Blockchain as an Enabler of Circular Supply Chains in the Food Industry

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Abstract. Circular economy (CE) has become prevalent worldwide due to its economic and environmental benefits. More and more practitioners have deployed CE in supply chains to improve operational efficiency and sustainability. Thus, the integration of CE and supply chain has developed a new concept: circular supply chain (CSC). In particular, the CE model could remarkably reduce food waste within food supply chains (FSCs) and diminish the environmental impact from FSCs. Such a FSC that adopts CE principle is known as circular food supply chain (CFSC). However, lack of technical support for effective communication is a significant difficulty in developing CFSCs. Blockchain technology (BCT) could be the potential solution to this problem because of its decentralisation, public information sharing, high traceability and transparency, high security etc. Although many researchers have studied CFSCs in recent years, few studies investigate BCT as an impetus for CFSC development. Therefore, this research will fill this gap, focusing on the feasibility of BCT-based CFSCs, how BCT can establish CFSCs, and possible barriers. In addition, a few recommendations on developing BCT-based CFSCs will be provided.

Keywords: Circular Economy, Blockchain Technology, Supply Chain Management, Food Supply Chain, Sustainability.

1. Introduction

The increasing food waste has raised worldwide concern these years, and food supply chains (FSCs) urgently need improvement to tackle this critical issue. According to the United Nations Environment Programme (UNEP) statistics, approximately 1.3 billion food is lost and wasted annually, accounting for one-third of total consumable food [1]. UNEP also coordinate with the Waste and Resources Action Programme (WRAP), publishing UNEP Food Waste Index Report 2021. The report points out that the food waste is primarily in family consumption (11% of total edible food consumers products humans) whilst food service accounts for 5%, and food retailers account for 2% [1].

However, the practical situation varies in countries with different development. Food loss and waste (FLW) mostly exist at the consumption stage in developed and developing countries, at the same time, FLW mostly generates at raw material supply and production stage in underdeveloped countries [2]. The less FLW at the early stage of FSCs in the medium- and high-income countries is because that they have some policies and regulations on encouraging raising crop yield and lowering the unit price of crops so that consumers can easily discard them [3]. Moreover, advanced technology and superior management methods are critical factors of low FLW in their FSCs [4]. Therefore, it is crucial to introduce innovative technology to reduce FLW within FSCs.

In addition, the waste within FSCs has negative influence on the environment. Food waste results in nitrogen loss in global soil and massive nitrogen emission [5], [6]. Nitrogen emission would pollute the atmosphere, leading to acid rain, fog haze, ozone pollution etc. [7]. Except for nitrogen emission, the high carbon footprint is another defective influence caused by food waste. During food production, particularly perishable food, energy and fuel use generate enormous greenhouse gas, which would increase when overproduction happens [8]. Besides, traditional approaches to handling food waste (i.e., burning landfills) can also produce copious greenhouse gas, mainly from its packaging [9], [10]. Meanwhile, livestock raising and aquaculture have a detrimental influence on biodiversity, and food waste reduction seems to be the optimal solution to this issue [11], [12]. Thus, it is necessary to develop environmentally sustainable supply chains for the food industry.

Circular economy (CE) could be a superior alternative mode for FSCs. Unlike the linear operational model, CE is a close loop model that maximally reduces waste. It has been introduced into supply chain management (SCM) and formed a new type of supply chain: circular supply chain (CSC) [13]. There are two categories of CE: extend product life cycle through repair, reproduction, upgradation and improvement, and recycle unusable materials to convert them into new valuable products [14]. The second type might not be a close loop but it still corresponds to CE's objectives: waste reduction, higher efficiency of resource usage, and maximum retention in the value of materials and products [15]. Moreover, some researchers developed the concept of sustainable CE and defined its environmental targets is to leverage material circulation and renewable energy to reduce consumption of original materials and energy, and decrease waste and emission [16]. The aims of CE are consistent with the need of current FSCs, so CE principles could be adopted in traditional FSCs to transform into circular food supply chains (CFSCs).

On the other hand, it is indispensable to gain technical assistance as close connection and collaboration among stakeholders are necessary for CSCs [17]. In this case, blockchain technology (BCT) can be a superior choice to support CSC development. Different from traditional digital databases, BCT is decentralised, which means data stored in each block is independent and has no interference with each other [18]. Meanwhile, the data in the block is encrypted and immutable, only authorised users can access it [19]. These characteristics of BCT guarantee the safety and authenticity of data, so the information flow in the supply chain can be more accurate [20]. Besides, the data on the BCT-based platform is public to all the stakeholders in the supply chain, allowing them to timely acquire the information they need [21]. Hence, information sharing could be more effective, and collaboration could be more efficient.

In brief, BCT-based CFSCs could help traditional FSCs move towards less FLW and more environmentally sustainable. Therefore, this research will focus on this specific topic. Two quantitative methods will be used to analyse previous studies on the use of BCT to build CFSCs and current practices of BCT adoption and CFSC development in some companies in the food industry. Then the discussion will be centred on the feasibility of this integration, how to develop BCT-based CFSCs and potential barriers. Finally, the last part will provide some recommendations on developing BCT-based CFSCs.

2. Literature Review

2.1 Circular Economy and Supply Chain

The circular economy (CE) concept has become a popular research topic in various fields, particularly SCM. CE is defined as "an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes" [22]. Based on this notion, the combination of CE and SCM is called circular supply chain management (CSCM) [23-25]. Moreover, a more comprehensive definition describes CSCM as introducing a circular mindset into SCM, its surrounding industries and ecosystem management, which encourages all the stakeholders to participate in the entire lifecycle of products or services, systematically retrieve technical materials and reuse recyclable materials to realise waste elimination within the supply chain [26]. Interestingly, some researchers hold a different view of the circular mindset in the definition. A study on the practical application of CE in Agri-FSCs and discovered that when adopting CE principles, supply chains are not necessarily designed to be circular [27]. However, they admitted that the mainstream trend of CE adoption in supply chains is to develop a CSC. This argument is realistic because under most circumstances, the circular model is the optimal option to adopt CE principles as it is easier to make the waste flow within the supply chain. As study argued that it is essential for participants to have mutual benefits when developing CSC [28]. Hence, stakeholders in the same supply chain would be more willing to cooperate to recycle the waste if CE adoption can bring advantages to the entire supply chain. With numerous benefits of CSC, such as sustainability improvement, resource-saving, increase in resource utilisation, supply chain efficiency and competitiveness, etc. [13], [29], many practitioners have attempted to introduce CSCM into their sectors.

2.2 Circular Food Supply Chain

At present, an increasing number of researchers have studied CE deployment in the food industry, generating CFSCs. As an emerging concept, a clear definition of CFSC has not been developed so far. However, according to CE principles, CFSC should minimise waste and emission of greenhouse gas by recycling and reusing food waste and food by-products, using renewable energy and effectively utilising natural resources [30]. This section will review articles about CFSC's most crucial parts and the driven forces and the barriers to developing CFSCs.

2.2.1 Food Loss and Waste

The primary purpose of a successful CFSC is to reduce FLW within FSC [31]. To reach this goal, it is crucial to figure out the stages of FSCs that contain the most FLW, the causes of FLW and prospective solutions. Many researchers studied diverse FSCs in different countries and observed at which stage of FSCs generated the most FLW (shown in Table 1). The table demonstrates that most FLW would exist at retailer stage. For perishable products, stages before sales (i.e., production, processing and storage) contain the most FLW.

Table 1. Stages contain the most FLW

Focus	Country	Food category	The stages contain the most FLW	Reference
The quantity and value of food waste in a large retail store in Italy, categorised by departments. Find out the percentage of edible parts in food waste.	Italy	All	Retailers	[32]
The causes of FLW and strategies to prevent FLW, propose a new food waste hierarchy and a circular ability framework for small and medium enterprises to adopt CE in FSC.	Indonesia	Agri-food	Distributors and retailers	[33]
The return policy is the critical risk factor of waste between suppliers and retailers. Reform the recycling practices to reduce food waste.	Sweden	Bread, milk, fresh fruits and vegetables	Retailers	[34]
Reveal parts with the most hidden information in CE and stakeholders in the meat industry.	Turkey	Meat	Production, processing and storage	[35]
Survey on main challenges of building CFSC in India, including poor government policies, shortage of technologies and weak awareness of farmers.	India	Dairy products	Transport and storage	[36]

When referring to the causes of FLW, researchers hold various opinions. One critical reason supported by many researchers is the shortage of related technologies and knowledge. A study has argued that food would be wasted due to a lack of improper storage or transport method (e.g., lack of cryogenic storage and cold chain transport), particularly perishable food [37]. However, this study was conducted in 2010, so the technologies at that time were less advanced than today. Many researchers studied the use of cold chain technology, digital platform, The Internet of Things (IoT), blockchain etc. in the perishable food supply chain and recommended practical schemes [38-41]. Hence, this problem seems not to be the most difficult to solve nowadays as technologies have developed rapidly over the last ten years. On the other hand, some researchers have stated that a crucial reason for FLW is the deficient technology for forecasting market demand, resulting in overproduction [34, 42, 43]. Besides, food that does not meet the specifications and standards of production or packaging would also turn to waste [33, 37, 44].

To tackle these problems, many researchers investigated real businesses in the food industry and proposed feasible suggestions. A study interviewed selected suppliers of perishable food in Sweden, developed a waste framework and suggested that the food distribution system should be designed based on financial incentive measures [34]. However, this framework tends to be more applicable for developed countries, developing countries are not considered. A study further modified their framework and developed a waste hierarchy corresponding to the FSCs in developing countries [33]. Meanwhile, they advised that the prevention of unnecessary overproduction should be prioritised, so they have argued that excessive products should be further processed into other derivatives if they are safe for humans to consume. This could be a superior option for reducing food waste and minimising detrimental environmental impacts. Because currently, the landfill is the most popular choice for addressing food waste and releasing harmful gases [3, 45]. Additionally, approaches and models of optimising demand forecasting that assists in reducing FLW are developed by many researchers [46-48].

2.2.2 Driven Factors of Developing CFSCs

Comparing the previous studies that focus on driven factors of developing CFSCs, although most researchers have pointed out similar characteristics, they have some differences in the priority of the elements.

In the earlier studies, the mainstream opinion on the dominant factors of establishing CSCs is the environmental benefits [49-51]. However, this view has been challenged by some other researchers recently. A study on agri-food SMEs in the UK and have noticed that environmental benefits still influence CFSC development, but competitiveness enhancement has become a more significant driven factor [52]. Nevertheless, this finding is based on the SMEs in the British food industry, so it might be limited by the location, which can only represent conditions in developed countries. Similarly, research on SMEs as well, but in the developing country, Indonesia, found that all the stakeholders' participation and cooperation contribute significantly to CFSC development [33]. Some other researchers have concurred with this opinion, and have insisted that a close cooperative relationship and a common goal could facilitate CFSCs establishment [27, 28, 53, 54, 55]. But some of them have some additional points of view to the cooperation. Formal contracts containing provisions referring to CE principles can motivate stakeholders to cooperate [27]. Except for contracts, technical support is vital for facilitating cooperation among stakeholders [54]. Technology such as a connection system allows effective communication among upstream and downstream stakeholders in the FSC. Hence, the food products requirement could be better met, and less FLW would exist [36].

Moreover, many researchers have asserted that government intervention is important in promoting CFSCs. Scholars have declared that government policies on supporting CE adoption could have a positive impact on CFSC establishment [56]. Besides policy support, propaganda of CE adoption in FSCs could indirectly influence consumers' and producers' awareness of CFSCs [57]. The prerequisite is that governments have adequate attention to CE and environmental issues. Studies discovered that governments in many countries have realised the importance of CE and have made some regulations to facilitate the transformation to CFSCs [35, 58]. From another aspect, the government could supervise environmental impacts from FSCs through legislation on quality and standards of procedures in FSCs, including planting, harvesting, production and recycling waste etc. [27]. In this case, organisations would be more willing to collaborate with those who meet these regulations. Therefore, governments are a vital driven factor in facilitating CFSCs development.

2.2.3 Barriers of Developing CFSCs

The first reason stakeholders hesitate to transform into CFSCs is insufficient finance. Some researchers interviewed enterprises in the food industry and have found that uncertain return is a significant barrier to develop CFSCs [55, 59]. Due to the high investment in the developing stage, CFSCs development could bring financial stress to companies [26, 60]. Meanwhile, it could be hard to sell recycled products because customers generally suspect their values and quality [61]. Furthermore, due to an unstable supply-demand relationship, sometimes a more extensive production quantity is needed to meet the higher demand, which increases investment in recycling FLW [57]. These are significant challenges for companies to create expected returns, so they might be reluctant to turn to CFSCs.

Another challenge is insufficient related laws and government supervision regulations [56, 62, 63]. Furthermore, scholars pointed out that even government has legislated on CE, it is still hard to implement in practice due to the inefficient execution mechanism [64]. It is worth noting that different from major research methods, i.e., case studies, expert interviews, practitioner interviews etc., this study uses fuzzy DEMATEL to analyse the data collected via questionnaires and have developed causal relationship graphs to reflect each barrier and their influence degree to CFCS development [64]. Thus, compared with a single qualitative research methodology, results based on this combined methodology could be more accurate. Hence, the essential barrier might be the lack of supervision on enterprises' obedience to these policies. However, it is hard for the government to track and appraise companies' performance in CE adoption [65]. In short, the lack of relevant policy and supervision mechanisms are two main obstacles to CFCS development at the government level.

In addition, a lack of technology adoption for control and managing FSCs is also a critical impediment of turning them into circular. Scholars studied eighteen barriers of developing CFSC and prioritised them by mathematic modelling and calculating the index of each factor's influence degree. This study pointed out that the lack of technology and innovation gained the highest number [66]. Meanwhile, this study found another two barriers: lack of reliable forecasting of FLW and lack of supply chain optimisation [66]. However, technology could also solve these two problems as digitalisation technology could help to prevent food waste and improve FSC operations by increasing the accuracy of planning and forecasting [53]. Thus, the root barrier seems still to be the lack of technology adoption. On the other hand, poor information circulation in FSCs resulting in low transparency and traceability is another obstacle that needs to be overcome when developing CFSCs [35], which also needs to be solved by adopting innovative technology [67]. Besides, scholars noticed that although parts of their interviewees have realised the importance of CE adoption in FSCs and studied or tried several renewable energy sources such as solar energy, the efficiency of the energy use is still low [27]. They attribute this problem to the lack of technology. Similarly, another study discovered that some organisations could not effectively reduce environmental impacts from the process of addressing food waste, which is caused by a lack of technology as well [54].

2.3 Blockchain Technology

Blockchain is a disruptive technology that could be an alternative solution to the above barriers and assist in building CFSCs. This section will review research focusing on BCT application, BCT for SCM and BCT for CSCM.

Currently, studies on BCT have developed rapidly, but there has not generated a standard definition of this technology. Blockchain is a decentralised, public and transparent database, and is defined blockchain as a distributed ledger of transactions in the form of a database, which is encrypted and is under the management of a specific consensus mechanism. This definition is more detailed as it indicates some conditions when using blockchain [68]. Furthermore, another definition of blockchain emphasises this technology uses a peer-to-peer network to transform information [69]. Compared with traditional databases, BCT has several unique characteristics. Some researchers have pointed out that the core characteristics of BCT are decentralisation, persistency, anonymity, immutability, autonomy and open source [70, 71].

With these features, BCT has numerous benefits for storing information and data. As the data in the blockchain is public to all the users and the data cannot be modified once uploaded [72], BCT has high transparency, which can accelerate data sharing and transaction processing [73]. Other than this advantage, independent nodes in blockchain cannot affect each other because of the decentralisation of BCT [74, 75]. This means that the data and information in other blocks would not be falsified even if hackers attack one block. Moreover, BCT generally uses an encryption algorithm to protect data and strengthen information security [76]. However, a study pointed out that the mistakes in the algorithm and hacker attacks could not be solved as soon as possible as BCT is still at the developing stage and the algorithm is new [77]. Nevertheless, many researchers have studied different BCT attacks and proposed practical solutions. A study uses a comprehensive survey on different types of attacks on blockchain as well as analysis of the underlying relationship among these attacks and suggested a few feasible prevention measures [78]. Its findings contribute to future research on solutions to BCT attacks at the technical level [78]. Hence, it is fairly to say that BCT would become safer and safer. In addition, a smart contract, a computer program based on blockchain, enables the automatic execution of instructions at lower costs and less time [79].

Although some researchers have argued that high investment in BCT development could be a barrier to adopt it in business [80-82], as equipment costs are decreasing whilst computing ability increasing every day [83]. Moreover, BCT adoption could effectively reduce operational costs [84]. Therefore, BCT has enormous potential to be used in different fields. The most famous BCT application is Bitcoin, but its application could be far beyond the financial sector [68, 85]. Nowadays, more and more researchers have explored how BCT could benefit SCM.

2.3.1 BCT and SCM

BCT adoption could benefit SCM in many aspects. BCT could reduce the influence of interrupt in the supply chain via its persistency, so supply chain resilience and anti-risk ability could be strengthened [86-88]. On the other hand, BCT allows the supply chain to gain high transparency and confidentiality can be assured simultaneously [89, 90]. Other than tamper resistance, the privacy of the internal supply chain could also be protected. Scholars proposed a blockchain-empowered scheme to limit users' accessibility of the data according to their identification [91]. The scheme allows better SCM under the assistance of BCT. Additionally, the smart contract could help to automatically operate if it identifies that the contract requirements are met [92]. In this case, supply chain efficiency would be significantly enhanced. Furthermore, smart contract removes unnecessary intermediaries in the supply chain to save transaction costs [93]. Another benefit of smart contracts used in BCT is that they could improve the traceability of supply chains [94]. Nonetheless, the study also pointed out that as data could not be revised in the smart contract, bogus data from some stakeholders could have a detrimental impact on the SCM [94]. Similarly, scholars stated that false information caused by human mistakes cannot be deleted as BCT still needs human participation [95]. After all, the advantages of BCT outweigh its defects. Table 2 shows the key benefits that BCT could bring to SCM.

Table 2. Main benefits of BCT for SCM

Benefits	Description	References
Increase transparency	All the stakeholders could access the information on products and transaction fulfilment.	[90, 96-98]
Improve traceability	Stakeholders can trace product and asset situations, which can be against counterfeits and fake transactions.	[93, 98, 99]
Save time and costs	Transactions could be processed faster by automatise partial manual procedures. Operational costs could be reduced by removing third-party intermediaries.	[93, 95, 100-102]
Improve security	Supply chain information stored in the blockchain is tamper-resistant. Transactions are protected by Encryption. Suspicious action can be terminated automatically.	[95, 98, 100]
Anti-interruption	The entire supply chain will not be influenced if several blocks have been attacked or have errors.	[87, 101, 103]
Improve flexibility	BCT could integrate supply chain processes for better demand forecasting and management to optimise supply planning and inventory control.	[87, 88, 97]

Research on BCT-based supply chains in various non-financial sectors has developed over these years. Based on the theoretical foundations, many researchers have suggested that BCT could be used in the drug supply chain for against counterfeit drugs [104-106]. A study furthered the research by proposing a framework with Hyperledger adoption, a mainstream technology based on BCT, to record data in the drug supply chain [107]. Likewise, scholars proposed a Hyperledger Caliper -based drug supply chain to assure medicine's safe delivery and integrity [108]. Hyperledger Caliper tested the performance of the two frameworks, but the framework proposed by the later study is much better [108]. This might be because although they used a similar programming language, the later codes are superior. Hence, the technical factor is vital for BCT-based supply chain performance. From another aspect, a few research on BCT adoption in the food industry. BCT adoption enables the agri-food supply chain to be more transparent [109] and traceable [110], so agri-food safety can be guaranteed [111]. Scholars designed a BCT-based wine supply chain model to trace the wine's information and avoid fraud [112]. Likewise, it has been found in another study BCT could help build a traceable and stable dairy supply chain and improve product quality and safety [113]. However, the study mainly focus on the record of food information, some other practical functions of blockchain for FSC (e.g., automation, demand forecasting, suppliers selection etc.) have not been explored. As recommended by scholars, BCT could assist in better decision-making and sustainable development [114].

2.3.2 BCT for CSCM

A few researchers have testified that BCT implementation in CSC is feasible and further analyse deployment methods. Scholars developed a framework and pointed out the main stages of CSCM that are supported by BCT [115]. This study also examined the critical success factors of this framework but did not cover detailed measures and processes in the CSC [115]. In contrast, another study proposed a BCT-based CSC framework, including manufacturers, reverse logistics service providers, selection centres, recycling centres and landfills [116]. This framework could improve the management of waste circulation and product exchange or return [116]. Reverse logistics service providers being stakeholders is innovative and could easily capture supply chain information with BCT. As timely information sharing could boost cooperation among stakeholders [117, 118], reverse logistics service providers could better serve supply chain organisations to improve CSCM. Still, these suggestions are generality of utilising BCT to develop CSC, but the compatibility in different industries is not considered. At present, there is a limited number of research on BCT applications in specific industries, in total only nine papers (see Table 3).

Thus, the studies on BCT assist in building CSC is underrepresented. In particular, although there are a few studies on its application in some sectors, only two papers concentrate on BCT-enabled CSC for the food industry. Therefore, this study will focus on this specific research gap.

Table 3. Studies on BCT-enabled CSC for diverse sectors

Sector	Methodology	Main findings	Reference
Coffee	Case study	Determine how to use BCT to assist CE adoption in the coffee supply chain. Critical successful factors contain sharing benefits, relationship establishment between customers and producers, and financial sustainability.	[119]
Textiles and clothing industry	Literature review	A combination of BCT and IoT could be an ideal tool to realise CE in the textiles and clothing industry. It helps monitor water waste, CO_2 emission and parts with considerable waste.	[120]
	Semi-structured interviews	BCT could enhance information sharing in the circular textile supply chain. Textile recyclers are encouraged to use BCT at their stage to narrow the information gap.	[121]
	Modelling	Combined BCT and Bigdata, and proposed a Bigchaindb-Textile supply chain framework and its performance was tested good. This model can appraise and select appropriate suppliers to reduce the costs of product quality inspections and re-ordering the same products.	[122]
Tea industry	Experts survey Questionnaires	Studied the Indian tea industry and proposed an RFID and BCT-enabled circular supply chain framework for B2B tea companies. This framework aims to tackle sustainable issues, improve tea supply chain performance and sell/resell, recycle or reuse the tea leaves according to their situations and quality.	[123]
Pharmaceutical industry	Fuzzy full consistency and fuzzy quality function deployment	Suggested solutions to overcome lack of finance, market challenges and lack of coordination among supply chain when developing CSCM. Proposed a BCT-enabled CSC to digitalise the drug supply chain to take advantage of medications and against counterfeit drugs.	[124]
Built Environment	Life cycle assessment, life cycle costing and building information management	Demonstrated using BCT to efficiently monitor materials and resources at each stage in the built environment industry and facilitate CSC.	[125]
	Literature review and case study	Suggested that BCT is the driver of CE adoption in the built environment sector. Proved that decentralisation of BCT could adapt to diverse stakeholders and loose organisations in this industry.	[126]
Fast fashion industry	Modelling	Proposed a BCT-based circular supply chain framework for the fast fashion industry to realise the zero-waste goal and improve supply chain performance.	[127]

3. Research Methodology

3.1 Research Design

This study uses hybrid qualitative research methods of systematic literature review and case study, relying on online research. A systematic literature review could develop a theoretical foundation for this research. Meanwhile, a case study could form an in-depth and versatile conception and conclusion of the issues from a practical perspective. There are several reasons to use qualitative research methods instead of quantitative research methods in this research. The primary reason is that there is little practical data for this research. 'BCT as an enabler of CFSCs' is a novel research topic, and its practice has not existed, it would be tough to reach relevant data of any organisation. In this case, quantitative is unsuitable for this research as it requires factual data support [128]. Besides, this study focuses on explaining how to use BCT to build CFSCs, data in such descriptive and explanatory research is not amenable to be counted or measured. In contrast, qualitative research methods utilise cognition and perception to explore problems [129]. This is more beneficial for generating new findings and opinions. Meanwhile, qualitative research methods are more flexible as problems can be adjusted quickly according to the quality and character of collected information. For all the reasons above, qualitative research methods are more appropriate for this research.

3.2 Research Method

A systematic literature review and case study research methods are selected to compose the hybrid approaches for this study. The systematic literature review method is usually used to tackle specific research questions while other literature review methods are for narrow or broad questions [130]. This study concentrates on utilising BCT to build CSCs for the food industry, which will be divided into several specific research questions. Thus, the systematic literature review is the optimal research method for this research.

In addition, case study method has a few advantages. Firstly, compared with other qualitative research methods, it is easier to determine the scope and object of the case study. It requires researchers to conduct theoretical research before studying the descriptive cases, which have already covered the scope and depth of the case study [131]. Hence, when entering case study stage, there would be clear standards to select suitable cases and conduct adequate analysis. Secondly, there is no geographical limitation for the case study. The data collection approaches for cases are vibrant, researchers could conduct high-quality research even if in the library [132]. Under this circumstance, typical organisations worldwide could be considered for this case study, which enlarges the range of selectable examples. Thirdly, case study could compensate for the shortage of current theories. A case study encompasses realistic situations and deeper relevant data [133]. It could facilitate new theories and strengthen previous research results. Also, readers can better understand the complex theoretical concept as the cases are closer to real life. Therefore, this combination could make the research results more comprehensive and credible.

A systematic literature review includes five steps [134]:

Framing questions

Identifying relevant

Assessing the quality of studies

Summarising the evidence

Interpreting the findings

The processes of this systematic literature review take the above steps as the reference and some modifications are made according to this research's needs. First of all, three research questions are identified as followings:

The feasibility of BCT facilitating CFSC development

How does BCT assist in developing CFSCs

Barriers of developing CFSCs

Next, the keyword of searching is initially determined as 'blockchain circular food supply chain'. However, the results show that no articles study using BCT to develop CFSC. Hence, the research range is enlarged to two parts: 'blockchain' and 'circular food supply chain'. Numerous studies discuss BCT, but this research focuses on its support to CSC in the food industry, so the different keyword is modified as 'blockchain for supply chain', 'blockchain for circular supply chain' and 'blockchain for food supply chain'. On the other hand, articles about CFSC are limited, for a better understanding of this concept and its principles, research on it is divided into three topics: 'circular economy', 'circular supply chain' and 'circular food supply chain'.

Afterwards, the quality appraisal of search results is conducted to select the most relevant literature. Filtering out the studies for their inferior research approaches could negatively influence the generality of research [135]. Therefore, the assessment of research methods is not included in the selection criteria. Besides, citation counts can be seen as a strong indicator of study quality [136], so studies that are cited massively are selected preferentially. Moreover, assessing the quality of studies should also depend on the specific situations of the research [137]. As an emerging topic, many studies on BCT-based CSC were just published these two years, with low citation counts. But these studies are also considered as meaningful as they have generated innovative findings, so they are selected in this research as well. Particularly, nine journal articles that focus on BCT application in CSC for specific sectors are added, most of which were published this year. Finally, over a hundred articles and books are selected for this research. The detailed processes of the systematic literature review are shown in Figure 1.

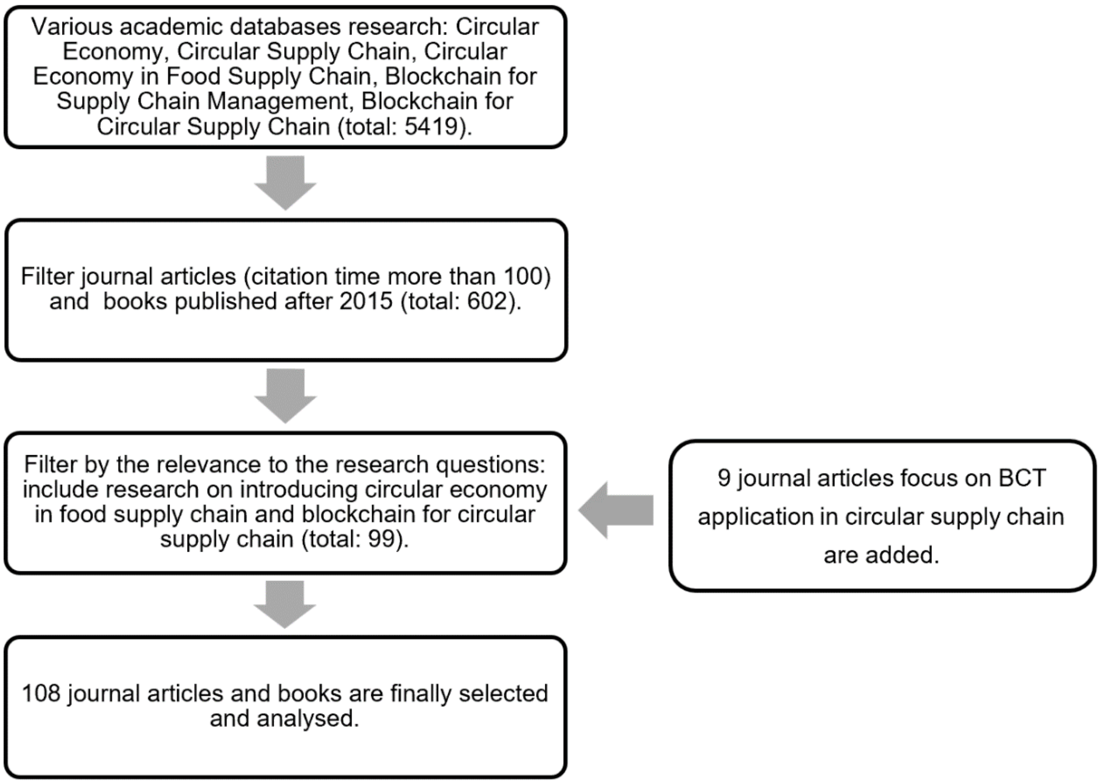

Figure 1. Processes of systematic literature review

For a case study, the main steps are case selection, case analysis and findings (see Figure 2). At first, it intends to accurately search companies that use BCT to develop CFSCs, but there is no company in the results. Thus, the search range is expanded to companies using BCT or adopting CE in their FSC. Afterwards, the most typical cases are selected for further analysis. Based on the results of these two research approaches, suggestions for food companies to develop BCT-based CFSCs will be proposed.

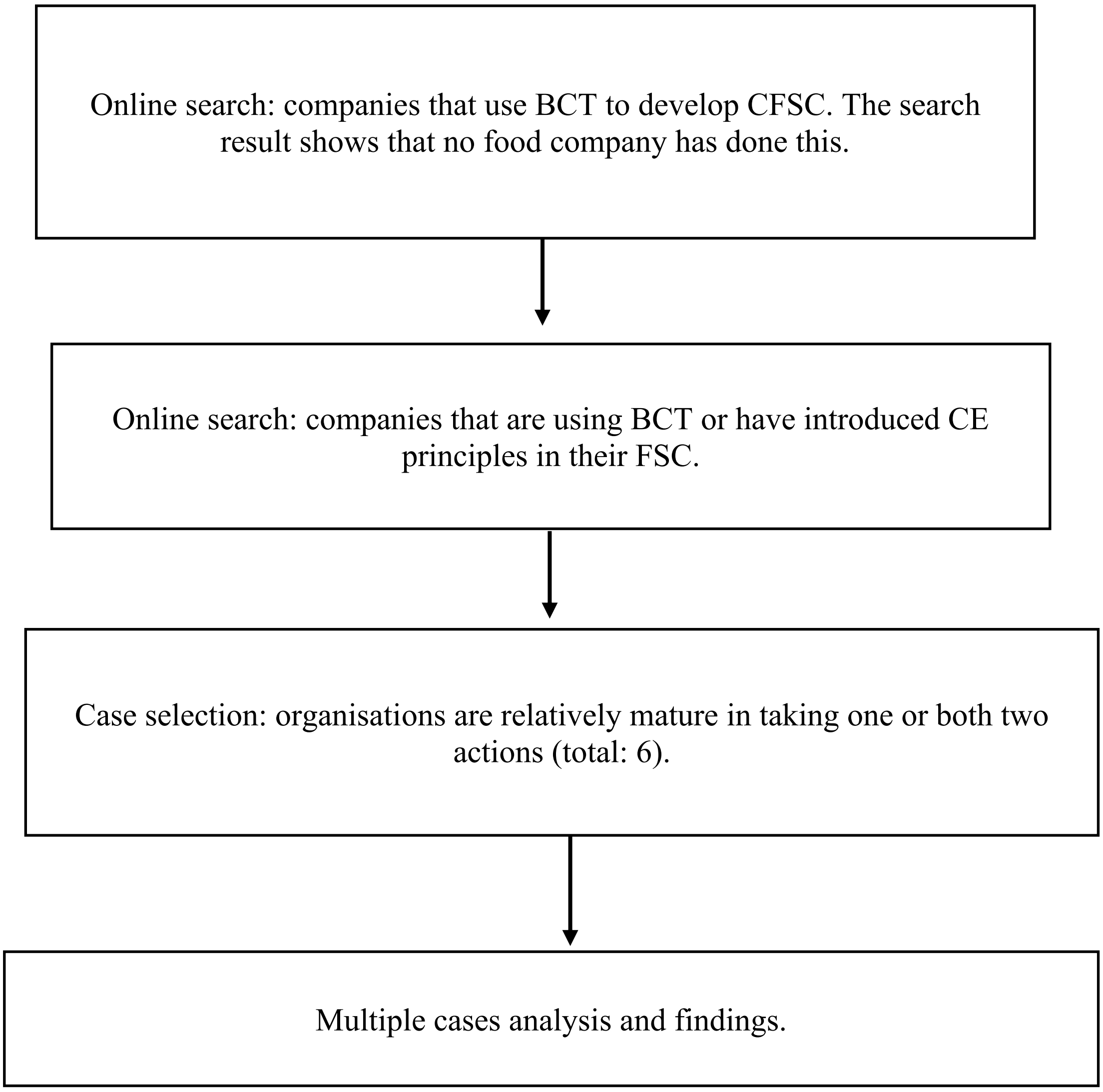

Figure 2. Steps of case study

3.3 Data Type and Sources

This research is based on secondary data, mainly from published documents. The use of secondary data has various advantages. First, compared with data collection methods of primary data (i.e., interviews, field visits, surveys etc.), secondary data is easier to access and time-saving to collect because it could be gathered from previous research. Also, the cost of collecting secondary data is much lower than collecting data from scratch. There is no cost for collecting secondary data through Internet (visit documents via sponsoring organisations such as universities) [138]. Hence, researchers could spend the most time analysing data instead of preparing data. Second, the range of applicable data is broader in secondary data collection. Secondary data includes diverse information about organisations that locate in different places [139]. Meanwhile, tremendous secondary data is available as copious information could be stored in digital databases [139]. Sufficient data could be an important support to the research. Third, secondary data is usually of a high professional level. For instance, much federal data is consolidated by the staff or experts with substantial working experience for many years or studying experience in particular fields. In contrast, it is hard for individuals and minor research projects to gather such data. Therefore, using secondary data could enhance the professionalism and credibility of this research.

For a systematic literature review, it is essential to choose credible and authoritative academic research databases to ensure the quality of the journal articles and books. Besides, various sources should be used to retrieve the studies to improve the comprehensiveness of research results [140].

Thus, Scopus, Emerald Insight, IEEE Xplore, Taylor and Francis Online, and MDPI are selected as the sources. These academic databases include numerous journal articles, conference papers, books, reports etc. This research uses journal articles and books related to CSC, CFSC, BCT and their application in SCM and CSCM. In terms of case study, the resources are published documents online, mainly including company reports, companies' official websites, reliable news releases and web pages, etc.

3.3.1 Journal Article List

After selecting the most relevant articles and deleting repetitive ones, the journal articles used in this research are listed in Table 4.

Table 4. Journal Articles List

Number	Authors	Year	Article
1	Abbas, K., Afaq, M., Khan, T.A. and Wang-Cheol, S.	2020	A Blockchain and Machine Learning-Based Drug Supply Chain Management and Recommendation System for Smart Pharmaceutical Industry, doi: 10.3390/electronics9050852.
2	Ada, N., Kazancoglu, Y., Sezer, M.D., Ede-Senturk, C., Ozer, I. and Ram, M.	2021	Analyzing Barriers of Circular Food Supply Chains and Proposing Industry 4.0 Solutions, doi: 10.3390/su13126812.
3	Adamashvili, N., State, R., Tricase, C. and Fiore, M.	2021	Blockchain-Based Wine Supply Chain for the Industry Advancement, doi: 10.3390/su132313070.
4	Ahmadi, V., Benjelloun, S., El Kik, M., Sharma, T., Chi, H. and Zhou, W.	2020	2020. Drug Governance: IoT-based Blockchain Implementation in the Pharmaceutical Supply Chain doi: 10.1109/MobiSecServ48690.2020.9042950.
5	Ahmadi, V., Benjelloun, S., El Kik, M., Sharma, T., Chi, H. and Zhou, W.	2021	A Comparative Study: Blockchain Technology Utilization Benefits, Challenges and Functionalities. doi: 10.1109/ACCESS.2021.3050241.
6	Alves, L., Ferreira Cruz, E., Lopes, S.I., Faria, P.M. and Rosado da Cruz, A.M.	2022	Towards circular economy in the textiles and clothing value chain through blockchain technology and IoT: A review, doi: 10.1177/0734242X211052858.
7	Anastasiadis, F., Manikas, I., Apostolidou, I. and Wahbeh, S.	2022	The role of traceability in end-to-end circular agri-food supply chains, doi: 10.1016/j.indmarman.2022.04.021.
8	Andoni, M. et al.	2019	Blockchain technology in the energy sector: A systematic review of challenges and opportunities doi: 10.1016/j.rser.2018.10.014.
9	Annosi, M.C., Brunetta, F., Bimbo, F. and Kostoula, M.	2021	Digitalization within food supply chains to prevent food waste. Drivers, barriers and collaboration practice doi: 10.1016/j.indmarman.2021.01.005.
10	Arunraj, N., Ahrens, D., Fernandes, M. and Müller, M.	2014	Time series sales forecasting to reduce food waste in retail industry, doi: 10.13140/RG.2.1.4829.1607.
11	Arunraj, N.S. and Ahrens, D.	2015	A hybrid seasonal autoregressive integrated moving average and quantile regression for daily food sales forecasting, doi: 10.1016/j.ijpe.2015.09.039.
12	Azzi, R., Chamoun, R.K. and Sokhn, M.	2019	The power of a blockchain-based supply chai doi: 10.1016/j.cie.2019.06.042.
13	Baratsas, S.G., Pistikopoulos, E.N. and Avraamidou, S.	2021	A systems engineering framework for the optimization of food supply chains under circular economy considerations, doi: 10.1016/j.scitotenv.2021.148726.
14	Baygin, N., Baygin, M. and Karakose, M.	2019	Blockchain Technology: Applications, Benefits and Challenges, doi: 10.1109/UBMYK48245.2019.8965565.

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Number	Authors	Year	Article
15	Beck, R., Avital, M., Rossi, M. and Thatcher, J.B.	2017	Blockchain Technology in Business and Information Systems Research. Business & Information Systems Engineering 59(6), pp. 381–384. doi: 10.1007/s12599-017-0505-1.
16	Casino, F., Kanakaris, V., Dasaklis, T.K., Moschuris, S., Stachtiaris, S., Pagoni, M. and Rachaniotis, N.P.	2021	Blockchain-based food supply chain traceability: a case study in the dairy sector, doi: 10.1080/00207543.2020.1789238.
17	Centobelli, P., Cerchione, R., Vecchio, P.D., Oropallo, E. and Secundo, G.	2021	Blockchain technology for bridging trust, traceability and transparency in circular supply chain, doi: 10.1016/j.im.2021.103508.
18	Chen, S., Liu, X., Yan, J., Hu, G. and Shi, Y.	2021	Processes, benefits, and challenges for adoption of blockchain technologies in food supply chains: a thematic analysis, doi: 10.1007/s10257-020-00467-3.
19	Chen, Y. and Bellavitis, C.	2020	Blockchain disruption and decentralized finance: The rise of decentralized business model, doi: 10.1016/j.jbvi.2019.e00151.
20	Chen, Y. and Chen, F.	2019	On the Competition between Two Modes of Product Recovery: Remanufacturing and Refurbishing, doi: 10.1111/poms.13082.
21	Cicatiello, C., Franco, S., Pancino, B., Blasi, E. and Falasconi, L.	2017	The dark side of retail food waste: Evidences from in-store dat, doi: 10.1016/j.resconrec.2017.06.010.
22	Ciccullo, F., Cagliano, R., Bartezzaghi, G. and Perego, A.	2021	Implementing the circular economy paradigm in the agri-food supply chain: The role of food waste prevention technologies, doi: 10.1016/j.resconrec.2020.105114.
23	De Angelis, R., Howard, M. and Miemczyk, J.	2018	Supply chain management and the circular economy: towards the circular supply chain, doi: 10.1080/09537287.2018.1449244.
24	de Moraes, C.C., de Oliveira Costa, F.H., Roberta Pereira, C., da Silva, A.L. and Delai, I.	2020	Retail food waste: mapping causes and reduction practice, doi: 10.1016/j.jclepro.2020.120124.
25	Del Giudice, M., Chierici, R., Mazzucchelli, A. and Fiano, F.	2020	Supply chain management in the era of circular economy: the moderating effect of big data, doi: 10.1108/IJLM-03-2020-0119.
26	Di Vaio, A. and Varriale, L.	2020	Blockchain technology in supply chain management for sustainable performance: Evidence from the airport industry, doi: 10.1016/j.ijinfomgt.2019.09.010.
27	Dora, M.	2019	Collaboration in a circular economy: learning from the farmers to reduce food waste, doi: 10.1108/JEIM-02-2019-0062.
28	Dossa, A.A., Gough, A., Batista, L. and Mortimer, K.	2022	Diffusion of circular economy practices in the UK wheat food supply chain, doi: 10.1080/13675567.2020.1837759.
29	Dutta, P., Choi, T.-M., Somani, S. and Butala, R.	2020	Blockchain technology in supply chain operations: Applications, challenges and research opportunities, doi: 10.1016/j.tre.2020.102067.
30	Eriksson, M., Ghosh, R., Mattsson, L. and Ismatov, A.	2017	Take-back agreements in the perspective of food waste generation at the supplier-retailer interface, doi: 10.1016/j.resconrec.2017.02.006.

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Number	Authors	Year	Article
31	Etemadi, N., Borbon-Galvez, Y., Strozzi, F. and Etemadi, T.	2021	Supply Chain Disruption Risk Management with Blockchain: A Dynamic Literature Revie, doi: 10.3390/info12020070.
32	Fanning, K. and Centers, D.P.	2016	Blockchain and Its Coming Impact on Financial Services, doi: 10.1002/jcaf.22179.
33	Farooque, M., Zhang, A., Thürer, M., Qu, T. and Huisingh, D.	2019	Circular supply chain management: A definition and structured literature review, doi: 10.1016/j.jclepro.2019.04.303.
34	Gedam, V.V., Raut, R.D., Lopes de Sousa Jabbour, A.B., Tanksale, A.N. and Narkhede, B.E.	2021	Circular economy practices in a developing economy: Barriers to be defeated, doi: 10.1016/j.jclepro.2021.127670.
35	Geissdoerfer, M., Savaget, P., Bocken, N.M.P. and Hultink, E.J.	2017	The Circular Economy – A new sustainability paradigm? doi: 10.1016/j.jclepro.2016.12.048.
36	Genovese, A., Acquaye, A.A., Figueroa, A. and Koh, S.C.L.	2017	Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications, doi: 10.1016/j.omega.2015.05.015.
37	Golosova, J. and Romanovs, A.	2018	The Advantages and Disadvantages of the Blockchain Technology, doi: 10.1109/AIEEE.2018.8592253.
38	Govindan, K. and Hasanagic, M.	2018	A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective, doi: 10.1080/00207543.2017.1402141.
39	Gružauskas, V., Gimžauskienė, E. and Navickas, V.	2019	Forecasting accuracy influence on logistics clusters activities: The case of the food industry doi: 10.1016/j.jclepro.2019.118225.
40	Hader, M., Tchoffa, D., Mhamedi, A.E., Ghodous, P., Dolgui, A. and Abouabdellah, A.	2022	Applying integrated Blockchain and Big Data technologies to improve supply chain traceability and information sharing in the textile sector, doi: 10.1016/j.jii.2022.100345.
41	Haji, M., Kerbache, L., Muhammad, M. and Al-Ansari, T.	2020	Roles of Technology in Improving Perishable Food Supply Chains, doi: 10.3390/logistics4040033.
42	Hastig, G.M. and Sodhi, M.S.	2020	Blockchain for Supply Chain Traceability: Business Requirements and Critical Success Factors doi: 10.1111/poms.13147.
43	Hsiao, Y.-H., Chen, M.-C. and Chin, C.-L.	2017	Distribution planning for perishable foods in cold chains with quality concerns: Formulation and solution procedure, doi: 10.1016/j.tifs.2016.11.016.
44	Huang, L., Zhen, L., Wang, J. and Zhang, X.	2022	Blockchain implementation for circular supply chain management: Evaluating critical success factors doi: 10.1016/j.indmarman.2022.02.009.
45	Jamil, F., Hang, L., Kim, K. and Kim, D.	2019	A Novel Medical Blockchain Model for Drug Supply Chain Integrity Management in a Smart Hospital doi: 10.3390/electronics8050505.
46	Kamilaris, A., Fonts, A. and Prenafeta-Boldǘ, F.X.	2019	The rise of blockchain technology in agriculture and food supply chains, doi: 10.1016/j.tifs.2019.07.034.
47	Kazancoglu, Y., Kazancoglu, I. and Sagnak, M.	2018	A new holistic conceptual framework for green supply chain management performance assessment based on circular economy, doi: 10.1016/j.jclepro.2018.06.015.

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Number	Authors	Year	Article
48	Khacef, K. and Pujolle, G.	2019	Secure Peer-to-Peer Communication Based on Blockchain. doi: 10.1007/978-3-030-15035-8_64.
49	Khan, F. and Ali, Y.	2022	Implementation of the circular supply chain management in the pharmaceutical industry, doi: 10.1007/s10668-021-02007-6
50	Kirchherr, J., Reike, D. and Hekkert, M.	2017	Conceptualizing the circular economy: An analysis of 114 definitions, doi: 10.1016/j.resconrec.2017.09.005.
51	Kouhizadeh, M. and Sarkis, J.	2018	Blockchain Practices, Potentials, and Perspectives in Greening Supply Chains, doi: 10.3390/su10103652.
52	Kshetri, N.	2019	Blockchain and the Economics of Food Safety, doi: 10.1109/MITP.2019.2906761.
53	Kumar Mangla, S., Börühan, G., Ersoy, P., Kazancoglu, Y. and Song, M.	2021	Impact of information hiding on circular food supply chains in business-to-business context, doi: 10.1016/j.jbusres.2021.06.013.
54	Kumar, R. and Tripathi, R.	2019	Traceability of counterfeit medicine supply chain through Blockchain, doi: 10.1109/COMSNETS.2019.8711418.
55	Kuo, L. and Chang, B.-G.	2021	The affecting factors of circular economy information and its impact on corporate economic sustainability-Evidence from China, doi: 10.1016/j.spc.2021.02.014.
56	Kurpjuweit, S., Schmidt, C.G., Klöckner, M. and Wagner, S.M.	2021	Blockchain in Additive Manufacturing and its Impact on Supply Chains, doi: 10.1111/jbl.12231.
57	Kusumowardani, N., Tjahjono, B., Lazell, J., Bek, D., Theodorakopoulos, N., Andrikopoulos, P. and Priadi, C.R.	2022	A circular capability framework to address food waste and losses in the agri-food supply chain: The antecedents, principles and outcomes of circular economy, doi: 10.1016/j.jbusres.2021.12.020.
58	Lahane, S., Kant, R. and Shankar, R.	2020	Circular supply chain management: A state-of-art review and future opportunities, doi: 10.1016/j.jclepro.2020.120859.
59	Lavelli, V.	2021	Circular food supply chains – Impact on value addition and safety, doi: 10.1016/j.tifs.2021.06.008.
60	Li, Q. and Wang, Y.	2021	Blockchain’s role in supporting circular supply chains in the built environment, doi: 10.1109/Blockchain53845.2021.00087.
61	Liu, L., Li, F. and Qi, E.	2019	Research on Risk Avoidance and Coordination of Supply Chain Subject Based on Blockchain Technology, doi: 10.3390/su11072182.
62	McDougall, N., Wagner, B. and MacBryde, J.	2022	Competitive benefits & incentivisation at internal, supply chain & societal level circular operations in UK agri-food SMEs, doi: 10.1016/j.jbusres.2022.02.060.
63	Mehmood, A., Ahmed, S., Viza, E., Bogush, A. and Ayyub, R.M.	2021	Drivers and barriers towards circular economy in agri-food supply chain: A review, doi: 10.1002/bsd2.171.
64	Meidute-Kavaliauskiene, I., Yıldız, B., Çiğdem, Ş. and Činčikaitė, R.	2021	An Integrated Impact of Blockchain on Supply Chain Applications, doi: 10.3390/logistics5020033.
65	Min, H.	2019	Blockchain technology for enhancing supply chain resilience, doi: 10.1016/j.bushor.2018.08.012.

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Number	Authors	Year	Article
66	Mohanta, B.K., Panda, S.S. and Jena, D.	2018	An Overview of Smart Contract and Use Cases in Blockchain Technology, doi: 10.1109/ICCCNT.2018.8494045.
67	Mondragon, A.E.C., Coronado, C.E. and Coronado, E.S.	2019	Investigating the Applicability of Distributed Ledger/Blockchain Technology in Manufacturing and Perishable Goods Supply Chains, doi: 10.1109/IEA.2019.8715005.
68	Moosavi, J., Naeni, L.M., Fathollahi-Fard, A.M. and Fiore, U.	2021	Blockchain in supply chain management: a review, bibliometric, and network analysis, Doi: 10.1007/s11356-021-13094-3
69	Nasir, M.H.A., Genovese, A., Acquaye, A.A., Koh, S.C.L. and Yamoah, F.	2017	Comparing linear and circular supply chains: A case study from the construction industry, doi: 10.1016/j.ijpe.2016.06.008.
70	Niranjanamurthy, M., Nithya, B.N. and Jagannatha, S.	2019	Analysis of Blockchain technology: pros, cons and SWOT, doi: 10.1007/s10586-018-2387-5.
71	Ozkan-Ozen, Y.D., Kazancoglu, Y. and Kumar Mangla, S.	2020	Synchronized barriers for circular supply chains in industry 3.5/industry 4.0 transition for sustainable resource managemen, doi: 10.1016/j.resconrec.2020.104986.
72	Panahifar, F., Byrne, P.J., Salam, M.A. and Heavey, C.	2018	Supply chain collaboration and firm’s performance: The critical role of information sharing and trust, doi: 10.1108/JEIM-08-2017-0114.
73	Parfitt, J., Barthel, M. and Macnaughton, S.	2010	Food waste within food supply chains: quantification and potential for change to 2050, doi: 10.1098/rstb.2010.0126.
74	Park, A. and Li, H.	2021	The Effect of Blockchain Technology on Supply Chain Sustainability Performances, doi: 10.3390/su13041726.
75	Paul, T., Islam, N., Mondal, S. and Rakshit, S.	2022	RFID-integrated blockchain-driven circular supply chain management: A system architecture for B2B tea industry, doi: 10.1016/j.indmarman.2021.12.003.
76	Priefer, C., Jörissen, J. and Bräutigam, K.-R.	2016	Food waste prevention in Europe – A cause-driven approach to identify the most relevant leverage points for action, doi: 10.1016/j.resconrec.2016.03.004.
77	Priyadarshi, R., Panigrahi, A., Routroy, S. and Garg, G.K.	2019	Demand forecasting at retail stage for selected vegetables: a performance analysis, doi: 10.1108/JM2-11-2018-0192.
78	Rincón-Moreno, J., Ormazábal, M., Álvarez, M.J. and Jaca, C.	2021	Advancing circular economy performance indicators and their application in Spanish companies, doi: 10.1016/j.jclepro.2020.123605.
79	Saad, M., Spaulding, J., Njilla, L., Kamhoua, C., Shetty, S., Nyang, D. and Mohaisen, D.	2020	Exploring the Attack Surface of Blockchain: A Comprehensive Survey, doi: 10.1109/COMST.2020.2975999.
80	Saberi, S., Kouhizadeh, M., Sarkis, J. and Shen, L.	2019	Blockchain technology and its relationships to sustainable supply chain management, doi: 10.1080/00207543.2018.1533261.
81	Salah, K., Nizamuddin, N., Jayaraman, R. and Omar, M. 2019.	2019	Blockchain-Based Soybean Traceability in Agricultural Supply Chain, doi: 10.1109/ACCESS.2019.2918000.
82	Schmidt, C.G. and Wagner, S.M.	2019	Blockchain and supply chain relations: A transaction cost theory perspective, doi: 10.1016/j.pursup.2019.100552.

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83	Sharma, Y.K., Mangla, S.K., Patil, P.P. and Liu, S.	2019	When challenges impede the process: For circular economy-driven sustainability practices in food supply chain, doi: 10.1108/MD-09-2018-1056.
84	Sheel, A. and Nath, V.	2019	Effect of blockchain technology adoption on supply chain adaptability, agility, alignment and performance, doi: 10.1108/MRR-12-2018-0490.
85	Shi, N., Tan, L., Li, W., Qi, X. and Yu, K.	2021	A blockchain-empowered AAA scheme in the large-scale HetNet, doi: 10.1016/j.dcan.2020.10.002.
86	Shojaei, A., Ketabi, R., Razkenari, M., Hakim, H. and Wang, J.	2021	Enabling a circular economy in the built environment sector through blockchain technology, doi: 10.1016/j.jclepro.2021.126352.
87	Singh, S. and Singh, N.	2016	Blockchain: Future of financial and cyber security, doi: 10.1109/IC3I.2016.7918009.
88	Sridhar, A., Kapoor, A., Senthil Kumar, P., Ponnuchamy, M., Balasubramanian, S. and Prabhakar, S.	2021	Conversion of food waste to energy: A focus on sustainability and life cycle assessment, doi: 10.1016/j.fuel.2021.121069.
89	Sunny, J., Undralla, N. and Madhusudanan Pillai, V.	2020	Supply chain transparency through blockchain-based traceability: An overview with demonstration, doi: 10.1016/j.cie.2020.106895.
90	Trollman, H., Garcia-Garcia, G., Jagtap, S. and Trollman, F.	2022	Blockchain for Ecologically Embedded Coffee Supply Chains, doi: 10.3390/logistics6030043.
91	Tseng, J.-H., Liao, Y.-C., Chong, B. and Liao, S.	2018	Governance on the Drug Supply Chain via Gcoin Blockchain, doi: 10.3390/ijerph15061055.
92	Vilariño, M.V., Franco, C. and Quarrington, C.	2017	Food loss and Waste Reduction as an Integral Part of a Circular Economy, doi: 10.3389/fenvs.2017.00021
93	Wang, B., Luo, W., Zhang, A., Tian, Z. and Li, Z.	2020	Blockchain-enabled circular supply chain management: A system architecture for fast fashion, doi: 10.1016/j.compind.2020.103324.
94	Winkler, H.	2011	Closed-loop production systems—A sustainable supply chain approach, doi: 10.1016/j.cirpj.2011.05.001.
95	Xia, C., Li, X., Wang, Z. and Perc, M.	2018	Doubly effects of information sharing on interdependent network reciprocity, doi: 10.1088/1367-2630/aad140.
96	Xu, P., Lee, J., Barth, J.R. and Richey, R.G.	2021	Blockchain as supply chain technology: considering transparency and security, doi: 10.1108/IJPDLM-08-2019-0234.
97	Yadav, J., Misra, M. and Goundar, S.	2020	An overview of food supply chain virtualisation and granular traceability using blockchain technology, doi: 10.1504/IJBC.2020.108997.
98	Zelbst, P.J., Green, K.W., Sower, V.E. and Bond, P.L.	2019	The impact of RFID, IIoT, and Blockchain technologies on supply chain transparency, doi: 10.1108/JMTM-03-2019-0118.
99	Zhang, X., Sun, P., Xu, J., Wang, X., Yu, J., Zhao, Z. and Dong, Y.	2020	Blockchain-Based Safety Management System for the Grain Supply Chain, doi: 10.1109/ACCESS.2020.2975415.
100	Zheng, Z., Xie, S., Dai, H., Chen, X. and Wang, H.	2017	An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends, doi: 10.1109/BigDataCongress.2017.85.
101	Zhu, Q., Geng, Y. and Lai, K.	2010	Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications, doi: 10.1016/j.jenvman.2010.02.013.

3.3.2 Book List

Except journal articles, several books are used in this research (see Table 5).

Table 5. Book List

Number	Author	Year	Book
1	Blakeney, M.	2019	Food Loss and Food Waste: Causes and Solutions. Edward Elgar Publishing
2	Crosby, M.	2016	BlockChain Technology: Beyond Bitcoin
3	Dorf, V., Jonsson, A. and Dalal, A.	2022	Exploration of blockchain technology in the Swedish textile recycling industry: Opportunities and challenges for traceabilit
4	Korpela, K., Hallikas, J. and Dahlberg, T.	2017	Digital Supply Chain Transformation toward Blockchain Integration
5	Pažek, K.	2021	Lean Manufacturing. BoD – Books on Demand.
6	Rennock, M.J.W., Cohn, A. and Butcher, J.R.	2018	BLOCKCHAIN TECHNOLOGY
7	Swan, M.	2015	Blockchain: Blueprint for a New Economy. O'Reilly Media, Inc.

3.4 Case Selection

Data collection in case studies must aim to define research questions [131], so organisations that use BCT to develop CFSCs would be the best cases. Nonetheless, most organisations are still in a transition stage since the food industry is traditional. Although new technologies and concepts have been introduced to FSC these years, no company has established BCT-based CFSC so far. However, some giant corporates such as Walmart, Nestlé and Dole have led the food industry by successfully using BCT and integrating CE into FSC. These companies are selected for this research. Moreover, two Aquaculture corporates that only focus on developing sustainable supply chains are also selected as this is one key aspect of CE principles. These cases are classified into the following categories (see Table 6).

Table 6. Selected cases

Action	Company/Group	Main business
Separate BCT and CE adoption in the supply chain	Walmart	Fresh food (e.g., fresh meat, fruits, etc.)
	Nestlé	Food (e.g., cereal, chocolate, etc.) and beverage (e.g., coffee, dairy, etc.)
	Dole	Fresh vegetables and fruits
BCT adoption and sustainable supply chain development	Sustainable Shrimp Partnership (SSP)	Shrimp supplier
	Cermaq	Salmon supplier, cooperating with Labeyrie (a leading French company that supplies smoked salmon)

3.5 Research Limitations

Although this research uses available data as much as possible, there are still some limitations. The most significant defect is the shortage of primary data collection such as interviews, questionnaire surveys, queries, observations, etc., which could lead to the research results be lack of internal perspective. Hence, the suggestions on developing CFSCs with BCT might be for general FSCs and cannot target a specific type. In addition, different from primary data, secondary data cannot include the latest information through interviews or surveys, so its timeliness could be inferior. Meanwhile, secondary data might not be utterly matchable with this research's needs. Primary data is always accurate for specific research questions while secondary data may not [141]. Another research limitation is that there is usually a limited number of cases for a case study, so the data might include some deviations. In addition, most data is collected from public documents on the Internet, which could also bring some deviations. For instance, some documents and archival records could contain reporting bias of the author [132].

4. Case Study

This section contains three main parts: case analysis of category A, case analysis of category B and key findings and comparisons. There are six cases, which are divided into two categories according to their current action:

Category A: BCT application and CFSC adoption

Category B: BCT application and sustainable supply chain development

For category A, the companies included are the giant food companies or retailers currently using BCT in their FSCs. Meanwhile, they are in the leading position of moving toward CFSCs in the food industry, aiming to reduce food waste within FSCs while building environmentally sustainable FSCs. Although they have not ledged BCT to support CE adoption in the FSCs, their practice still has reference meaning for BCT-based CFSC development. In contrast, the companies selected for category B are smaller food suppliers who adopt BCT in their supply chains. However, they are presently only pursuing sustainable FSCs and have not planned for food waste reduction so far. Still, their practice could inspire SMEs in the food industry how to improve their FSCs by BCT and environmental sustainability. After the analysis of these cases, the key findings of each case will be compared.

4.1 Category A: BCT Application and CFSC Adoption

4.1.1 Walmart Case Analysis

Walmart was a small discount retailer in Rogers and has been developed into a giant international chain store today, headquartered in the US. Nowadays, it operates around 10,500 stores globally and online stores [142].

(1) BCT application

Walmart has always pressed forward with enterprise digitalisation and can be seen as a pioneer in using BCT in the food industry. In 2016, Walmart cooperated with Tsinghua University and IBM, they leveraged BCT to build a food traceability system, then piloted in China to trace pork and in the US to trace mango [143]. These are known as the two proof of concept (POC) projects. After examination, Walmart claimed that this system could shorten the tracing time of mangoes in the US to 2.2 seconds from 7 days. With the success of the POC projects, more and more suppliers are invited by Walmart to join the platform to provide customers with transparent and authentic food information. Moreover, Walmart allied with IBM and many other giant food retailers to launch IBM Food Trust (a BCT service powered by Hyperledger Fabric) [144]. Till 2018, there were more than 25 products could be traced during this platform.

Except for IBM Food Trust, Walmart China cooperated with PwC and VeChain in 2019 to build a food traceability platform, relying on VeChain's Thor BCT. Suppliers, production centres and Walmart food distribution centres (FDC) upload food information to this platform and customer can access it via their own devices. The operational processes of this Vechain Blockchain-based platform are shown in Figure 3. At the end of 2020, customers could query information on over 100 food products (containing private brands of products from Sam, a membership-only warehouse club chain operated by Walmart) via this platform, including production and process, transport, warehousing, retail, etc. [145]. For instance, if a packet of rice is traceable on the platform, a QR code would be stuck to its outside package. Customers can scan the QR to view its batch number, raw material received time, inspection report of raw materials, production duration, inspection report of products leaving factories, annual external inspection report, delivery time and receiving time [146]. For fresh food like beef, customers could even trace the receive time and place of the cattle, slaughter time, and receive time of raw meat. Each food product on the platform has a specific blockchain-proof ID, which ensures the uniqueness and immutability of the food information. Still, Walmart has endeavoured to add more product lines on this platform to cover more food categories.

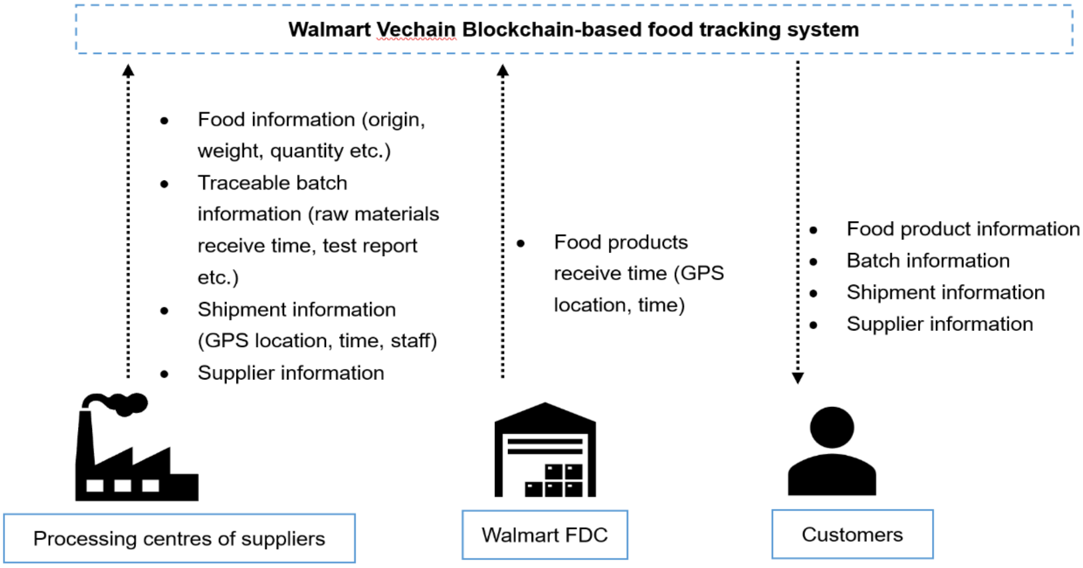

Figure 3. Schematics of Walmart Vechain Blockchain-based food tracking system [145]

(2) Solutions to food waste

To realise zero waste in its global FSCs, Walmart heavily focuses on two aspects: minimising food waste by cooperation, and reducing unsold food [147].

To minimise food waste in its operation, Walmart joined Champions 12.3 "10x20x30" initiative in 2019. Through this initiative, the ten largest food retailers worldwide promised to cooperate with twenty Walmart's suppliers in priority. It is predicted that FLW will be reduced 50% by 2030 through this plan. Two years later, Walmart joined the Pacific Coast Food Waste Commitment, which gathers leading enterprises in the US and Canada to collaborate to reach the common goal of halving food waste on the Pacific coast by 2030. Participators in the commitment can cooperate with local jurisdictions, preventing and recycling organic waste.

In addition, Walmart also takes some actions to deal with unsold food, which can be summarised in Table 7. On the other hand, Walmart cooperates with organisations in their FSCs to reduce food waste in the value chain. Apart from assisting upstream and downstream (i.e., farm, producers, retailers and customers) of FSCs in recycling food, Walmart also facilitate cooperation between food suppliers and food redistribution organisations. For example, these organisations could help to efficiently distribute reprocessed food produced by food suppliers [147].

Table 7. Walmart's solutions to unsold food [147]

Purpose/Objective	Actions
Reduce unsold food	Enhance demand forecasting techniques Improve inventory management Improve the efficiency of distribution centres Furnish discount on food nearing its expiration date
Edible unsold food	Donate to food banks, charities and communities Provide Charity Dietary System financial support to strengthen their food recycling and distribution ability
Inedible unsold food	Convert to animal feed and compost Convert to fuel and biogas through anaerobic digestion

(3) Solutions to environmental impact

From another aspect, Walmart also obeys the CE's principle of diminishing environmental impacts from FSCs. First, Walmart cooperates with other organisations through allies or initiatives (see Table 8) to decrease plastic pollution, improve food production's sustainability, and contribute to the transition to zero-carbon energy use. In terms of solutions to the food packaging issue, Walmart not only reduces the unnecessary packaging in their recycling business but also uses recyclable containers to transport agri-food, fruits and eggs. Besides, Walmart has gradually eliminated unrecyclable materials and forwards to reusable and degradable materials. Meanwhile, Walmart signs contracts for recycling plastic materials from their operation and customers' return with the suppliers. In 2021, Walmart recycled over 313 million pounds of rigid plastics and plastic film throughout the world, which is less than that in 2020. This implies that these actions have effectively decreased the quantity of plastic materials in Walmart's global operation.

Second, Walmart proactively engages customers concerned about food's environmental impact. In Walmart's physical stores, specific food products or shelves are tagged with certification labels (e.g., sustainable seafood for Walmart US). Additionally, food products in their online stores have a certification label for target customers to quickly identify. This label represents that food production processes have minimal detrimental effects on the environment and climate. Besides, recycle-friendly food is stuck with a label as well. Walmart set up the objective that 100% private food brands of Walmart US will be tagged with recycle-friendly labels in the future. By 2022, Walmart has achieved 80% of this goal.

Third, Walmart consistently advocates and supports public policies that benefit from reducing environmental impacts from FSCs. For procurement of partial food products (i.e., seafood, agri-food etc.), Walmart formulated a selection criterion for food supplier selection. The suppliers must with high sustainable awareness and meet standards of social sustainability. For instance, crop harvest and production should obey certificated regulations on sustainability. The products and packaging must meet Walmart's sustainable standards, such as 100% recyclable or compostable. Additionally, Walmart also purchases food products from areas that are beneficial for ecosystem protection.

Fourth, Walmart encourages and supports its food suppliers to further sustainable development. For example, Walmart invited suppliers to join Project Gigaton to use renewable energy provided by third parties and report greenhouse gas emissions via an online platform. Through this project, the suppliers reduced or avoided at least 574 million MT of CO_2 by 2022 [148]. In the meantime, Walmart plans to replace all its energy with renewable energy. Take Walmart Mexico for example, the energy sources of 91% of physical stores are five wind farms and two hydroelectric plants. In particular, the water sources of the stores are 756 sewage treatment plants [149]. Moreover, Walmart has developed an energy management system, which allows the operator to monitor and manage the energy consumption of Walmart stores in real-time.

Table 8. Initiative or group Walmart joined for reduction of environmental impact [146]

Initiative/group and Walmart's role	Main activities
A member of the Consumer Goods Forum	Reduce plastic waste and increase plastic recyclability Reduce food waste Protect forests Facilitate expanding producer responsibility to the globe to manage plastic and packaging waste
A co-lead of the Retail Race to Zero campaign along with IKEA, H&M, Kingfisher and Best Buy	Swiftly and fairly reduce emissions.
A member of the Clean Energy Buyers Association (CEBA)	Expand the energy market Flexible financing of renewable energy Federal carbon-zero green power system
A member and co-founder of the Midwest Row Crop Collaborative (MRCC)	Assist farms in developing renewable agricultural practice
A supporter of the Ellen MacArthur Foundation	Accelerate the progress of 100% reusable, recyclable and compostable packaging.
Founder of Beyond the Bag	Cooperate with stakeholders within the supply chain and other retailers to research and develop innovative alternatives to disposable plastics.

4.1.2 Nestlé Case Analysis

Being the biggest food and beverage corporation in the world, Nestlé has more than 2000 brands and its businesses spread over 186 countries and regions. Nestlé utilises the resources and energy to release the power of food to improve the quality of present and future generations while striving on the CE model. Through consistently pursuing zero impact on the environment, Nestlé gained the highest mark of environment indicator in the food industry, which is 100 out of 100 [150]. Besides the superb performance of environmentally friendly products and operations, Nestlé has achieved great progress in BCT adoption in their FSCs. At present, Nestlé has taken versatile actions to transfer to CFSCs.

(1) Zero waste

Firstly, Nestlé dedicates zero waste, ensuring there is no waste from their factories entering landfills. This is divided into several aspects: reduction of FLW from the sources, enhancement of people's awareness, stakeholders and partnerships involvement [151].

Nestlé helps expand the expiration period of food to increase the opportunity to sell out before it spoils. For instance, they furnish farmers in Kenya with a food preservation system to make fresh fruits and vegetables less perishable. Also, Nestlé suggests farmers adopt solar dryers for corn planting to prevent pests and harmful mould. Thus, corn yield would be maximised so that unnecessary corn loss could be drastically decreased.

From another aspect, Nestlé aims to create value from waste. Nestlé France collaborates with a pig farm, amalgamating organic waste from a cocoa processing factory and the pig farm in anaerobic digesters to convert them to wastewater that can be used for irrigation and electricity generation [152]. Additionally, Nestlé plans to make its packaging thoroughly reusable and recyclable by 2030. They cooperate with TerraCycle to design and develop some types of new packaging, including reusable containers of pet products, beverage ice cream and sweets, details are in Table 9. Besides, Nestlé also uses recycle-friendly materials to package foods. For example, Nestlé France uses recyclable paper to package the Maggi broth cubes instead of aluminiferous packaging. In the long term, Nestlé sets up a principle that when using one ton of plastic packaging, one-ton plastic should be recycled [153].

Table 9. Packaging innovation developed by Nestlé and TerraCycle [154]

Packaging innovation	Details
Cat litter container	Cat owners can register and purchase cat litter on Loop (a digital shopping platform for pet products), and it will be delivered to the door. The cat litter would be put in a kettle that can be refilled. After finishing the cat litter, the staff will pick the kettle up at the door and reuse it.
Deposit refund programme	In France, S.PELLEGRINO products can be put in glass bottles for selling, Consumers can get a deposit refund by returning the used glass bottles.
Reusable containers for food and beverage	Nestlé provides reusable containers for Nesquik cocoa powder, Ricoré chicory and coffee drink, Chocapic Bio cereals and Häagen-Dazs ice cream. The used containers will be collected and washed, then refilled and put in a circular system of Loop.
Sweets packaging recycling scheme	The plastic packaging of sweets will be recycled and crumbled for a second use, such as producing plastic bags or rigid plastic products.

Nestlé also aims to improve customers' awareness of reducing FLW. They guide customers on how to stop food waste in daily life, proposing ten ways to reduce food waste: make a schedule before purchasing food, utilise freezers, properly recognise expiration period, appropriate storage place, cook more meals at once, control portions, pay attention to the food you have, make food donations, turn food scraps into compost, track food waste (see Table 10) [155]. Another measure Nestlé executes is encouraging people to reduce waste by supporting their Maggi 'Krumm Glücklich Suppe' products. This series of food is made from vegetables with an unsightly appearance but of good quality. It is because customers are usually reluctant to buy 'ugly' vegetables, and they will end up being discarded [152]. Meanwhile, Nestlé built a digital platform in Italy to instruct customers on how to dispose of the packaging in appropriate approaches and avoid waste. Furthermore, Nestlé works with Tunyan Verde school in Argentina to motivate and educate the public to prevent food waste [153].

Table 10. Ten approaches to reducing food waste in daily life [155]

Measures	Description
Plan food quantity	Avoid buying massive amounts of food at once. Prepare a shopping list for each purchase and strictly stick to it.
Make advantage of the fridge	Freeze extra fruits, vegetables in season, and other food can be eaten slowly. Cook or pre-process perishable food and freeze them for use later.
Gain recognition of the expiration period of food	Most food is still safe and healthy even after expiration if appropriately stored and without evident spoilage. This kind of food should be used instead of discarded.
Store food appropriately	The life cycle of food can be extended when it is stored under the right temperature and humidity.
More meals at once	Cook several meals at once could save time, water and energy. Also, prepared food can reduce buying food out of plan.
Control portion	Control the portion of food for one meal can effectively minimise the quantity of food that will end up in rubbish bins.
Pay attention to the food in the fridge	Periodically check what residual food is in the fridge and consume it timely.
Donate excessive food	Donate extra food to relatives, neighbours or local food banks can help people in need as well as reduce food waste.
Compost food residue	This is the final approach to address food, which should be considered after all the above measures are taken, as this requires professional organisations to realise.
Track food waste	Record food thrown away weekly and improve the following week's shopping list.

On top of the above actions, Nestlé proactively engages with partnerships and stakeholders. In 2020, Nestlé invested 30 million dollars in Closed Loop Leadership Fund to advocate CE in the US. This finance will be used to promote recycling programmes and improve infrastructures for recycling. Through this investment, Nestlé can attain the recycled plastic materials, which are invested by this Fund, for food packaging [156]. Likewise, Nestlé is the core partner of New Plastics Economy, an initiative led by the Ellen MacArthur Foundation that gathers essential stakeholders to reconsider the future of plastic packaging [157]. Besides food packaging waste, Nestlé also joined Consumer Goods Forum to work with hundreds of retailers to pursue the goal of halving food waste in the operations (compared with the amount in 2016) by 2025 and reducing food loss with FSCs [158].

(2) Environmental sustainability

On the other hand, Nestlé makes an outstanding contribution to environmental sustainability. Above all, CO_2 emission is always put in priority in Nestlé's sustainable strategies. Table 11 shows the main actions that Nestlé takes to tackle this issue. There are both preventive measures (i.e., diverting to more sustainable packaging, logistics, renewable energy and developing low-carbon products) and measures of reducing current CO_2 (i.e., afforestation and turning ingredients to be sustainably available) [159].

Table 11. Nestlé's actions for CO_2 reduction [159]

Actions	Details
Sourcing ingredients sustainably	Modify the supplements and feed additives to reduce methane from digestion animals. Use more sustainable ingredients for animal feed. Use advanced technology and train the farmers on how to use it to manage herds sustainably. Promote regenerative agriculture to increase carbon content in the soil.
Improve packaging	Turn to reusable materials for packaging. Turn to low-carbon production of packaging. Provide packaging recycling platform for customers. Improve infrastructures for waste management.
Turn to cleaner logistics	Replace energy with renewable electricity in distribution centres. Reduce emissions by maximising the loading rate of transport vehicles and using clean energy.
Build carbon-neutral brands	Nestlé Waters: Most packaging is 100% recyclable. By 2025, they commit to use 100% renewable fuels for the Nestlé Waters supply chain. Invest in advanced offsets to eliminate and diminish carbon. Invest in wetland restoration and water preservation.
Develop low carbon-products	Train staff to gain knowledge of sustainability and its importance, which could help them make better decisions for product development. Assist managers in redesigning or improving the portfolio and products to reduce greenhouse gas emissions. Measure environmental impacts from the supply chain and develop solutions.
Use renewable energy	Replace traditional power with renewable electricity during the manufacturing process. Improve the efficiency of electricity use. Gradually obsolesce refrigerants with high potential in increasing global warming level.
Afforestation	Plant vegetation around water sources and wild animal habitats. Integrate tree planting and herd. Plant trees to help restore forest area.
Appeal to various parties to deal with climate issues	Advocate sustainable initiatives and programmes. Engage stakeholders to join the carbon reduction actions. Support and propose policies related to CO_2 reduction.

Besides, Nestlé emphasises sustainability and the protection of water resources. Nestlé uses a flowmeter to supervise the total quantity of water factories use and monitor water quality with tools. The water will be safely processed to meet the Nestlé environment standards before reusing in the operations or being emitted to oceans, rivers and lakes. At the same time, Nestlé focuses on decreasing water usage, particularly in the factories in waster-deficient areas. Moreover, Nestlé cooperates with Alliance for Water Stewardship (AWS) to improve its water usage efficiency. With a general framework and assistance furnished by AWS, Nestlé could know better about the water usage situation and the influence it brings, then the stakeholder could coordinate to improve water resource management [160]. Another model that Nestlé promotes is regenerative agriculture. The target of this agricultural approach is to improve soil conditions and protect soil fertility, water resource and biodiversity, specific measures are shown in Figure 4 [161].

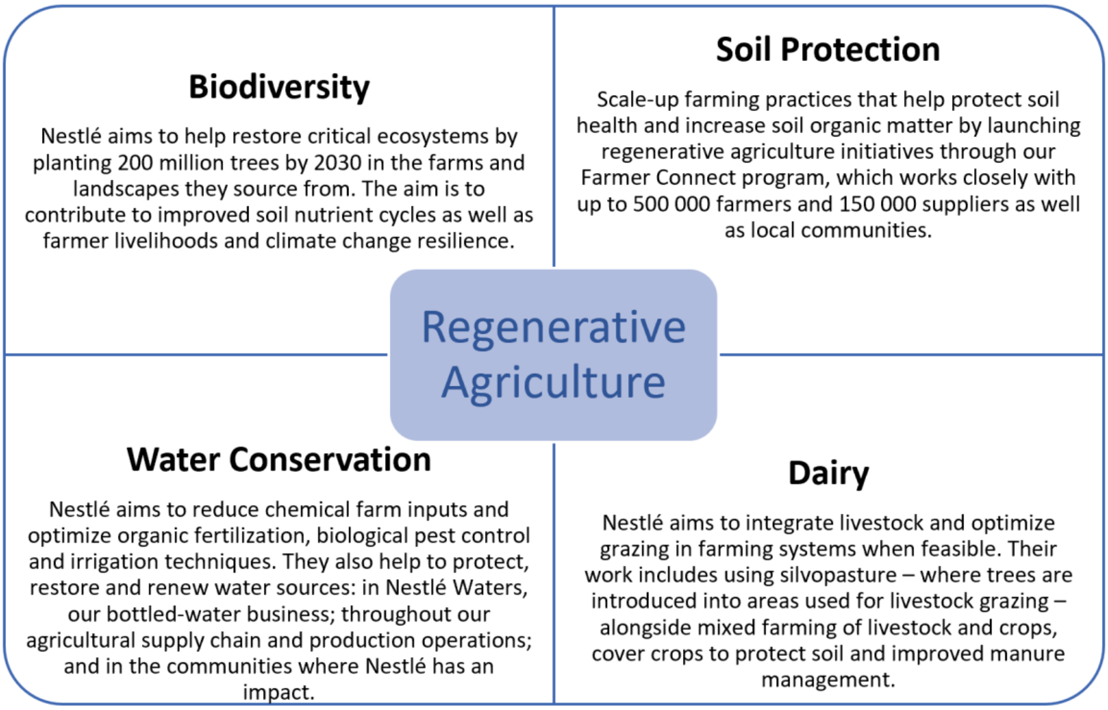

Figure 4. Measures of regenerative agriculture [154]

Regarding BCT deployment, Nestlé is also at the forefront of the food industry. Since 2017, Nestlé has consistently attempted to pledge BCT to improve the transparency of FSCs. Nestlé is the key founding member of IBM Food Trust, and this BCT adoption is firstly pivoted toward improving Nestlé's supply chain transparency and food traceability. The uploaded data in this BCT-based platform allows suppliers to avoid recall of all products. Even if there is a need to recall, the suppliers can recall specific parts with problems. For customers, they can easily trace all the information about the products [162]. Then in 2019, Nestlé collaborated with OpenSC, a public blockchain to support sustainable food sourcing. It maximises the transparency of KAHAWA ya CONGO (an organic coffee product of Nestlé). In addition to customers' access to the information on the process of coffee planting, production and transport, the OpenSC platform can automatically verify whether each farmer acquires the subsidy of the Nespresso AAA Sustainable Quality™ Program (initiated by Nestlé, aiming to advance social and environmental sustainability) [163], which could further development of Nestlé's sustainable supply chain.

4.1.3 Dole Case Analysis

Dole is an international food company with a long history dating back to 1851. Today, Dole has become the largest supplier of fresh fruits and vegetables with the vision of producing food with the most nutrition and the minimum environmental impact [164]. Still, Dole has persistently optimised its FSCs towards a more CE mode.

(1) Zero waste

To begin with, Dole endeavours to reach the goal of zero waste. To achieve this target, Dole strives to reduce ancillary supplies in farm and processing plant operations. On the banana plantation, Dole uses protective cases, plastic bags and ropes during the banana's growth to prevent damage and pests, which items will be reused and recycled. Dole even associated with Del Monte and Montecristo Group to found Recyplast, a unique recycling joint-venture, to deal with this issue. The establishment of this corporate aims to recycle banana bags and hemp ropes and then use them for trays in transport.

Afterwards, Recyplast expanded this solution to other agricultural products such as sweet melons and pineapples.

On the other hand, Dole aims to convert unusable materials in the plantation into valuable and innovative products. Dole Sunshine builds a partnership with Ananas Anam to convert pineapple plant leaves into a sustainable leather alternative. Ananas Anam is the founder of Piñatex, a natural textile made from pineapple leaf fibre. This cooperation enables Piñatex to collect more pineapple leaf fibre from Dole's pineapple orchards while Dole can reduce fruit waste [165]. Similarly, Dole Sunshine partners with Musa Fabric to reprocess banana waste to purposed fibre [166]. Also, organic waste would be monitored at each stage and fully used. For instance, Dole's factories in the US turn unusable vegetables during salad production into compost [167].

At the same time, Dole takes some measures to handle and reduce unsold fruit. First, they use unsold fruit to create new products, such as juice, snacks, etc. For unsold fruits and vegetables with an imperfect appearance but rich in nutrients, Dole propagates a proper recognition that they are worth buying [168]. Additionally, Dole considers the high qualification rate of fruit products as an essential factor in reducing unsold fruit. Because ensuring good quality can significantly reduce the number of fruit products not accepted by the stakeholders. Therefore, Dole installs more sophisticated equipment to increase food production quality and utilisation [168].

(2) Environmental issue

Dole also keeps making their supply chains to be more environmentally friendly. First, they are gradually moving toward clean energy in the supply chain to minimise carbon emissions. So far, this transition has gained success in the UK as Dole's business uses 100% renewable energy, covering central distribution site, production facilities, warehouses and their UK base [167]. Moreover, Dole invests in generating biogas and solar energy for their factories' electricity supply and even for replacing their vehicles' fuel, as Dole has introduced electric trucks for their fruit shipping [169]. Second, Dole commits that they will totally remove the use of fossil fuel for product packaging. Dole's primary measure to reach this goal is developing new alternative materials with its partners. Third, Dole is advancing regenerative agriculture in its pineapple and banana plantations. Under this agricultural model, Dole would plant some specific crops (e.g., mucuna) in idle farmland to mitigate the space of soil erosion and restore soil fertility [168]. Fourth, sustainable use of water sources in the supply chain is also an important strategy of Dole. As a member of the Alliance for Water Stewardship (AWS), Dole is supported by its guidance and framework for controlling water quality, proper water treatment and maintaining water balance. This initiative helps farmers know about the influence on the surrounding environment and community of their water use, and then assist farmers in improving the defects. Till now, 13 Dole farms have been certificated that meet AWS International Water Stewardship Standard [167].

(3) BCT adoption

From another aspect, Dole has cooperated with Walmart and IBM Food Trust to trialled BCT to improve their supply chains. Dole has a five-year plan for BCT adoption to strengthen food safety and maintain food quality. This plan aims to implement BCT for all Dole divisions by 2025. Dole intends to use BCT to monitor and distinguish problems during each process, including on the farm, during growing, pre-harvest, harvest, coolers, and sorting facilities. The monitoring details are shown in Table 12. Meanwhile, the product information from the farm to the dining table on this BCT-based platform is traceable for customers. With the assistance of BCT, Dole shortens the time of investigating safety problems to seconds, increasing the confidence of both stakeholders and customers in pollutant products [169]. Currently, Dole has adopted BCT across its salad and vegetable supply chains.

Table 12. Process monitoring of Dole farm [169]

Procedure	Monitoring details
On the farm	Monitor whether the added elements in the soil meet Dole requirement.
During growing	Control irrigation specifications, water tests, and anti-pest processes.
Pre-harvest	Eliminate defective crops if detected
At harvest	Control equipment and ensure the process meets hygiene requirements.
In coolers	Control appropriate temperature.
At sorting facilities	Strict handling practice and environmental controls.

4.2 Category B: BCT Application and Sustainable Supply Chain Development

4.2.1 SSP Case Analysis

SSP is a young group established by the major shrimp producers in Ecuador in 2018. The members of this partnership promise to farm shrimps with the highest standards, complete traceability, zero antibiotics and sustainability [170]. Despite its short establishment time, SSP is the pioneer that creates value in products and sustainability through collaboration among the producers. The exceptional performance of this disruptive initiative has demonstrated that it could bring reform to the future of the shrimp farming industry and even the seafood industry. SSP dedicates to furnishing top-quality shrimps while turning this industry into a successful worldwide practice of clean and sustainability. To realise this vision, SSP obeys four fundamental principles: accountability, transparency, inclusion and progressive leadership [171].

Accountability ensures SSP's actions are performance and result oriented. It also indicates the progress of improving environmental and social performance they committed. Regarding examining current performance, SSP is sponsored by The Sustainable Trade Initiative, the World Wildlife Fund (WWF) and SSP Advisory Board Members. They launch an improvement program to compare farms' current performance with substantial environmental and social indicators to determine improvement opportunities [172]. Except for complying with Aquaculture Stewardship Council (ASC) standards, SSP also enacts their exclusive stringent standards of operation and production (see Table 13) for the members, including neutral impact on water, zero antibiotics and traceability. It is worth noting that although most shrimp industry in the world puts antibiotics into shrimp farming to prevent diseases, the Ecuadorian shrimp industry takes a different strategy. They help the shrimps to strengthen resistibility, including improving ingredients in shrimp feeds [173]. Under the assistance of the Colombian Institute of Technical Standards and Certification, SSP's members are continuously verified that their farming and production hardly hurt the local environment and have optimal compliance with the specifications [174].

Table 13. SSP standards [175]

SSP standards	Description
ASC Certification	These are the basic standards of SSP farms, representing that they concern more about environmental and social performance indicators than other farms.
Zero Antibiotics	No use of antibiotics guarantees the pureness and health of SSP's shrimp products.
Traceability	Through the advanced and safe BCT technology, customers can know information about the whole journey of the shrimp from its hatching to sale.
Neutral Impact on Water	SSP keeps estimating water quality to minimise the impacts on water from shrimp farming.

On the other hand, transparency enables customers' availability of information about SSP's practice, product origins and sustainability level. In this case, customers who pay attention to environmental sustainability could make wise decisions when purchasing shrimp. In 2019, SSP leveraged IBM Food Trust to launch a traceability application to ensure the highest transparency of their products. SSP is the first group to provide shrimp products on the IBM Food Trust platform. By scanning the QR code outside the SSP BLUE BOX shrimp package, customers could trace all the critical product information from the farm to their forks, including hatchery, farm location, culture time, shrimp farmers, culture and processing patterns [176]. Not only for serving customers, this BCT-based platform is also excellent for the accountability and transparency of SSP's internal operation. Operators use it to supervise each stage of the entire shrimp supply chain and ensure there is no use of antibiotics during the production cycle. Besides, due to information sharing on this platform, SSP could flexibly control and manage inventory [173]. Moreover, Grupo Nueva Pescanova, a member of SSP, announced in 2021 that they expanded the BCT use to all seafood products, relying on IBM Food Trust [177].

Furthermore, SSP has always remained high inclusion in seeking external cooperation. Through cooperating with other corporates and non-government organisations, they aim to improve the whole industry's sustainable level as well as environmental and social sustainability. Besides achieving technology support from the companies mentioned above, another important strategy is to embrace more farms and regions to engage in SSP. Therefore, with the assistance and guidance of the SSP Advisory Board – IDH, The Sustainable Trade Initiative, WWF and ASC, they put forward and carried out SSP Scale-Up Programme. This programme helps producers who intend to improve their sustainability performance customise their development trajectory, including guidance and training [172]. It is a bottom-up method to facilitate gradual improvement of sustainability, details are represented in Figure 5. Relying on this programme, participators could gradually improve their product quality, start from being capable for export, then meet ASC standards, which would be stricter. Ultimately, they would meet extra standards set by SSP, which is the strictest. So far, 22 farms have been involved in this programme, most of which have entered the second stage, while 12 have produced shrimps according to SSP standards [174, 178].

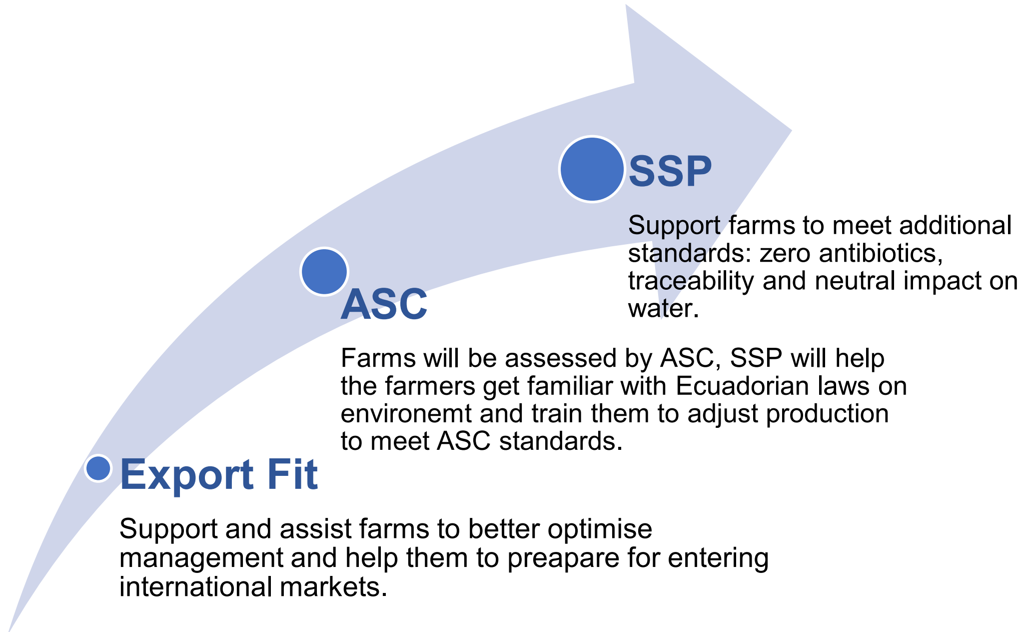

Figure 5. SSP Scale-up Programme

Last but not least, SSP has persistently figured out how to reform and motivate the advancement of the shrimp industry with progressive leadership. SSP initiates Sustainable Leadership Roundtable with other corporates, non-government organisations, stakeholders and SSP Advisory Board. Its purpose is to help all the shrimp farming industries worldwide move towards sustainable development by sharing professional knowledge, developing improvement approaches, and identifying potential challenges and how to overcome them. The primary topics of the roundtable are the use of antibiotics in the entire industry, impacts of climate change, accelerate environmental improvement, intelligent agricultural practice, an increase in feed efficiency, etc. [179]. SSP Advisory Board provides consultant services for sustainability enhancement. Also, SSP builds its feed working group, which gathers feed companies to help to develop innovative solutions to more sustainable feed for shrimp farming [179].

4.2.2 Cermaq Case Analysis

Cermaq is a leading global salmon producer headquartered in Norway, endeavouring to healthier and climate-friendly food and operation [180]. It farms salmon in Norway, Chile and Canada, producing sustainable, safe and reliable salmon products for global consumers. Except for independent research, Cermaq also keeps expanding collaborative relationships with external organisations to develop CE.

(1) Cooperation for reducing environmental impact

In 2021, Cermaq and Folla Alger established a cooperative partnership, working with leading research environments in Norway. Algae play an essential role in the transition to sustainable seafood as it can reduce carbon emission and be an alternative to feed materials. Through mixed aquaculture of salmon and kelp, they take good advantage of nutrients from salmon cages to farm kelp and use kelp as a feed ingredient for salmon. The water-solvable nutrients released by salmon cages can increase the carbon capture capability of Algae so that the carbon footprint of farming salmon could be decreased [181]. On the other hand, bioactive components in kelp could enhance the salmon's immune system and intestinal and skin health [182]. This disruptive hybrid farming approach is an outstanding CE practice in the seafood industry.

Besides, Cermaq works with a Chilean compost company to extract organic waste in sludge (a mixture of fish manure feed residue and water) and transit it into fertiliser for local forestry and agriculture. Cermaq strictly filters the sludge before deciding if it is suitable to be converted to compost. Sludge that meets the quality requirement will then be mixed with unique materials to reach specific consistency and mature naturally [183].

In 2022, Cermaq cooperates with Nord University to conduct various research with external participants in the long term. Terjesen, head of the R&D department of Cermaq, is appointed to be the professor in the teaching team of Nord University. The aquaculture farming courses he teaches will not only be for students on campus but also open to fish farming companies [184]. This helps promote environmental sustainability in the aquaculture industry and can bring potential cooperative opportunities to Cermaq.

(2) Reduce impact on ocean

Furthermore, Cermaq announced a new sustainable strategy in August 2022: 'Sea the Solution'. It is research on solutions to the food, social, environmental, and climate challenges [185]. The latter two research is significant for the sustainable development of Cermaq. There are two main challenges for the environmental issue: balance between salmon feeding and ocean ecosystems and risks of sea lice for the other marine organism. Cermaq sustains no waste during the feeding process and minimises medicine use to around zero as effective solutions [186]. Also, they use iFarm (a monitoring system developed by themselves) to classify the salmon in the farming area and only deal with the salmon in need (e.g., gather sick salmon in a small water area and treat them with medicine) [187]. Instead of intensive treatment, this is more moderate and has a less negative influence on the ocean.

(3) Lower carbon level

Cermaq also dedicates to reducing greenhouse gas emissions and maintaining a low carbon level. As greenhouse gas from feed accounts for 80% of salmon farming, Cermaq has researched new materials for improving feed. Currently, Cermaq is testing algae, yeast and insects to replace feed ingredients that contain high CO_2 [188]. To reduce impacts on climate change, Cermaq creates a completed evaluation of carbon emissions in 2019, including carbon emissions within both Cermaq's operations and upstream and downstream in their value chain. Through this, Cermaq identifies that diesel fuel is the primary emission source. Afterwards, they put effort into transiting diesel generators at seawater sites towards grid power and using hybrid power to modify their ships. This could help to decrease at least 40% use of diesel fuel. Another factor results in high carbon emissions are the transport of salmon. Due to the lower carbon emission of sea freight, Cermaq plans to use sea freight for salmon transport instead of carbon-intensive air freight [189].

(4) BCT adoption

In order to increase traceability and transparency, Cermaq cooperates with Labyrie (the French leading salmon brand, a client of Cermarq) to adopt BCT provided by IBM Food Trust. Customers could access all the information about the salmon (i.e., origin, incubation period, its freshwater facility, size when transiting to seawater, its seawater farming facility, vaccine it received, its feed and harvest time etc.) via scanning QR code outside its package. Labyrie also represents the vital information technologies in their production chain to the customers [190]. BCT helps consumers to ensure that the salmon fish they choose is farmed in a reliable and sustainable mode.

4.3 Key Findings and Comparisons

All five analysed organisations introduced IBM Food Trust in their supply chains primarily to increase transparency and traceability. The primary two advantages of this BCT-based system are internal operation improvement (i.e., inventory management and problem detection) and for customers to access all the information about the products they buy. Walmart, Nestlé, Dole and SSP all make the best use of the two functions. Walmart and Nestlé use the sharing data on the BCT-based platform to detect defective products, and timely recall them, while Dole uses it to monitor the procedures of planting and processing. Similarly, SSP determines the responsibility of the participators within the supply chain when there is a problem. In particular, Nestlé also uses the BCT-based platform provided by OpenSC for supervising sustainable indicators of its coffee supply chain with automatic verification. Unlike IBM Food Trust targeting for ensuring food safety [191], OpenSC specialises in helping organisations improve food sustainability and verify low carbon at source [192]. Although Nestlé has not utilised it to tackle food waste issues, this still can be seen as an embryonic CFSC as environmental sustainability is an indispensable component of CE [193]. However, Cermaq chiefly furnishes customers with sustainable information via the BCT-based platform and does not use it for internal supply chain optimisation. Therefore, the common function of the BCT-based platform exerted by the five companies is recording data and ensuring its authenticity and accessibility. Only Nestlé explores its automatic execution function and fulfils its usefulness for sustainable supply chains.

On the other hand, the five companies join IBM Food Trust in different forms. Walmart, Nestlé and Dole are the founders of IBM food Trust, working with IBM to research and develop this BCT-based platform, especially for the FSCs [194]. It only took them two to three years to finally launch this BCT-based platform, and these companies use this service for their FSCs independently. But unlike these giant food companies, small shrimp producers in Ecuador established an alliance, SSP, and then used IBM Food Trust in the second year. Likewise, Cermaq allies with another salmon producer and use the platform collaboratively instead of using this BCT service itself. Moreover, Cermaq has its monitoring system, iFarm, but they still choose a BCT-based platform to record and track product-related information.

Regarding CFSCs, each company's progress in CE implementation across supply chains is different. Walmart, Nestlé and Dole have developed relatively consummated systems and schemes, achieving superior performance. They consider the two most essential factors of CFSCs development: minimisation of FLW and environmental impact. A common measure for Walmart, Nestlé and Dole to avoid food waste is to boost food product sales. However, the specific methods are different, as Walmart cooperates with other food retailers to guarantee the stable purchase of products for its suppliers, while Nestlé and Dole encourage customers to buy good-quality fruits and vegetables in wrong shape. For the unsold food or waste within food production, all of them take the action of creating values from it via turning it into compost or reprocessing it into other types of products. In addition, Walmart and Nestlé seek external cooperation to reduce food waste with other organisations, as both join the Consumer Goods Forum. Although not joining such a large partnership, Dole works with a company that uses disruptive technology to turn usable waste from orchards into sustainable materials. Similarly, Nestlé also reduces waste at the source, helping farmers to minimise crop loss with advanced technology. Particularly, Nestlé engages customers to participate in food waste reduction by providing specific guidance and even cooperating with colleges. But for SSP and Cermaq, it seems that they have not taken relevant actions to tackle FLW in their supply chains. Nonetheless, their operations have gained outstanding achievements in environmental sustainability.

To pursue the goal of lessening environmental impacts from supply chains, which is another significant factor of CFSCs, all these five companies have adopted various measures. All of them emphasise lowering carbon emissions. There are some common approaches for them or parts of them to tackle this issue (e.g., reduce and recycle plastic waste from product packaging, develop innovative packaging materials, use renewable energy, move towards green logistics, organic waste reprocess and reuse, join relative initiatives or groups, engage customers to join sustainable development etc.).

For the FSCs that contain animal feeding (i.e., Nestlé, SSP and Cermaq), they pay attention to improving the animal feed ingredients to reduce the carbon emission from the process. Meanwhile, regenerative agriculture is promoted by Nestlé and Dole, as there is a large amount of soil used in their FSCs. On the other hand, all five companies pay attention to water source prevention and management. Table 14 summarises the solutions the five companies develop to lower environmental impacts.

Table 14. Summary of solutions to lower environmental impacts

Solutions	Walmart	Nestlé	Dole	SSP	Cermaq
Replace plastic packaging with sustainable alternatives	√	√	√		
Recycle and process plastic wastes	√	√	√		
Turn to green logistics	√	√	√		√
Convert organic wastes into usable products	√	√	√		√
Turn to renewable energy	√	√	√		√
Join sustainable initiatives/groups for cooperation	√	√	√	√	√
upgrade ingredients of feed		√		√	√
Advance regenerative agriculture		√	√		
Customer engagement of sustainable development	√	√			√
Water source prevention/management	√	√	√	√	

5. Discussion

Given the findings of the systematic literature review and case study, the potential answers to research questions (shown below) will be discussed in this section:

Question 1: The feasibility of BCT facilitating CFSC development

Question 2: How does BCT assist in developing CFSCs

Question 3: Barriers of developing CFSCs

The answers to the first question will be divided into two parts: why it is feasible to integrate CE in FSCs and use BCT in FSCs. For the second questions, it will focus on two aspects: how BCT help to reduce waste at the stages that generate the most FLW and how BCT assist in improving the environmental sustainability of the entire FSCs. Finally, the barriers of developing CFSCs will be discussed from aspects of finance, government policy, and collaboration.

5.1 Feasibility of BCT Facilitating CFSC Development

5.1.1 Feasibility of CE Integration in FSCs

In the first place, the objectives of CE and the cooperation among stakeholders are achievable. As in the case study, companies set the goal of zero waste and have achieved appreciable achievement so far (Walmart, Nestlé and Dole), implying that most food waste can be recycled and reused. Also, the food waste can be processed to clean energy (e.g., Walmart and Nestlé convert organic waste into methane). This innovative waste treatment can simultaneously abide by the two fundamental principles of CE identified in the literature review: recycle and reuse the waste while using renewable energy [30]. On the other hand, the collaboration among stakeholders for CFSC establishment is attainable. Leading companies like Walmart and Nestlé can use their significant influence and resources to initiate and engage upstream and downstream within the FSCs to use the BCT-based platform. Smaller companies like Cermaq or members of SSP can seek counterparts with the same goal (e.g., increasing transparency and transparency of FSC) to use the BCT-based platform collaboratively. Hence, it is realisable to integrate CE into FSCs to help improve waste minimisation and sustainability.

5.1.2 Feasibility of BCT for FSCs

On the other side, the literature review findings and the BCT practices of the analysed companies in the case study demonstrate that this technology is compatible with FSCs, as it can benefit FSCs from many aspects, and companies can easily acquire it nowadays.

Above all, BCT helps to tackle key technical issues and brings various advantages to FSCs. The most critical obstacle to CFSC development is low transparency and traceability caused by inefficient information sharing [35]. BCT could overcome this problem by connecting multiple separate stakeholders in the FSCs because of its unique features (information sharing, immutable data, block independence etc.). Moreover, this improvement is identified in the cases as all the companies successfully use BCT to increase the transparency and traceability of their supply chains. Besides, other benefits of BCT for SCM identified in the literature review are also confirmed in the case study, such as saving time in handling issues (Walmart and Dole), improving the security of data (SSP), increasing flexibility of supply chains (Nestlé, Dole and SSP).

Then, BCT is not as difficult as before to be available for companies in the food industry. It is identified in the literature review that BCT will become more and more mature while the investment will decrease [83]. Meanwhile, it only takes Walmart and its partners two to three years from trial and the BCT-based platform for FSCs [144]. Both of them indicate that the research and development BCT-based platform for the food industry is less difficult. Furthermore, even smaller companies without sufficient finance to develop such a platform could ally with other corporates in the food industry to acquire the BCT service with lower costs (like SSP and Cermaq). Hence, BCT could be available for most companies in the food industry nowadays.

5.2 How Does BCT Assist in Developing CFSCs

When it comes to how to build a BCT-based CFSC, the deployment should start at stages that contain the most waste and then expand to other stages gradually. From the literature review, it is identified that retailers generate the most FLW [32-34], then the production [35]. According to the case study, retailers and producers generate the most food waste, as the measures of minimising waste are mainly concentrated in the sale and the source. Combined with the research results, reducing waste at retailers and producers with the deployment of BCT should be emphasised. Afterwards, how to use BCT to improve the environmental sustainability of FSCs will be elaborated.

5.2.1 BCT Application at Retailer Level

Above all, like Walmart, food retailers could reduce food waste by avoiding overproduction. BCT-based platforms can help retailers automatically upload information about sales. As the data is accessible to all the suppliers, it would be easier for them to check the sales performance and predict the demand to make their production plan. On top of that, more data in the supply chain will make forecasting results more accurate [195]. Data on the BCT-based platform is immutable and cannot be deleted, which means data loss will not happen, and the amount of data within the supply chain will accumulate consistently. Thus, the forecasting results would be more and more accurate and reliable so that there would be less food waste from overproduction.

Second, BCT can help reduce food waste from unsold and returned food. Through the BCT-based platform, retailers can check the information related to the defective food products and account for the responsibility. Furthermore, food retailers could develop reports and analyse the suppliers periodically based on the sharing data stored on the platform. Under this circumstance, retailers could select the optimal suppliers for their food products. Thus, the food quality would be ensured, which has the most positive influence on customer loyalty [196]. It would be more likely for retailers to stabilise the sales and also reduce the risk of returning from customers so that less waste would exist in the retailers.

5.2.2 BCT Application at Producer Level

First, the food producers can categorise and deal with diverse FLW, relying on a BCT-based platform. For example, producers could use the platform to assess FLW and classify it into different types, and unnecessary food loss and recyclable or reusable waste could be identified. Afterwards, similar approaches taken by Dole (i.e., introducing more sophisticated equipment to improve food utilisation and enhance quality) can be used to reduce unnecessary food loss. For the recyclable and reusable waste, producers could cooperate with professional companies to convert it into by-products, compost or other valuable innovative products. Meanwhile, the BCT-based platform can track the waste's direction until it is reprocessed.

Second, producers could use the BCT-based platform to immediately recall defects when detecting problems. If the food producer suddenly discovers that the raw materials of a batch are suspicious, the producers could immediately recall the food via tracking it via the BCT-based platform. Additionally, producers could utilise the BCT's automatic execution function to terminate the flow of the detects within FSCs. For instance, a specific QR code can be attached to each batch of food products to confirm in each section that the food meets the production standards. When the BCT-based platform detects a problem, the QR code will be invalid at once, so it cannot flow into the next section. As a fast response can prevent defects from entering the market and the producers can gain maximum time to reprocess the flaws before their spoilage [197], the risk of returning the product would decline. Hence, food waste caused by unqualified food products can be reduced at producer level.

5.2.3 BCT for Improving Environmental Sustainability of FSCs

Apart from the above, the stakeholders in FSCs can also pursue the sustainable goals of CE with the assistance of BCT. First, the FSC operators could monitor key sustainability performance indicators, including greenhouse gas emission, water usage, energy consumption etc. [198]. Based on the different situations of each section, stakeholders who join the BCT-based platform can formulate the common standards of each performance indicator (e.g., CO_2 emissions from producers cannot exceed five tons annually). All the stakeholders can develop an annual sustainability report based on the data on the platform and participators who do not meet the standards can make modifications timely. On the other hand, BCT can also help to reduce CO_2 emissions from food transport. As high transport efficiency could lower fuel use and reduce carbon footprint [199], logistics providers can optimise the operations of truck fleets with a BCT-based platform. For instance, the supervisor could view the real-time situation of each truck's load on the platform and promptly schedule the trucks to avoid wasted movement. In short, a BCT-based platform is to store and share information related to sustainability within the FSCs for stakeholders to use and analyse.

5.3 Barriers of CFSC Development

5.3.1 Financial Factor

The first barrier for companies to develop CFSCs is the lack of sufficient finance. As identified in the literature review, high investment in the developing stage [60, 200], and the risk of low return [55, 59] would be a barrier for organisations to transform to CFSCs. This also could be seen from the case study, as the approaches that Walmart, Nestlé and Dole take require high investment, e.g., converting organic waste into compost or biogas, research and developing alternative packaging materials, and support upstream and downstream to reduce waste and environmental impact, recycle and reprocess the waste to by-products or innovative products, replace all the power into renewable energy etc. In particular, Nestlé initiates a unique programme to furnish the farmers in the FSCs with premiums to help them improve its improvement of production [163]. On the contrary, smaller food companies like SSP and Cermaq have not taken similar measures but presently just aim to improve the sustainability of their operations. Although such actions effectively reduce environmental impact at source and within the FSCs but cannot be imitated by most SMEs in the food industry because of inadequate finance.

5.3.2 Government Policy

Besides, the lack of related policy is also a critical barrier to develop CFSCs. From the findings of the literature review, except governments have not regulated laws on the CE issue [56, 62, 63], even if related regulations have been enacted, it is also hard for the government to supervise organisations' performance of CE adoption [65, 200]. On the other hand, the case study reveals that CE adoption in FSCs is generally propelled by giant food companies (Nestlé and Dole) or food retailers (Walmart), and related regulations or standards are formulated by the relevant groups or participators of the FSC. All the stakeholders or the initiator of CE-related actions are responsible for supervision (e.g., SSP assists the members in monitoring whether their products meet its environmental standards). There is little supervision on CE issues from the government, and the companies hardly refer to relevant local laws. Therefore, as government intervention is essential, but only a few countries have developed a correlative plan and set out [13], it would be challenging to develop CFSCs.

5.3.3 Collaboration

Lastly, collaborative relationship establishment is a significant obstacle for CFSC development, particularly for SMEs. Based on the literature review findings, it is crucial to maintain intimate cooperation among participants in CFSCs [33]. However, through the comparison of the case study, only giant companies (Walmart, Nestlé and Dole) have the power and influence to engage the upstream and downstream stakeholders to develop CFSCs together. These leading companies can play the role of connecting all the participants, sharing valuable resources and moving towards the common objectives of CE adoption. In contrast, small companies are less likely to have the opportunity of reaching numerous resources and persuade cooperators of the FSC to develop CFSC together. Except for the common goal setting, another difficulty in facilitating cooperation is the stakeholders' unwillingness to use new systems or platforms. When creating CFSCs, new tools like connection systems are required to introduce into the supply chain for effective communication among stakeholders. But it is hard for companies with low trust to believe and use a new system [201]. In this case, companies must build and retain the firm trust before working together to develop CFSCs, which might take years. Thus, companies should overcome such a cooperation issue when developing CFSCs.

6. Recommendations

This section will concentrate on proposing recommendations for developing BCT-based CFSCs, including accessibility of BCT, accountability issues, safety issues and customer awareness enhancement.

First of all, the approach of gaining BCT support could be diversified for different companies. For giant food companies, they could seek cooperation with other technology companies to build the BCT-based system. Moreover, if there is an abundant investment and superior technology level, the food companies could customise the layout and specific functions of the platform, depending on their need for CE adoption. For instance, Walmart hopes to select more sustainable suppliers to improve the sustainability of their FSCs. So, they could use the BCT-based platform to automatically filter out the suppliers that do not meet their sustainable standards. In comparison, it would be better for SMEs to purchase developed BCT support services. Besides collaborating with several similar companies, SMEs could also join BCT-based supply chains operated by leading companies in the food industry to reach such a resource. This can help SMEs to save the investment and the cost of operations and maintenance of the BCT-based system.

Another issue that needs to be paid attention to is the accountability when using BCT for CFSCs. As the BCT system can execute some instructions without permission of a third-party agency when the default conditions are triggered [202], it is hard to define the responsibility when there are problems. Because there is no direct manipulation from any stakeholders in the supply chain. Moreover, currently, relevant laws of BCT supervision or specification of BCT use have not been enacted so far [203]. Thus, it is suggested that specific and clear clauses related to this issue should be included in the contract before adopting BCT. For instance, all the participators should agree that if false execution manipulated by the BCT-based system automatically is not withdrawn within the regulated period, this would be recognised as that the execution is on behalf of the stakeholders' willingness. In this case, the stakeholders would be responsible for the problems.

Meanwhile, due to complexity and intersection of BCT-based CFSCs, operators should enhance supervision of safety. The first safety issue that should be considered that prevention of companies' confidential information leakage. It is necessary to ensure open communication within a CFSC, which requires information sharing among all the stakeholders. For this purpose, the blockchain for CFSCs should be a public blockchain so that all the stakeholders can access the core information [204]. Under this circumstance, there is a potential risk of disclosing companies' confidential data. One solution to this issue is that BCT service producers could make special encryption of each BCT node in the CFSCs to protect companies' internal information. Meanwhile, the BCT system operator could authorise stakeholders with different permission to access data on the BCT-based platform, according to their specific needs. For example, the suppliers could be authorised to only access the internally public information of the stakeholders that have direct transactions with the suppliers and have product or material flows mutually. On the other hand, it is also significant to ensure the safety of by-products. Food waste and its by-products are good resources of abundant nutrition, but the antinutritional factors (an ingredient that can interfere with the digestion and utilisation of protein, carbohydrates and minerals in biological bodies) can destroy their nourish value and even be harmful to consumers' health [205]. In this case, companies should strictly monitor and control the level of antinutritional factors and other bacteria in the waste, assuring their content meets the standards for further reprocessing.

Furthermore, companies could take measures to form a market preference for traceable food and CE adoption. As customer preference is an essential facilitator for CSC development [206], so it is suggested that companies are better to cultivate customer habits of tracing food via the BCT-based platform. Food retailers could promote traceable food and allow customers to experience the food journey's transparency and reliability. Besides, it is advised to increase interaction between customers and stakeholders to increase their awareness of reducing food waste and environmental impact. For example, if customers recycle the reusable packaging to the food suppliers through designated places or via specific platforms, they could gain some points or discounts for next purchase. Gradually, with more and more related measures taken, market preference will emerge. When there is demand in the market, CFSCs will tend to be more motivated and stable.

In summary, when developing BCT-based CFSCs, companies should consider the driven factors and obstacles of both BCT adoption and CFSC establishment. The recommendations mentioned above: ways to reach BCT resources, clear accountability mechanism, safety assurance, and customers' preference cultivation would benefit CFSC development under BCT support, but the details still require negotiation between stakeholders in FSCs and coming into an agreement.

7. Conclusion

In conclusion, this study examined how blockchain technology (BCT) supports circular food supply chains. Growing food loss and waste (FLW), environmental pressures, and the need for more sustainable food supply chain management prompted the research. Circular economy (CE) principles have been widely promoted as a way to reduce waste and improve resource use, but limited transparency, information sharing, and stakeholder collaboration make circular food supply chains difficult to implement. This study used a systematic literature review and multiple case studies to assess the feasibility of integrating blockchain technology into food supply chains, analyse how blockchain can support circular food supply chains, and identify the main implementation barriers. Blockchain technology and circular economy concepts may benefit the food business, according to the research.

First, the study shows that food supply chains can incorporate circular economy ideas. The stories show that food corporations are reducing waste, recovering resources, recycling, and using renewable energy. Walmart, Nestlé, and Dole have taken steps to reduce food waste and promote sustainability.

These approaches show that food supply chain operations can achieve circular economy goals including waste minimisation and resource rotation. Second, blockchain technology has great potential to help circular food supply chain development. Blockchain offers transparency, traceability, data security, information sharing, and operational efficiency, according to the literature. Case studies validated these benefits in practise. Blockchain provides stakeholders with accurate, real-time information throughout the supply chain, decreasing information asymmetry and boosting coordination. Traceability helps companies monitor product conditions, identify waste, and address quality and safety issues faster. Blockchain reduces food waste and improves supply chain performance. Additionally, blockchain can aid CFSC growth through numerous means. Blockchain helps retailers decrease overstocking and food waste by improving inventory visibility and demand management. Blockchain improves producer decision-making and resource management by monitoring and tracing manufacturing processes. Blockchain increases openness about carbon emissions, trash management, recycling, and resource use, supporting environmental sustainability. These characteristics help food supply systems accomplish circular economy goals.

Blockchain technology has great potential, but significant obstacles remain. Since blockchain deployment requires a large initial investment, financial constraints remain a major issue for small and medium-sized organisations. Government impediments including weak rules, policy support, and enforcement may also delay blockchain and circular economy implementation. Additionally, supply chain stakeholders must collaborate effectively yet struggle to do so. Lack of stakeholder trust, coordination, or commitment may hinder blockchain platform deployment because they require information exchange and collaboration. This research bridges blockchain technology and circular food supply chain research, adding to the literature. While blockchain has been extensively studied in supply chain management and circular economy practices, its function in circular food supply chains has received less attention. Blockchain can reduce waste, increase sustainability, and improve food supply chain coordination, as shown in this study.

This study has several limitations. Instead of main empirical evidence, the study used secondary data and case studies. Meanwhile, because few companies are implementing blockchain-enabled circular food supply chains, the scenarios may not reflect all industry situations. The rapid growth of blockchain technology means certain findings may change as technology advances. Future research could validate this study using quantitative methodologies, surveys, or interviews. Researchers can also examine the economic performance of blockchain-enabled circular food supply chains, compare implementation outcomes across countries and industries, and examine how blockchain integrates with other emerging technologies like IoT, AI, and big data analytics. Studying how digital technology might speed the transition to sustainable and circular food supply systems would improve understanding.

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