomatoes harvested spoils due to lack of cold storage facilities as a result of a lack of electricity supply (Rutta, 2022).

When assets are acquired, the circular economy precepts must be added to the capital investment plan from the onset. Decisions around the acquisition of assets would include what type of asset to acquire, what is the purpose of the asset, how much energy will the asset consume, the impact on the environment, longevity, and cost. The capital investment decision should be based on partnering with the right suppliers of assets to acquire the correct assets that will help us to include reverse logistics and other circular economy principles. The maintenance and service functions of assets must be prioritised and regularly executed so that the life cycle of assets can be extended to support increased utilisation thought the incorporation reverse logistics strategies. As such, additional uses are derived from exiting infrastructures and processes within the food supply chain.

Essentially, the assessment of the life cycles of infrastructure and assets throughout the food supply chain will also enable assets to be reused or reintroduced into other contexts before they reach their end-of-life stages (Baumann, 2022). The acquisition and use of refurbished assets will eliminate the need to use new raw materials to manufacture new assets, which favors the environment. The use of environmentally friendly products will also reduce the carbon footprint of the food supply chain through reduced emissions. Engineered assets and

infrastructures can, at the end of their life cycles, be resold (to new owners) to recover some capital, repaired (broken components fixed to extend the life cycle of the asset), refurbished (renovate or recondition an asset to extend the asset's life cycle) or repurposed (redeployment of assets for a different use). These decision areas in asset management directly impact the circular economy through reverse logistics processes. Figure 3 explains circular activities based on the life cycle of an asset.

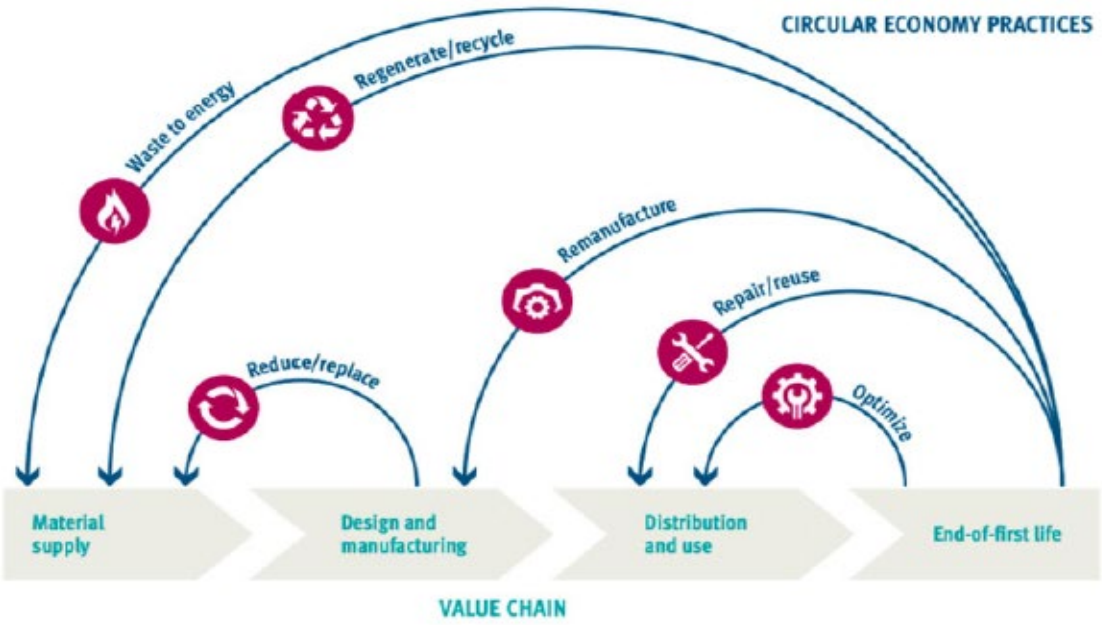

Figure 3: Circular economy practices

UNIDO, 2020

Strategies in food production (agriculture) must find application throughout the food value chain by engaging on different levels with food supply chain partners and processes. Coopetition introduces possibilities to share assets across supply chains that previously competed with one another (De Angelis et al., 2018). Collaboration and effective communication through real-time databases will improve sustainability performance in implementing circularity across the food supply chain. The effective management of assets (facilities, equipment, food packaging facilitates, storage) and food handling, transport and preservation mechanisms is essential for preventing food waste.

The focus of sustainability is not only concentrated on environmental damage but also the triple bottom line in the form of long-term benefits and the creation of a competitive advantage. Reverse logistics opportunities can be linked to circular economies and sustainable practices (Sudusinghe and Seuring, 2021). Reverse logistics in agriculture refers to the process of

managing the return or disposal of agricultural products that are no longer needed or cannot be sold. This can include products that are expired, damaged, or otherwise unsellable. When products are not sold and left to spoil, they release methane and other greenhouse gases, contributing to climate change. By diverting these products to composting or other forms of recycling, the environmental impact can be greatly reduced. The goal of reverse logistics in agriculture is to minimise waste and ensure that products are handled in an environmentally responsible manner (Tavakkoli et al, 2019). This can include recycling, repurposing, or composting agricultural products, as well as managing packaging and other materials used in the distribution of agricultural products.

Through reverse logistics, a bidirectional flow is created using the existing assets and infrastructure: food is moved from the farm to the end user in one direction, while waste created and the products that are at the end of their life cycles are moved back in the other direction through the same infrastructure, that is, facilities, logistics and the like (Bottani et al., 2019). These assets and infrastructure need to be properly managed for the processes to be effective and for the principles of a circular economy to find application.

Reverse logistics can help to support circular economy initiatives by reducing waste and ensuring that resources are used in an efficient and sustainable manner. For example, by diverting products that are not sold and left to spoil to composting or other forms of recycling, the environmental impact can be greatly reduced, while also providing a valuable source of nutrients for the soil (Velasco-Muñoz et al., 2021). Additionally, by managing returns and disposals effectively, growers, processors, and retailers can reduce their costs and improve their bottom line, while also contributing to a more sustainable and circular agricultural industry. Implementing reverse logistics in agriculture can also help to improve the overall efficiency of the supply chain.

3. Research Methodology

A desktop literature review was used to explore circular economy principles that can assist in building sustainable food systems The conceptual approach used in this study lends itself to a content analysis supported by the literature review. In this study, the researchers adopted an interpretivist approach to understand and describe the meaning of the study. Since the study was descriptive in nature, a qualitative approach was employed to review strategies that can enhance sustainable food systems through circular economy precepts and (ii) support the second goal of sustainable production. Qualitative research was chosen because it provides

researchers with theoretical lenses that provide research direction (Cohen et al., 2011). The literature search followed the typical research literature review format (Creswell, 2009). The databases searched included Google Scholar, Science Direct, Scopus and Web of Science databases, for studies published between January 2010 and February 2023. The search keywords used included; “food systems”, "circular economy, “food supply chains”, “food insecurity”.

4. Discussion and Findings

There is increasing recognition of the need to adopt an all-inclusive approach to support and promote global sustainable food systems. Integrated food system approaches recognise that food producers, consumers, governments, the financial sector, and many other stakeholders will all play a role in shaping food production in the future. There is a need to create and manage food records on both a regional and global scale to realise real-time data that can be used to promote the creation of circular economies. Blockchain and IoT technologies may be useful in building sufficient databases where real-time information about food systems and the assets used to manage them can be stored and updated.

The management of physical infrastructure assets (sustainable environment, circular economy) and engineered assets (operations, production and supply chain) by companies must allow a bidirectional flow of information to make provision for reverse logistics processes that will incorporate the effective management and control of waste, as well as products, equipment, machinery and other assets that may have reached their end-of-life stages and need to absorbed back into the supply chain for circular economy strategies to be triggered. Key decisions must start with embedding circular economy principles into the capital investment decision-making process from the acquisition to the end-of-life stages of assets in the food supply chain.

Surplus management systems need to be put in place to redistribute available food to undernourished and undersupplied communities (Geueke, Groh and Muncke, 2018). In addition, the CO_2 emissions that are associated with the production and distribution of food should be reduced. There is a need to record the impact that different role players in the food supply chain have on the environment. The many and diverse processes and role players involved in food systems create complexities that must be further understood.

The transition to a circular economy will require governments to finance and promote effective solid waste management policies and strategies. Consumers will need to be upskilled and oriented in term of circular economy precepts to reject unsustainable linear food consumption

patterns. Food systems and the infrastructure on which they depend must be well maintained and restructured to make provision for reverse logistics processes that can help waste to become inputs into the circular economy. Incentives for the production of nutritious and healthy food using sustainable practices must be created.

5. Managerial Implications

It is recommended that the management of assets in the food supply chain extend towards circularity initiatives. Firstly, **implement comprehensive data management systems:** Companies should prioritise establishing comprehensive data management systems to support the development of circular economies and informed decision-making. This involves adopting technologies like blockchain and IoT to create and manage real-time food records on regional and global scales. By collecting and analysing data related to food systems and their assets, companies can gain insights into their operations, identify areas for improvement, and make data-driven decisions. This information can also be shared with relevant stakeholders to foster collaboration and promote transparency within the food supply chain. Actionable advice would be to conduct assessment of the current data management capabilities and identify gaps. Develop a clear for integrating comprehensive data management system.

Secondly, **integrate reverse logistics processes**: Effective asset management is crucial for implementing circular economy strategies in the food supply chain. Companies should focus on establishing a bidirectional flow of information to enable reverse logistics processes. The integration includes managing physical infrastructure assets and engineered assets efficiently, such as operations, production, and supply chains. By incorporating waste management, recycling, and reutilisation practices, companies can extend the life cycle of assets, reduce waste, and optimise resource utilisation. This requires implementing systems and protocols that facilitate the proper handling and absorption of products, equipment, machinery, and other assets that have reached their end-of-life stages back into the supply chain. Actionable advice would be to create cross-functional teams involving supply chain, logistics, waste management and sustainable experts to develop a holistic strategy. There is a need to also define key performance indicators to measure the success of reverse logistics initiatives and regularly assess progress and make necessary adjustments when a need arises.

Lastly, **sustainability must be viewed in terms of all three dimensions of the triple bottom line**. Sustainability should be approached holistically, considering all three dimensions of the triple bottom line-environmental, social, and economic. By managing food waste through

collaborative partnerships in the food supply chain, redistribution strategies could help to reduce hunger as we work towards fulfilling SDG 12. Actionable advice would include partnership building through collaborations with NGOs, community organisations to facilitate the redistribution of surplus food to those in need. Promote public awareness by communicating the organisation's commitment to triple bottom line sustainability through various channels and highlight efforts to reduce food waste and contribute to communities' well-being. By implementing these recommendations, companies can enhance their operational efficiency, reduce waste, promote sustainability, and contribute to the development of global sustainable food systems.

6. Conclusions, Limitations and Future Research

In conclusion, the imperative to embrace a comprehensive approach to fostering global sustainable food systems is increasingly acknowledged. Integrated food system strategies acknowledge the collective involvement of stakeholders—ranging from producers, consumers, and governments to the financial sector—in shaping the trajectory of future food production. A pivotal step lies in creating and managing food records at regional and global scales, supported by real-time data facilitated by technologies like blockchain and IoT. The management of both physical and engineered assets necessitates a bidirectional flow of information, enabling the incorporation of reverse logistics procedures for efficient waste and end-of-life asset integration into circular economy strategies. Transitioning to a circular economy demands government support for waste management policies, consumer education in circular principles, and the restructuring of food system infrastructure. Ultimately, by adhering to the recommendations for comprehensive data management, reverse logistics integration, and holistic sustainability, companies can augment operational efficacy, curtail waste, advance sustainability objectives, and contribute to the establishment of enduring global sustainable food systems.

Future research may focus on tracking the supply chain of food systems and examining the challenges of conforming to circular economy precepts and SDG 12.

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