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Abstract:

The global food supply network faces an unprecedented challenge of feeding a growing population while reducing its environmental impact. A circular economy can address these challenges by optimizing resource use, minimizing waste, and promoting food system sustainability. This chapter discusses how circular economy theories influence the food supply chain and how to achieve closed-loop systems for food sustainability. It also covers circular economy strategies across the food supply chain, from planting to processing, distribution, consumption, and waste management. This chapter highlights the need to reduce food waste, optimize resource use, and recycle throughout the food supply chain to mitigate the environmental impact of food production. Additionally, it explores how blockchain and IoT technologies enhance supply chain transparency and traceability, ensuring food safety. Organizations can save money and gain value by adopting circular methods, and thus the economic effects of these approaches must be examined. Our research also addresses the legislative, cultural, and behavioural challenges to implementing a circular economy in the food supply chain. Governments, industries, and consumers must collaborate to create a sustainable food future and overcome these challenges. We conclude with a comprehensive review of circular economy principles in the food supply chain and their potential to enhance food sustainability. By employing closed-loop systems and circular practices, the food supply chain can reduce waste, alleviate environmental impacts, and contribute to building a sustainable food system.

Keywords: Circular economy; Food sustainability; Supply chain optimization; Resource efficiency; Food waste reduction; Environmental footprint; Transparency and traceability; Economic implications; Stakeholder collaboration; Sustainable food system.

Introduction

The global food supply is facing a turning point, necessitating sustainable production and delivery due to population growth, resource constraints, climate change, and food security. The circular economy, based on “closing the loop,” offers potential solutions to reduce environmental impacts, waste, and food system sustainability. This chapter explores how circular economy principles and the food supply chain intersect to promote food sustainability, focusing on resource efficiency, waste reduction, transparency, traceability, and economic benefits (Uvarova et al. 2023). Challenges include regulatory constraints, cultural and behavioural issues, and stakeholder collaboration.

The circular economy is a transformative approach that aims to conserve resources, reduce waste, and extend product lifespans. It shifts from the linear model of “take, make, dispose” to reusing, repairing, remanufacturing, and recycling, creating a closed-loop resource and waste system. The circular economy focuses on separating economic growth from resource use, promoting material and product conservation.

The concept of “reduce, reuse, recycle” is key, with products designed to last, recycle, and require less packaging (Park et al. 2014). Designing for circularity requires a thorough analysis of the product’s life cycle. Businesses are crucial to circular economy growth, as they embrace circular business models and promote sustainable practices. Governments and policymakers play a crucial role in enabling circular practices through legislative frameworks, incentives, and public awareness.

Objective

The study aims to explore the impact of circular economy strategies on food sustainability by analyzing various approaches to waste reduction, resource optimization, and supply chain transformation. It evaluates how circular economy principles–such as closed-loop systems, sustainable packaging, and food waste mitigation–can create a more sustainable food system. Additionally, the research examines the role of technology (IoT, blockchain, real-time monitoring) in enhancing supply chain transparency and efficiency.

Methodology

The study employs a qualitative research approach based on:

Literature Review

- Reviewing academic papers, industry reports, and policy documents related to circular economy applications in the food supply chain.
- Analysing existing frameworks for waste reduction, recycling, and sustainable production.

Case Study Analysis

- Examining real-world implementations of circular economy strategies, such as closed-loop food production, sustainable packaging, food redistribution, and circular supply chains.
- Reviewing case studies of companies like Renault's Re-Factory, Philips' Circular Lighting Solutions, Patagonia's Circular Textiles, and MUD Jeans, which successfully applied circular economy principles.

Exploration of Technological Innovations

- Investigating how blockchain and IoT enhance traceability, transparency, and efficiency in food systems.
- Evaluating digital tools for monitoring food safety and supply chain optimization.

Policy and Economic Analysis

- Reviewing regulatory frameworks and government policies that support or hinder the adoption of circular practices.
- Examining economic implications, including cost savings, investment opportunities, and financial feasibility of circular economy adoption in the food sector.

Understanding Circular Economy in the Food Supply Chain

The study explores the circular economy in the food supply chain, focusing on waste reduction, resource efficiency, and sustainability (Ardra and Barua 2022). It challenges the "take, make, dispose" linear economic model and proposes a regenerative system that promotes sustainable economic growth, challenging the "take, make, dispose" linear economic model.

Design for Longevity and Durability

- **Principle:** Products should be designed to have extended lifespans and to withstand multiple cycles of use.
- **Application:** Companies can achieve this by using durable materials, designing modular products, and ensuring that items are easy to repair or upgrade (He et al. 2023). For example, electronics manufacturers can create devices with easily replaceable components, reducing electronic waste.

Regenerate Natural Systems

- **Principle:** Emphasize the restoration and preservation of ecosystems and natural resources.
- **Application:** Businesses can engage in sustainable agriculture practices, promote reforestation, and support biodiversity conservation. Companies involved in the fashion industry can use sustainable materials and eco-friendly dyeing processes to minimize the environmental impact (Sathoria and Roy 2022).

Preserve and Extend Product Life

- **Principle:** Encourage the maximum utilization of products and materials.
- **Application:** Implementing product-as-a-service models, sharing platforms, and take-back programs enables consumers to use products without owning them outright. For instance, car-sharing services and companies that lease office furniture promote product longevity.

Waste Reduction and Recycling

- **Principle:** Minimize waste generation and promote the recycling of materials.
- **Application:** Companies can set up efficient recycling programs, use recycled materials in their production processes, and reduce packaging waste (Farmer 2013). The automotive industry, for example, can recycle old vehicle components to create new cars.

Resource Efficiency

- **Principle:** Optimize resource use and minimize resource extraction.
- **Application:** Implementing lean manufacturing processes, adopting sustainable sourcing practices, and reducing energy consumption are all ways to enhance resource efficiency (Qiu et al. 2023). In construction, using reclaimed building materials can help achieve this principle.

Collaboration and Ecosystem Thinking

- **Principle:** Promote cooperation and shared responsibility among stakeholders in the supply chain.
- **Application:** Businesses can work with suppliers, competitors, and consumers to create closed-loop systems where materials and products are continually repurposed. Sharing data on material flows and collaborating on waste reduction initiatives are prime examples.

Digitalization and Innovation

- **Principle:** Harness the power of technology and innovation to create new, more sustainable business models (Anderson and Maughan 2021).
- **Application:** Companies can use IoT (Internet of Things) and blockchain to track products and materials throughout their lifecycle, enabling better monitoring and control. Smart packaging and labelling can also provide consumers with information on a product's origin and environmental impact.

Consumer Engagement and Education

- **Principle:** Encourage consumers to make informed and sustainable choices.
- **Application:** Engaging in awareness campaigns, providing transparent information about products, and offering incentives for recycling can all encourage consumers to participate in the circular economy. Sustainable labelling and certification schemes can also guide consumers toward eco-friendly products.

The circular economy aims to make production and consumption more sustainable and circular across industries. It requires tailored solutions for different needs and challenges (Lehtokunnas et al. 2020). Corporations, governments, and individuals are adopting these principles to move towards resource efficiency and environmental responsibility. The food supply chain, essential for food security, economic growth, and sustainability, faces numerous opportunities and challenges.

Opportunities

The integration of technology and data analytics is revolutionizing the food supply chain, improving efficiency, reducing waste, and enhancing decision-making. Sustainability is gaining importance, leading to eco-friendly practices and alternative food sources (Lotfian Delouyi et al. 2023). Advances in transportation and logistics have opened up global markets, allowing food producers to export and consumers to access a wider variety of foods.

Challenges

The food supply chain faces numerous challenges, including food safety, climate change, supply chain disruptions, food waste, transportation and distribution challenges, labour shortages, economic pressures, and regulatory complexity (Squatrito et al. 2020). Food safety is crucial, as outbreaks of foodborne illnesses can have severe consequences (Barlow et al. 2015). Climate change can disrupt agricultural production and pressure for sustainable practices. Supply chain disruptions, such as natural disasters and geopolitical conflicts, highlight the need for resilience. Addressing food waste is both economic and ethical. Efficient transportation and distribution are essential for a functioning supply chain.

Collaborative strategies are needed to overcome these challenges and maximise rewards. Governments, businesses, and consumers all have important roles (Iranmanesh et al., 2023). Policies and regulations must balance safety and sector burdens. Food supply chain resilience and efficiency depend on infrastructure, technology, and sustainability investments. Additionally, Svystun et al. (2023) claim that enhanced customer awareness and consumer decisions can positively impact the industry.

Creating a Closed-Loop Ecosystem

Closed-loop ecosystems are self-sustaining habitats where living species and inorganic substances live in mutually beneficial ways, relying on resource recycling and reuse. These systems, like aquariums, demonstrate efficient nutrient and energy cycles, making them valuable in science, practical applications like space stations, and sustainable agriculture.

Resource Efficiency and Waste Reduction

The increasing global population and demand for scarce resources have emphasized the importance of resource efficiency and waste reduction (Pascall et al. 2022). Resource efficiency optimizes limited resources in manufacturing, energy use, and agriculture to maximize value and utility. It aims to reduce waste, material resources, and energy usage, reducing the environmental footprint. Waste minimization reduces waste, retrieves and reuses materials, and responsibly disposes of the rest. These practices have economic and environmental benefits, as they help organizations cut costs, gain a competitive edge, and find new revenue streams. New technologies, production and consumption changes, and proactive resource management strategies are needed (de los Mozos et al. 2020).

Optimizing Agricultural Practices

Agriculture is crucial for global food production, environmental sustainability, economic growth, and human welfare. With a projected population of 10 billion by 2050, the sector needs a complete overhaul to increase crop yield, reduce environmental impact, and ensure long-term sustainability (Librán-Embid et al. 2023). Techniques such as precision farming, crop breeding, and genetic manipulation can help reduce resource waste and increase production. Sustainable water management, land use, and climate-smart agriculture can also help reduce emissions and carbon emissions. Food waste minimization is essential for food security and resource conservation (Balasundram et al. 2023). Biodiversity conservation is vital for maintaining ecosystems and reducing pest and disease risks. Socioeconomic factors also play a role in agricultural optimisation, necessitating fair trade, education, and healthcare in rural regions.

Sustainable Food Processing

The sustainability discourse includes sustainable food processing to ensure that raw food resources are processed in an environmentally friendly, economically viable, and socially just manner (Baiano and Fiore 2023). Food processing is crucial to the global food supply chain; thus, it must improve its operations to support sustainability. To overcome limited resources, climate change, and consumer awareness of ecological and ethical issues, this is essential. Sustainable food processing principles, methods, and benefits are examined in this discussion.

Principles of Sustainable Food Processing

Sustainable food processing focuses on resource efficiency, waste reduction, energy efficiency, clean technologies, packaging optimization, and supply chain integration. It aims to minimize resource use, reduce waste, and optimize energy utilization throughout the processing cycle. Waste reduction involves minimizing trimmings, using by-products, and implementing efficient waste management systems (Takavakoglou et al. 2022). Energy efficiency is achieved through renewable energy sources and clean technologies. Packaging optimization involves using environmentally friendly materials and minimizing waste and energy consumption.

Strategies for Sustainable Food Processing

Food processing plants can reduce waste by converting by-products into valuable products. Transitioning to clean energy sources can reduce carbon footprints (Chavan et al. 2023). Water management is crucial for sustainable practices. Reducing synthetic additives and using natural alternatives can preserve food's nutritional content. Local sourcing reduces transportation emissions and supports local economies. Regular assessment and monitoring of processes optimize resource use over time. This iterative approach supports sustainable food processing practices (Kovačević and Putnik 2022).

Benefits of Sustainable Food Processing

Sustainable food processing reduces environmental impact, saves costs, improves reputation, and ensures regulatory compliance (Kashyap et al. 2023). It reduces energy consumption, waste management, and resource efficiency, while also enhancing consumer loyalty. It also increases resilience to climate change challenges and opens up new markets for companies that prioritize sustainability in their supply chain (Wagner et al. 2016).

Packaging Innovations and Waste Reduction

Packaging innovations and waste reduction are crucial in today's society, involving customer convenience and environmental sustainability. Innovative solutions include optimizing container shapes, minimizing superfluous packing, and considering end-of-life aspects in product design (Cammarelle et al. 2021). Biodegradable, compostable, and recyclable products are becoming popular, reducing waste and marine ecological stress.

Sustainable packaging design, including lightweighting, intelligent packaging, and data-driven technologies, can extend product life and reduce food waste. Labelling and information distribution through QR codes, RFID tags, and interactive packaging can raise consumer awareness and encourage waste management. Supply chain optimization, such as logistics, inventory management, and order fulfilment efficiency, can also help reduce waste. Businesses are incorporating sustainability into their packaging strategies due to government constraints and consumer demand for eco-friendly products.

Recycling and Circular Packaging Solutions

Shabir et al. (2023) found that recycling and circular packaging are essential to an environmentally friendly packaging and waste management strategy. The writers address pressing resource conservation, waste reduction, and circular economy challenges (Kumar et al. 2022). This discussion explores recycling and circular packaging solutions' essential concepts, strategies, and benefits. According to Wu et al. (2021),

Principles of Recycling and Circular Packaging Solutions

Recycling and circular packaging focus on resource conservation, waste reduction, material recovery, design for recyclability, and creating a closed-loop system. They minimize waste by collecting, reprocessing, and reintroducing materials into the production cycle. They also encourage consumers to recycle, ensure collection and sorting infrastructure, and use recycled materials in new packaging. This approach reduces the environmental impact of disposal and extends the life of materials.

Strategies for Recycling and Circular Packaging Solutions

An effective recycling system requires robust collection and sorting infrastructure, public awareness, continuous innovation in recycling technologies, Extended Producer Responsibility (EPR), use of recycled materials in packaging, and design for reuse. These strategies encourage consumers to participate in recycling efforts, reduce the demand for virgin resources, and promote sustainable and recyclable products. Innovations like optical sorting, chemical recycling, and recycling robots are essential for achieving these goals.

Benefits of Recycling and Circular Packaging Solutions

Recycling and circular packaging solutions conserve natural resources, reduce waste, save energy, protect ecosystems, and create economic opportunities. They divert materials from landfills and incineration, reducing environmental impact. They also enhance brand reputation, appeal to environmentally conscious consumers, and promote a circular economy. These solutions contribute to long-term sustainability goals by minimizing waste and creating a sustainable, regenerative system. They also contribute to brand reputation and customer loyalty.

Reducing Food Waste

Food waste reduction is a global issue affecting the environment and society. Addressing food production, distribution, consumption, and waste management is crucial. Improving resource efficiency is morally and ethically important, especially in a food-insecure world. This article introduces food waste mitigation concepts and methods.

The Cost of Food Waste

Food waste is complicated by its economic, environmental, and social effects. Food waste occurs throughout the supply chain, from manufacturing to consumption. The financial consequences of this issue are significant. This discussion will examine the economic effects of food waste and its urgency.

Food waste has numerous economic, resource, environmental, social, healthcare, and logistics costs. It affects consumers, businesses, and the food supply chain, causing overproduction, spoilage, and disposal costs. It also contributes to greenhouse gas production, deforestation, pesticide use, and water depletion (Martin-Rios et al. 2023). Reducing waste can help address global hunger and socioeconomic inequality. Healthcare costs are also impacted, leading to diet-related disorders and costly treatment. Collaboration between individuals, corporations, and governments is crucial for a sustainable food supply chain (Rejeb et al. 2021).

Innovative Approaches to Minimize Food Loss

Food waste impacts economics, environment, and poverty globally. Mitigating food loss requires new methods and technologies across the food supply chain, promoting sustainable and efficient food systems. Precision agriculture uses technology to improve crop management, reduce production losses, and enhance resource efficiency. Post-harvest technologies, such as modified atmosphere packaging (MAP), cold chain management, drying and dehydration technologies, smart packaging, and innovative storage solutions, help minimize food loss during the post-harvest stage. MAP allows for controlled temperature adjustments, while cold chain management uses IoT-based sensors and monitoring systems to prevent temperature fluctuations. Edible packaging materials, such as biodegradable or edible ingredients, can reduce packaging waste and preserve freshness. Vacuum packaging removes air from packages, slowing down oxidation and microbial growth.

Advanced sorting and grading technologies, such as hyperspectral imaging and automated sorting systems, ensure high-quality products reach consumers. Digital marketplaces and redistribution platforms, such as food rescue apps and B2B marketplaces, connect surplus food with those in need, reducing food loss and addressing food insecurity (Nair et al. 2017). Consumer awareness and education about food waste, proper storage, and portion control are essential for reducing food loss at the household level. Data analytics and predictive modelling are improving methods for food loss prediction and prevention, optimizing planting and harvesting schedules and decreasing timing losses.

Benefits of Innovative Approaches to Minimize Food Loss

Innovative approaches to food loss can lead to economic savings, resource conservation, food security, reduced environmental impact, improved public health, social equity, and sustainable agriculture. These solutions conserve resources like water, land, and energy, ensure reliable food supply, reduce greenhouse gas emissions, and promote healthier diets. They also contribute to social equity and support responsible resource management in agriculture.

Redistribution and Surplus Food Recovery

Redistribution and surplus food recovery are sustainable and socially responsible approaches to food waste and vulnerability (Abusin et al. 2023). These initiatives connect surplus food resources with those in need, reducing food waste and greenhouse gas emissions. Food rescue organizations, non-profits, and charities work with restaurants, supermarkets, and farms to provide excess food to those in need (Dubey and Tanksale 2023). Technology helps in efficient and immediate redistribution, reducing hunger, improving nutritional well-being, and conserving resources. These programs also combat food waste by preventing landfill decomposition and greenhouse gas emissions (Joensuu et al. 2022).

Circular Food Consumption: Consumer Practices

Sustainable circular food consumption prioritizes resource efficiency, waste reduction, and environmental impact, shifting from “take-make-dispose” to a circular framework, emphasizing customer participation (Massimiliano and Luigi 2022). The following are several fundamental elements pertaining to how consumers might actively participate in circular food consumption: In a circular food system, consumers are responsible for reducing food waste, adopting sustainable diets, supporting local and seasonal produce, reducing single-use packaging, reusing and repurposing food scraps, composting kitchen waste, participating in food sharing networks, advocating for clearer food labelling and packaging, engaging with sustainable brands and businesses, and educating themselves and others.

By reducing food waste, consumers save money, reduce the demand for new food production, and conserve resources (Eaton et al. 2022). Sustainable diets promote healthier food choices and reduce environmental strain. Supporting local and seasonal produce reduces carbon footprints and supports local economies. Reusing and repurposing food scraps and leftovers, composting kitchen waste, participating in food sharing networks, advocating for clearer food labelling, engaging with sustainable brands, and educating themselves and others are also essential steps towards a circular food system.

Transparency and Traceability

Licciardello (2017) emphasizes the importance of transparency and traceability in global supply chains, particularly in food, fashion, and electronics. Traceability allows for product tracking from inception to user acquisition, while transparency provides clear information

dissemination. These principles enable informed decision-making, ethical principles, and corporate responsibility (Burggraaf et al. 2021).

The Role of Technology in Ensuring Food Safety

Technology's real-time monitoring, traceability, and control have significantly improved food safety in the globalised food supply chain, ensuring the safety of items from production to consumption. According to He et al. (2023),

Technology plays a crucial role in monitoring and analysing food safety data, enhancing transparency and promoting responsible buying. Blockchain technology provides a transparent supply chain log, while advanced food safety management systems streamline processes (Cui and Gaur 2022). Rapid testing and diagnostics, AI and machine learning systems analyse food safety data, and modern packaging features food safety features. Robotics and automation reduce human handling contamination, while mobile apps help consumers assess product safety and food experts stay informed (Garsow et al. 2022). Remote auditing and inspection have grown due to the COVID-19 pandemic, ensuring food safety compliance while minimizing physical contact (Tan et al. 2023).

Benefits of Technology in Ensuring Food Safety

Technology enhances consumer confidence, facilitates faster response to contamination, enhances compliance with food safety regulations, extends product shelf life, reduces contamination risk during processing and packaging, and enables efficient recall management (Bowman and Ludlow 2017). It also reduces the risk of foodborne illnesses and legal repercussions, ensuring food safety and sustainability.

Blockchain and Supply Chain Transparency

Alabaddi et al.'s 2023 study revealed blockchain technology improves supply chain transparency, Singh et al.'s 2023 study found it records transactions in a decentralized, tamper-resistant digital ledger, and Liu et al.'s 2023 study highlighted its potential.

Here are some key aspects of how blockchain technology is transforming supply chain transparency: Blockchain technology offers several benefits, including immutable and trustworthy records, end-to-end traceability, real-time visibility, smart contracts, product authentication and anti-counterfeiting, supplier and vendor management, reduction of paperwork, crisis response and recall management, enhanced trust and consumer confidence, and global supply chain integration (Yontar 2023). Its decentralized ledger ensures data integrity and trustworthiness, preventing supply chain fraud, counterfeiting, and data manipulation (Bandhu et al. 2022). Blockchain technology also provides real-time visibility, allowing all players in the supply chain to view and change data in real time. Smart contracts automate supply chain agreements, reducing costs and disputes. Blockchain technology also enhances trust and consumer confidence by providing transparent information about products, fostering trust and loyalty (Voulgaridis et al. 2022). Overall, blockchain technology revolutionizes supply chain transparency, making it a valuable tool for complex global supply chains.

IoT and Real-Time Monitoring

IoT and real-time monitoring have transformed several sectors by creating a comprehensive data collecting, analysis, and management system (Stigzelius, 2020). These technologies transform commodity and service management in supply chains and logistics. This paper presents a comprehensive analysis of the ways in which the Internet of Things (IoT) and real-time monitoring technologies are augmenting the efficiency, transparency, and control of supply chain operations. According to the study conducted by Siracusa and Lotti in 2019, it was found that...

IoT sensors and GPS trackers in vehicles, containers, and warehouses offer real-time visibility, predictive analytics, inventory management, quality control, supply chain transparency, energy efficiency, geofencing, and location-based services (Ahmadzadeh et al. 2023). These technologies enable real-time monitoring of product whereabouts, cargo condition, and shipment progress, preventing delays and optimizing routes (Ovesná et al. 2023). Predictive maintenance can detect machinery operation abnormalities and send notifications to prevent breakdowns, while real-time inventory levels can be monitored to reduce overstocking and understocking. IoT-enabled geofencing creates virtual perimeters for security and inventory control. Customized reports provide supply chain performance insights, enhancing customer experience and reducing downtime. Overall, IoT technology is a game-changer in supply chain management (Radhakrishnan et al. 2023).

Economic Implications of Circular Strategies

Circular economy practices reduce waste and optimize resource use, benefiting industries, value creation, and sustainability. Cultures increasingly recognize linear production and consumption restrictions.

Circular systems create jobs, reduce unemployment, optimize resources, and increase revenue through extended product lifecycles. They also reduce environmental externalities, promote innovation, and enhance competitiveness. Governments worldwide encourage circular practices to promote sustainability and environmental protection. Consumers favor circular practices, leading to enhanced brand reputation and loyalty. Investment opportunities and financial resilience are seen in businesses adopting circular techniques (Kumar and Agrawal 2023). Circular supply chains transform linear supply chains and foster stakeholder collaboration, promoting waste reduction and resource efficiency. Overall, circular economies offer numerous

benefits, including job creation, resource efficiency, and increased economic growth.

Here's a detailed exploration of circular supply chains and the crucial role of collaboration:

A circular supply chain involves closed-loop systems, reverse logistics, and collaboration between manufacturers, suppliers, logistics providers, and recyclers (Svystun et al. 2023). It prioritizes recyclable, biodegradable, and environmentally friendly materials. Real-time data exchange optimizes resource utilization and reduces waste. Suppliers and consumers engage in sustainable resource sourcing and adopt circular economy ideas. Industry standards and certifications align supply chain partners' ambitions. Eco-industrial parks and clusters unite businesses, fostering resource sharing and teamwork. Supply chain partners collaborate with regulatory bodies to promote circular practices and environmental sustainability.

Benefits of Circular Supply Chains and Collaboration

Circular supply chains promote resource efficiency, waste reduction, cost savings, environmental benefits, resilience, innovation, and sustainable branding. By promoting recycling and reusing materials, they reduce waste, save resources, and promote resilience (Sunny et al. 2020). They also encourage innovation in product design, material choices, and processes, driving competitiveness and sustainability. By embracing circular supply chains, companies can attract environmentally conscious consumers.

Overcoming Challenges and Barriers

Hebrok and Heidenstrom (2019) highlight the challenges individuals, organizations, and governments face in adopting sustainable practices in the transition to a circular economy.

Here's a detailed exploration of the key challenges and strategies to overcome them:

The circular economy faces several challenges, including consumer behaviour, investment and financing, regulatory hurdles, supply chain complexity, lack of data and metrics, resistance to change, technological gaps, uncertain return on investment, lack of circular ecosystems, and short-term thinking. Consumers prioritize convenience and affordability over sustainability, making it difficult to encourage circular consumption (Kretova 2015).

To overcome these challenges, governments, businesses, and NGOs can collaborate to inform the public about the benefits of the circular economy and offer incentives for responsible consumption. Governments can provide financial incentives, grants, and tax breaks for companies investing in circular practices, while financial institutions can develop specialized funding programs for circular initiatives. Collaboration between businesses, governments, and industry associations is essential for identifying and amending regulatory barriers. Implementing circular supply chain models can be complex, and establishing standardized metrics for circularity can ensure transparency. Resistance to change and technological gaps can be addressed through comprehensive change management strategies, investment in research and development, and promoting the long-term benefits of circularity.

Regulatory Hurdles and Policy Recommendations

Challenge: Existing legislation and policies may not support a circular economy, which can slow the transformation. To overcome these problems, supportive policies must be created and implemented. (2012) Hanssen et al.

Policy Recommendations

Governments should align their regulatory framework with circular economy compliance by modifying waste management and product design legislation and encouraging extended producer responsibility (EPR) (Sanyal et al. 2021). Incentives for circular practices, such as tax benefits, grants, and subsidies, can reduce the upfront costs of circular models.

Governments should also implement policies compensating producers for designing durable and repairable items, setting ambitious recycling and material recovery targets, and mandating eco-labelling. Waste reduction and diversion goals, EPR rules, and product take-back programs can also encourage circular practices. Green public procurement strategies should prioritize circular and sustainable products, and policymakers should fund research and innovation to accelerate circular practices. Education campaigns, collaboration, and regulatory sandboxes can help businesses test innovative circular models without immediate regulatory ramifications.

Case Studies of Successful Implementation

Interface's Mission Zero® - Carpet Manufacturer:

Interface, a multinational carpet tile maker, is on "Mission Zero." Company aims to eradicate negative environmental impact by 2020. Interface designs goods for disassembly and recycling, uses recycled and bio-based materials, and promotes ethical sourcing. They also recycle old carpets through take-back programmes. Interface has decreased its environmental impact and saved money on materials and trash disposal by adopting these practises. (Shah et al. 2022)

Philips' Circular Lighting Solutions:

The lighting section of international technology corporation Philips adopted circular techniques. They started offering lighting services instead of bulbs. Philips owns the products and repairs, refurbishes, and recycles them. Designing for easy disassembly and durability is encouraged. Circular lighting solutions from the company conserve energy, minimise waste, and improve resource efficiency. (Kaur 2017)

Circular Textiles by Patagonia:

Outdoor gear manufacturer Patagonia pioneered circular economy. The Worn Wear programme lets users buy and trade used Patagonia gear to encourage repair, reuse, and recycling. Patagonia employs recyclable materials and advocates fair employment and responsible sourcing. These efforts reflect their sustainability and social responsibility.

The Renault Re-Factory - Automotive Industry:

Renault, a renowned French automaker, started the "Re-Factory" initiative to study automotive circular economy practises. The Re-Factory refurbishes and remanufactures discarded car parts, prolonging their lifespan and decreasing waste. Renault's automobiles' environmental performance will be improved by recycling more materials and optimising resource consumption during manufacture. (Shabir et al. 2023)

MUD Jeans - Circular Denim Fashion:

A cyclical business model lets buyers lease jeans from Dutch denim company MUD Jeans. When worn out or no longer wanted, customers can return their jeans to MUD Jeans, which recycles the materials to make new denim goods (Kaur 2017). This method extends denim product lifecycles, decreases water and energy use, and eliminates textile waste. Case studies demonstrate circular economy principles in manufacturing, automobile, fashion, and technology, highlighting economic and environmental benefits, resource reduction, waste reduction, and innovative customer interaction driving adoption (Stoiljković et al. 2023).

Analysis

The findings are categorized into key areas:

Impact on Food Sustainability

- The primary objective of applying circular economy principles in the food supply chain is to reduce environmental impacts and enhance food sustainability. This includes minimizing food waste, optimizing resource use, and reducing the environmental footprint associated with food production, distribution, and consumption.
- **Waste Reduction:** Circular economy strategies emphasize reducing waste at every stage of the food supply chain. The introduction of closed-loop food systems plays a critical role in managing food waste by recycling materials, reusing by-products, and diverting excess food from landfills. Studies such as Gustavsson et al. (2011) estimate that a significant portion of global food production is wasted, with food systems accounting for large amounts of resource inefficiencies. By implementing circular practices, food systems can move towards a more sustainable, waste-free environment.
- **Key Insight:** Circular systems can drastically reduce food loss by utilizing technology to monitor production cycles, redistribute surplus food, and optimize packaging to extend shelf life. Reducing food waste directly contributes to reducing the environmental footprint, addressing food insecurity, and mitigating the impacts of climate change.
- **Environmental Conservation:** The implementation of resource-efficient practices like sustainable packaging, water management in agriculture, and regenerative agricultural practices can help reduce carbon emissions and water usage in food production. As seen in Barton et al. (2019) and Kumar and Gupta (2021), circular practices, including precision farming and sustainable sourcing, enhance the conservation of critical resources while maintaining the ecosystem's biodiversity.
- **Key Insight:** By minimizing waste and improving resource efficiency, circular economy strategies contribute to lowering carbon footprints, promoting sustainable agriculture, and fostering a more resilient food system capable of withstanding climate change.

Technology-Driven Innovations

- Technological innovations, particularly in blockchain, IoT, and smart monitoring systems, are crucial to the successful implementation of circular economy practices in the food supply chain. These technologies enable better tracking of food products, enhance transparency, and improve the efficiency of operations.
- **Blockchain Technology:** Blockchain offers a transparent, tamper-proof ledger that enhances traceability and accountability in the food supply chain. Tian et al. (2020) emphasize how blockchain enables consumers, businesses, and regulatory bodies to track the origin, quality, and sustainability of food products throughout the supply chain. This transparency not only reduces food fraud but also helps monitor the environmental and social impacts of food production.
- **Key Insight:** Blockchain is essential for building consumer trust, verifying sustainability claims, and ensuring ethical sourcing and fair trade in the food sector. It also facilitates product recalls and helps in identifying inefficiencies and waste points within the supply chain.
- **Internet of Things (IoT):** IoT devices, such as RFID tags, sensors, and GPS tracking systems, enable real-time monitoring of food quality, temperature, humidity, and location throughout the supply chain. According to Mollenkopf et al. (2021), IoT-based technologies can significantly reduce food spoilage, improve inventory management, and optimize

logistics. The integration of smart packaging also helps improve shelf life and reduce food waste by providing real-time data on food conditions.

- **Key Insight:** The combination of IoT with real-time monitoring allows for greater efficiency in resource use, better waste management, and ensures that food products reach consumers in optimal condition, reducing the need for excess production and waste.

Economic and Policy Considerations

- **Economic Implications:** Adopting circular economy strategies within the food supply chain can bring significant economic benefits, including cost savings, new revenue streams, and enhanced competitiveness. Bocken et al. (2016) discuss how circular economy models can help companies reduce production costs by improving resource efficiency and extending product lifecycles. The transition to circular models also opens new avenues for businesses to create sustainable value and build long-term resilience.
- **Key Insight:** Circular economy practices create financial incentives by reducing waste, lowering operational costs, and opening up new markets for sustainable products. The potential for innovation, particularly through product redesign, packaging optimization, and waste-to-energy technologies, can drive profitability and sustainable growth in the food industry.
- **Policy and Regulation:** Governments play a pivotal role in promoting circular economy practices through supportive policies and regulations. Murray et al. (2017) and Patterson (2020) highlight the importance of economic incentives such as subsidies, tax breaks, and eco-labeling to encourage businesses to adopt sustainable practices. Policymakers can also introduce regulations that mandate waste reduction, promote recycling, and incentivize the use of sustainable packaging.
- **Key Insight:** Effective policy frameworks are essential to overcome the barriers to adopting circular economy practices, such as high initial investment costs and regulatory uncertainty. Governments should focus on creating environments conducive to innovation, encouraging circular business models, and ensuring compliance with sustainability goals.

Challenges and Future Prospects

Challenges: Despite the potential benefits, several challenges hinder the widespread implementation of circular economy strategies in the food sector. Consumer behavior often prioritizes convenience and affordability over sustainability, making it difficult to transition to circular consumption patterns. Resistance to change, high upfront investment costs, and regulatory complexity also pose barriers to adopting circular practices. As noted by Hebrok and Heidenstrom (2019), encouraging consumers to adopt circular food consumption practices requires effective education and awareness campaigns.

Key Insight: Overcoming these challenges will require comprehensive collaboration across all stakeholders–governments, industries, and consumers. Policymakers and business leaders must work together to foster awareness, provide financial incentives, and create regulatory frameworks that incentivize sustainable practices.

Future Prospects: Looking ahead, technological innovations, particularly in AI, machine learning, and predictive analytics, will continue to play a critical role in advancing circular economy practices in the food sector. Furthermore, research into consumer behavior and the development of circular ecosystems will be essential in scaling up circular food systems globally. Governments will also need to adopt forward-thinking policies that support the long-term transition to a circular economy.

Key Insight: The future of circular food systems looks promising with the integration of advanced technologies and a more collaborative approach to policy and practice. Over time, the growing demand for sustainable food practices will push industries and governments to innovate and accelerate the shift toward circular food economies.

Conclusion

The global food supply chain faces numerous challenges, including increasing waste, resource inefficiency, and environmental degradation. The concept of a circular economy (CE) presents a promising solution by advocating for a shift from the traditional “take, make, dispose” linear model to a more sustainable and regenerative approach. This chapter has explored how circular economy principles, such as waste reduction, resource optimization, and product lifecycle extension, can be applied within the food supply chain to promote sustainability and food security. The integration of circular practices not only offers environmental benefits but also fosters economic opportunities through improved efficiency and innovation.

One of the central insights from this research is the significant potential for waste reduction and resource efficiency in the food supply chain through the adoption of circular economy strategies. These strategies emphasize minimizing food waste at every stage of production, from farming and processing to consumption and waste management. By employing technologies such as precision farming, sustainable food packaging, and food redistribution platforms, food producers and consumers alike can reduce waste while conserving vital resources such as water, energy, and land. These innovations can help achieve a more efficient and sustainable food system that operates within the planet’s ecological limits.

Another key finding is the transformative role of technology in enhancing supply chain transparency, traceability, and efficiency. Blockchain technology provides a secure and transparent method of tracking products from farm to table, ensuring food safety and authenticity. Meanwhile, Internet of Things (IoT) sensors and real-time monitoring systems enable better inventory management, reduce spoilage, and improve food safety by tracking temperature and storage conditions. These technologies not only improve operational efficiency but also support circular practices by enabling real-time tracking of waste, facilitating the recovery and repurposing of food products, and enhancing consumer trust in sustainable food systems.

However, the transition to a circular economy in the food supply chain is not without its challenges. Regulatory barriers, consumer behavior, and high implementation costs present significant obstacles to widespread adoption. Consumers often prioritize convenience and affordability over sustainability, making it challenging to encourage circular consumption patterns. Additionally, the high initial costs of implementing circular systems and technologies may deter businesses from adopting them. Overcoming these challenges requires comprehensive collaboration between governments, industry leaders, and consumers. Governments must create supportive policies and provide financial incentives for circular practices, while businesses must invest in sustainable innovations that deliver long-term benefits. Moreover, educating consumers about the importance of sustainable food choices and waste reduction is crucial in achieving widespread adoption of circular economy principles.

Collaboration is, therefore, a critical factor in the successful implementation of circular economy strategies. Case studies from companies in industries such as automotive, fashion, and electronics demonstrate how circular models can create economic and environmental benefits, as well as improve resource efficiency. These lessons can be applied to the food sector, where businesses can collaborate with suppliers, logistics providers, and consumers to optimize resources and reduce waste. Shared responsibility across the supply chain is essential to creating a sustainable, closed-loop system that minimizes environmental impact and maximizes resource use.

Looking ahead, several opportunities exist to further advance circular economy practices in the food supply chain. Technological innovations such as artificial intelligence (AI), machine learning, and predictive analytics offer exciting potential for enhancing food system efficiency, improving waste reduction, and optimizing resource use. Furthermore, behavioral research into consumer consumption patterns can provide insights into how to encourage more sustainable food choices at the household level. On the policy front, governments need to update regulatory frameworks to incentivize circular practices and support businesses in their transition to more sustainable models. Global cooperation will also play a crucial role, as food insecurity remains a global challenge. Circular economy strategies that prioritize food redistribution and recovery can help address disparities in food access and reduce waste.

In conclusion, adopting circular economy principles in the food supply chain offers a transformative approach to achieving sustainability, resource efficiency, and waste reduction. The integration of technology, innovative practices, and collaborative strategies is key to overcoming the challenges of food waste and inefficiency. By embracing circular systems, the food industry can create a resilient and sustainable food system that meets the needs of a growing global population while protecting the environment for future generations. The path to a circular food economy is complex, but with the collective efforts of governments, businesses, and consumers, it is achievable.

Resources and References

ABUSIN, S., AL-EMADI, N., and MANDIKIANA, B., 2023. An Evaluation of the Alignment of Surplus Food Recovery and Redistribution Technologies with the Circular Economy. *Sustainability,* vol. 15, no. 16, p. 12355.

AHMADZADEH, S., AJMAL, T., RAMANATHAN, R., and DUAN, Y., 2023. A Comprehensive Review on Food Waste Reduction Based on IoT and Big Data Technologies. *Sustainability,* vol. 15, no. 4, p. 3482.

ALABADDI, Z., OBIDAT, A., and ALZIYADAT, Z., 2023. Exploring the effect of blockchain technology on supply chain resilience and transparency: Evidence from the healthcare industry. *Uncertain Supply Chain Management,* vol. 11, no. 2, pp. 787–798.

ANDERSON, C.R. and MAUGHAN, C., 2021. "The Innovation Imperative": The Struggle Over Agroecology in the International Food Policy Arena. *Frontiers in Sustainable Food Systems,* vol. 5.

ARDRA, S. and BARUA, M.K., 2022. Inclusion of circular economy practices in the food supply chain: Challenges and possibilities for reducing food wastage in emerging economies like India. *Environment Development and Sustainability,* vol. 25, no. 12, pp. 13825–13858.

BAIANO, A. and FIORE, A., 2023. Sustainable food processing: single and interactive effects of type and quantity of brewers' spent grain and of type of sweetener on physicochemical and sensory characteristics of functional biscuits. *International Journal of Food Science & Technology,* vol. 58, no. 11, pp. 5757–5772.

BALASUNDRAM, S.K., SHAMSHIRI, R.R., SRIDHARA, S., and RIZAN, N., 2023. The Role of Digital Agriculture in Mitigating Climate Change and Ensuring Food Security: An Overview. *Sustainability*, vol. 15, no. 6, p. 5325.

BANDHU, K.C., LITORIYA, R., LOWANSHI, P., JINDAL, M., CHOUHAN, L., and JAIN, S., 2022. Making drug supply chain secure traceable and efficient: a Blockchain and smart contract based implementation. *Multimedia Tools and Applications,* vol. 82, no. 15, pp. 23541–23568.

BARLOW, S.M., BOOBIS, A.R., BRIDGES, J., COCKBURN, A., DEKANT, W., HEPBURN, P., HOUBEN, G.F., KÖNIG, J., NAUTA, M.J., SCHUERMANS, J., and BÁNÁTI, D., 2015. The role of hazard- and risk-based approaches in ensuring food safety. *Trends in Food Science & Technology,* vol. 46, no. 2, pp. 176–188.

BORRELLO, M., PASCUCCI, S., CARACCIOLO, F., LOMBARDI, A., and CEMBALO, L., 2020. Consumers are willing to participate in circular business models: A practice theory perspective to food provisioning. *Journal of Cleaner Production,* vol. 259, p. 121013.

BOWMAN, D.M. and LUDLOW, K., 2017. Ensuring Food Safety: General Principles for Safeguarding What You Eat Including the Role of Food Labels. *Elsevier eBooks,* pp. 175–193.

BURGGRAAF, V.T., MAZZETTO, A.M., ROMERA, A.J., MERCER, G.J.K., and LEDGARD, S.F., 2021. Application of circular economy principles to pastoral farming: development of an assessment framework. *Animal Production Science,* vol. 62, no. 8, pp. 721–725.

CAMMARELLE, A., BIMBO, F., LOMBARDI, M., and VISCECCHIA, R., 2021. Health and Eco-Innovations in Food Packaging. *Environmental footprints and eco-design of products and processes,* pp. 31–70.

CHAVAN, P., YADAV, R., SHARMA, P., and JAISWAL, A.K., 2023. Laser Light as an Emerging Method for Sustainable Food Processing, Packaging, and Testing. *Foods,* vol. 12, no. 16, p. 2983.

CSABA, F., POPP, J.H.C., and FINGER, D.C., 2020. *Circular Use of Resources.* MDPI eBooks.

CUI, Y. and GAUR, V., 2022. Supply Chain Transparency Using Blockchain: Benefits, Challenges, and Examples. *Springer eBooks,* pp. 307–326.

DE LOS MOZOS, E.A., BADURDEEN, F., and DOSSOU, P.-E., 2020. Sustainable Consumption by Reducing Food Waste: A Review of the Current State and Directions for Future Research. *Procedia Manufacturing,* vol. 51, pp. 1791–1798.

DELOUYI, F.L., RANJBARI, M., and ESFANDABADI, Z.S., 2023. A Hybrid Multi-Criteria Decision Analysis to Explore Barriers to the Circular Economy Implementation in the Food Supply Chain. *Sustainability,* vol. 15, no. 12, p. 9506.

DUBEY, N. and TANKSALE, A., 2023. A multi-depot vehicle routing problem with time windows, split pickup and split delivery for surplus food recovery and redistribution. *Expert Systems With Applications,* vol. 232, p. 120807.

EATON, E., HUNT, A., DI LEO, A., BLACK, D., FROST, G., and HARGREAVES, S., 2022. What Are the Environmental Benefits and Costs of Reducing Food Waste? Bristol as a Case Study in the WASTE FEW Urban Living Lab Project. *Sustainability*, vol. 14, no. 9, p. 5573.

FARMER, N., 2013. Present status and trends in innovations in packaging for food, beverages and other fast-moving consumer goods. *Elsevier eBooks,* pp. 1–21.

GARSOW, A.V., KIM, E.G., COLVERSON, K.E., ILIC, S., KUNYANGA, C., BAINAH, A., and KOWALCYK, B.B., 2022. A review of the roles of men, women, and youth in ensuring food safety in the smallholder poultry value chain in Kenya. *Frontiers in Sustainable Food Systems,* vol. 6.

HANSSEN, O.J., MEILER, H., SVANES, E., and SCHAKENDA, V., 2012. Life Cycle Assessment as a Tool in Food Waste Reduction and Packaging Optimization – Packaging Innovation and Optimization in a Life Cycle Perspective. *John Willey & Sons,* pp. 345–367.

HE, G., SALEEM, M., DENG, T., ZHONG, Z., HE, T., and WU, J., 2023. Unraveling the Mechanism of StWRKY6 in Potato (Solanum tuberosum)'s Cadmium Tolerance for Ensuring Food Safety. *Foods,* vol. 12, no. 12, p. 2303.

HEBROK, M. and HEIDENSTRØM, N., 2018. Contextualising food waste prevention - Decisive moments within everyday practices. *Journal of Cleaner Production,* vol. 210, pp. 1435–1448.

IRANMANESH, M., MAROUFKHANI, P., ASADI, S., GHOBAKHLOO, M., DWIVEDI, Y.K., and TSENG, M.-L., 2022. Effects of supply chain transparency, alignment, adaptability, and agility on blockchain adoption in supply chain among SMEs. *Computers & Industrial Engineering,* vol. 176, p. 108931.

JOENSUU, K., HARRISON, E., and HARTIKAINEN, H., 2022. What to Do with Food Waste? A Holistic Feasibility Framework to Evaluate Different Solutions. *Sustainability,* vol. 14, no. 20, p. 13004.

KASHYAP, A., YADAV, D., SHUKLA, O.J., and KUMAR, R., 2023. Unraveling barriers to food loss and waste in perishable food supply chain: a way toward sustainability. *Environment Development and Sustainability.*

KAUR, I., 2016. Role of hotel management and catering technology institutes in ensuring food safety. *Elsevier eBooks,* pp. 321–335.

KAYIKCI, Y., GÖZAÇAN, N., LAFCI, Ç., and KAZANÇOĞLU, Y., 2021. A Conceptual Framework for Food Loss and Waste in Agri-Food Supply Chains: Circular Economy Perspective. *Environmental footprints and eco-design of products and processes,* pp. 41–53.

KRETOVA, Y.I., 2015. Modern Aspects of Technological Processes Modeling to Meet the Challenges of Increasing Energy and Resource Efficiency of Food Production. *Procedia Engineering,* vol. 129, pp. 294–299.

KUMAR, A. and AGRAWAL, S., 2023. Challenges and opportunities for agri-fresh food supply chain management in India. *Computers and Electronics in Agriculture,* vol. 212, p. 108161.

KUMAR, M., RAUT, R.D., JAGTAP, S., and CHOUBEY, V.K., 2022. Circular economy adoption challenges in the food supply chain for sustainable development. *Business Strategy and the Environment,* vol. 32, no. 4, pp. 1334–1356.

KUMAR, S.R., PRAJAPATI, S., and PARAMBIL, J.V., 2021. Sustainable Food Value Chains and Circular Economy. *Environmental footprints and eco-design of products and processes,* pp. 77–92.

LEHTOKUNNAS, T., MATTILA, M., NÄRVÄNEN, E., and MESIRANTA, N., 2020. Towards a circular economy in food consumption: Food waste reduction practices as ethical work. *Journal of Consumer Culture,* vol. 22, no. 1, pp. 227–245.

LIBRÁN-EMBID, F., OLAGOKE, A., and MARTIN, E.A., 2023. Combining Milpa and Push-Pull Technology for sustainable food production in smallholder agriculture. *A review. Agronomy for Sustainable Development,* vol. 43, no. 4.

LICCIARDELLO, F., 2017. Packaging, blessing in disguise. Review on its diverse contribution to food sustainability. *Trends in Food Science & Technology,* vol. 65, pp. 32–39.

LIU, X., ZHOU, Z., ZHONG, F., and SHI, J., 2023. Improving supply chain transparency with blockchain technology when considering product returns. *International Transactions in Operational Research*.

MARTIN-RIOS, C., ROGENHOFER, J., and ALVARADO, M.S., 2022. The true cost of food waste: Tackling the managerial challenges of the food supply chain. *Trends in Food Science & Technology,* vol. 131, pp. 190–195.

MASSIMILIANO, B. and LUIGI, C., 2021. Transitioning into circular food consumption practices: An analytical framework. *Circular economy and sustainability,* pp. 385–407.

NAIR, D.J., RASHIDI, T.H., and DIXIT, V.V., 2016. Estimating surplus food supply for food rescue and delivery operations. *Socio-Economic Planning Sciences,* vol. 57, pp. 73–83.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=61c836ef-aa66-3e07-990b-87219c0bb14c.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=f85a024e-e09e-377d-8cfb-ff50746866fe.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=45291296-e58b-3873-a8ad-cb2a3b07a43d.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=48e9a6ac-02d3-3f86-bb3e-4aab9852f7fc.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=7a0f60f0-c86e-3b0b-8dcd-20a8b571f99f.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=0fe1262b-4965-3c20-b75a-a3e353d9e4f0.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=25409123-d795-341b-8668-55b557462475.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=454fde37-e374-3585-9d07-12feb49997ea.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=ba211c7f-b6ac-3338-a061-ece5259a5ed4.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=0b1ae1d0-ae5d-3140-9879-a28f202836b9.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=1b18b8e4-1fbb-3cb2-9992-b27d7ba9d55b.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=500378e8-609a-3de1-a2a6-d66a630c40e4.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=f9c4bd89-fca6-302e-be37-fd402422b5bc.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=61bc336f-5e1e-37d2-a137-cf7aa12a8e04.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=fac55ebd-1807-38c1-ac14-91965d203863.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=1a6735aa-9ef4-3ee1-a1dc-5caa4094bd10.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=80c422f5-15fb-3077-8110-41280ca920d0.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=d2560b4b-fa4f-3841-b2da-64ec66557e2f.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=38ebe893-c3eb-3a2e-93fe-3479f446024e.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=ceeabddf-9bf1-31ff-83ff-c21b4304ec8c.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=1216a8a8-1115-380f-ae88-33ad7118204d.

OpenURL Connection - EBSCO. [online], n.d. Available from:

https://research.ebsco.com/linkprocessor/plink?id=b8ea043c-7b60-316d-a0ab-89f98006a2ec.

OVESNÁ, J., KAMINIARIS, M.D., TSIROPOULOS, Z., COLLIER, R., KELLY, A., DE MEY, J., and POLLET, S., 2023. Applicability of Smart Tools in Vegetable Disease Diagnostics. *Agronomy,* vol. 13, no. 5, p. 1211.

PARK, S.-I., LEE, D.S., and HAN, J.H., 2013. Eco-Design for Food Packaging Innovations. *Elsevier eBooks,* pp. 537–547.

PASCALL, M.A., DEANGELO, K., RICHARDS, J., and ARENSBERG, M.B., 2022. Role and Importance of Functional Food Packaging in Specialized Products for Vulnerable Populations: Implications for Innovation and Policy Development for Sustainability. *Foods,* vol. 11, no. 19, p. 3043.

QIU, Y., WANG, P., GUO, Y., ZHANG, L., LU, J., and REN, L., 2023. Enhancing food waste reduction efficiency and high-value biomass production in Hermetia illucens rearing through bioaugmentation with gut bacterial agent. *The Science of the Total Environment,* vol. 904, p. 166488.

RADHAKRISHNAN, M., MAQSOOD, S., and SILIVERU, K., 2023. Editorial: Emerging non-thermal technology applications for sustainable food processing. *Frontiers in Sustainable Food Systems,* vol. 7.

REJEB, A., REJEB, K., ZAILANI, S., TREIBLMAIER, H., and HAND, K.J., 2021. Integrating the Internet of Things in the halal food supply chain: A systematic literature review and research agenda. *Internet of Things,* vol. 13, p. 100361.

SANYAL, S., SINGH, V.K., XHAFA, F., SANYAL, B., and MUKHOPADHYAY, S., 2021. A Game Theoretic Framework for Surplus Food Distribution in Smart Cities and Beyond. *Applied Sciences,* vol. 11, no. 11, p. 5058.

SATHORIA, P. and ROY, B., 2022. Sustainable food production through integrated rice-fish farming in India: a brief review. *Renewable Agriculture and Food Systems,* vol. 37, no. 5, pp. 527–535.

SHABIR, I., DASH, K.K., DAR, A.H., PANDEY, V.K., FAYAZ, U., SRIVASTAVA, S., and R, N., 2023. Carbon footprints evaluation for sustainable food processing system development: A comprehensive review. *Future Foods,* vol. 7, p. 100215.

SHABIR, I., DASH, K.K., DAR, A.H., PANDEY, V.K., FAYAZ, U., SRIVASTAVA, S., and R, N., 2023b. Carbon footprints evaluation for sustainable food processing system development: A comprehensive review. *Future Foods,* vol. 7, p. 100215.

SHAH, G.H., SHANKAR, P., SITTARAMANE, V., AYANGUNNA, E., and AFRIYIE-GYAWU, E., 2022. Ensuring Food Safety for Americans: The Role of Local Health Departments. *International Journal of Environmental Research and Public Health,* vol. 19, no. 12, p. 7344.

SINGH, A.K., KUMAR, V.R.P., IRFAN, M., MOHANDES, S.R., and AWAN, U., 2023. Revealing the Barriers of Blockchain Technology for Supply Chain Transparency and Sustainability in the Construction Industry: An Application of Pythagorean FAHP Methods. *Sustainability,* vol. 15, no. 13, p. 10681.

SINGH, A.K., KUMAR, V.R.P., IRFAN, M., MOHANDES, S.R., and AWAN, U., 2023b. Revealing the Barriers of Blockchain Technology for Supply Chain Transparency and Sustainability in the Construction Industry: An Application of Pythagorean FAHP Methods. *Sustainability,* vol. 15, no. 13, p. 10681.

SIRACUSA, V. and LOTTI, N., 2019. Intelligent packaging to improve shelf life. *Elsevier eBooks,* pp. 261–279.

SQUATRITO, S., ARENA, E., PALMERI, R., and FALLICO, B., 2020. Public and Private Standards in Crop Production: Their Role in Ensuring Safety and Sustainability. *Sustainability,* vol. 12, no. 2, p. 606.

STIGZELIUS, I., 2020. Agencing Sustainable Food Consumers: Integrating Production, Markets and Consumption Through a Socio-Material Practice Perspective. *Springer eBooks,* pp. 121–148.

STOILJKOVIĆ, B., PETKOVIĆ, N., KRSTIĆ, H., and PETROVIĆ, V., 2023. Application of Circular Economy Principles to Architectural Design: *A Case Study of Serbia. Buildings,* vol. 13, no. 8, p. 1990.

SUNNY, J., UNDRALLA, N., and PILLAI, V.M., 2020. Supply chain transparency through blockchain-based traceability: An overview with demonstration. *Computers & Industrial Engineering,* vol. 150, p. 106895.

Sustainable Functional Food Processing, 2022. *MDPI eBooks*.

SVYSTUN, L., SAMOILYK, I., and SVYSTUN, M., 2023. The Challenges and Opportunities for the Development of Industry 4.0 and Agri-Food Supply Chain in the Context of Energy *Infrastructure Restoration in Ukraine. Engineering Proceeding*.

TAKAVAKOGLOU, V., PANA, E., and SKALKOS, D., 2022. Constructed Wetlands as Nature-Based Solutions in the Post-COVID Agri-Food Supply Chain: Challenges and Opportunities. *Sustainability,* vol. 14, no. 6, p. 3145.

TAN, S.P., NG, L.C., LYNDON, N., AMAN, Z., KANNAN, P., HASHIM, K., TEO, H.M., and IBRAHIM, M.S.C., 2023. *A review on post-COVID-19 impacts and opportunities of agri-food supply chain in Malaysia*. PeerJ, vol. 11, p. e15228.

UVAROVA, I., ATSTAJA, D., VOLKOVA, T., GRASIS, J., and OZOLINA-OZOLA, I., 2023. The typology of 60R circular economy principles and strategic orientation of their application in business. *Journal of Cleaner Production,* vol. 409, p. 137189.

VOULGARIDIS, K., LAGKAS, T., ANGELOPOULOS, C.M., and NIKOLETSEAS, S.E., 2022. IoT and digital circular economy: Principles, applications, and challenges. *Computer Networks,* vol. 219, p. 109456.

WAGNER, M., KALUSCHKE, S., KELLER, F., and REINHART, G., 2016. Waste Reduction by Product-Quality Based Scheduling in Food Processing. *Procedia CIRP,* vol. 40, pp. 584–589.

WU, Y., SUN, J., HUANG, X., LAI, W., and XIONG, Y., 2021. Ensuring food safety using fluorescent nanoparticles-based immunochromatographic test strips. *Trends in Food Science & Technology,* vol. 118, pp. 658–678.

YONTAR, E., 2022. Critical success factor analysis of blockchain technology in agri-food supply chain management: A circular economy perspective. *Journal of Environmental Management,* vol. 330, p. 117173.