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Key Fitting Points of Agri-food Supply Chain Collaboration and Blockchain: Literature Review on Agri-food Supply Chain Collaboration with the Integration of Blockchain Technology

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***Abstract*—**The Agri-food supply chain is pivotal for sustaining and nourishing global populations. Ensuring its high-efficiency, transparency, and integrity is paramount for each party in the supply chain. This paper aims at identify the fitting points between Agri-food Supply Chain Collaboration and Blockchain Technology through a comprehensive review. Research articles and materials related to Agri-food Supply Chain Collaboration with the integration of Blockchain Technology were collected from online databases such as Scopus, CNKI, and Google Scholar for a period of 10 years (2014-2023). It first provides an overview of the characteristics of Agri-foods and Blockchain Technology, and then details the data collection and analysis process. FineReport software is used to complete content and descriptive analysis. Next, the key fitting points of Agri-food Supply Chain Collaboration and Blockchain Technology are discussed, such as smart contracts, trust, quality and safety control, and information sharing. A case analysis on DongNan Rice as for Agri-food Supply Chain Collaboration integrated with Blockchain Technology is carried out. This paper also discusses the current research gaps. It is ended with the conclusions and future research directions.

***Keywords**: Agri-food, Blockchain Technology (BCT), Integration, Supply Chain Collaboration (SCC).*

Introduction

In the Agri-food supply chain (SC), due to the particularity of Agri-foods, the complexity of the organizational structure, the diversity of participants, and the uneven regional development, there have been diverse problems such as unstable cooperative relationships between farmers and enterprises, high default rates, and poor quality and safety, weak guarantee and competitiveness of Agri-food SCs [1], which seriously restrict the process of

agricultural modernization.

Under the conditions of market economy, the continuous promotion of reform and opening up in agriculture and rural areas is an inevitable trend of agricultural modernization. Agricultural industrialization is the main path to achieve agricultural modernization [2]. The industrialization of agriculture is gradually deepening, and forms of Agri-food SCs such as cooperative production, contract sales, and strategic alliances are gradually becoming new forms of agricultural economy. Agri-food SC organizations are constantly developing and strengthening in various regions [3]. Reference [4] concentrated on the analysis of Strengths, Weakness, Opportunities and Threats of BCT-applied SC relevant to Agri-foods. As in [5], it was believed that the popularization of the IOT technology will bring intelligent management and operation to the economic society, while the traditional centralized Internet security technology is not completely suitable for the topology and resource constraints of the IOT, but the technical characteristics of the BCT are suitable for the data storage and network security. BCT and the IOT can be coupled to build a decentralized, real-time information sharing application platform, and there have been applications such as automatic settlement through technology [6]. Reference [7] conducted a systematic bibliometric analysis of the BCT in the Agri-food system, and focused on the major policy implications of BCT. They revealed that BCT offers multiple benefits and scope in the Agri-food SCC in terms of enabling food safety and traceability, timely and transparent payment mechanism, record keeping, efficient Supply Chain Management (SCM), and warranting credit as well as insurance.

The integration of BCT and Agri-food SCC is becoming an important research direction, achieved some research results. The main focus of this paper is to identify the fitting points between Agri-food SCC and BCT through a comprehensive review. First, we study the characteristics of Agri-foods and BCT in the usual sense, paving the way for literature analysis of BCT applied to Agri-food SCC. Further the rest of the study is organized as follows. In section II we briefly describe the data collection and analysis process. In section III, by word cloud conducting content and descriptive analysis, the frequency of occurrence of keywords in the collected articles is identified. The column chart shows the frequency of fitting points of Agri-food SCC and BCT. Section IV specifically discusses the fitting points of BCT and Agri-food SCC, namely smart contracts, trust, quality and safety control, and information sharing. Section V also presents a case of the DongNan Rice for comprehensive analysis of Agri-food SCC with the integration of BCT. Section VI studies the gap. Last Section provides conclusions and future directions on this topic.

Review Methodology

Review methodology is formulated to ensure comprehensive coverage, unbiased assessment, and rigorous analysis of the literature associated with Agri-food SC collaboration with the integration of BCT. A descriptive analysis is conducted to elucidate both quantitative and qualitative patterns from the selected literature. Such a methodology not only ensures the accuracy and relevance of the included literature but also provides a robust foundation for subsequent analyses and insights. In this context, we applied both quantitative and qualitative assessment methods to holistically evaluate the existing body of work on the topic. This dual approach is vital to highlight not only the statistical patterns and trends but also the underlying nuances, themes, and subjective interpretations inherent to any research area.

A. Data Collection

The primary step involved sourcing relevant literature. Databases such as Google Scholar, Web of Science, PubMed and CNKI were systematically searched for peer-reviewed articles, journals, white papers, and case studies published between 2010 and 2022. A combination of keywords, including "Agri-food", "Supply Chain Collaboration", "Blockchain Technology", and "integration", were used.

B. Data Analysis

Upon gathering the relevant literature, we utilized FineReport Software to conduct data analysis. Through data analysis, we:

- Analyzed interpretations and implications of BCT in Agri-food SCC.
- Finding the fitting points between Agri-food SCC and BCT emerging in the sourced literature.

- Recognized gaps in the existing literature, paving the way for potential future directions.

C. Category selection

We then categorized the papers like general literature review of Agri-food SCC based on BCT, fitting points of Agri-food SCC and BCT.

D. Material evaluation

The selected articles were rigorously reviewed to analyze problems related to the Agri-food SCC with the integration of BCT to explore research gaps in previous literature.

II. Descriptive Analytics of Agri-Food SCC with the Integration of BCT Literature Using FineReport Software

World Cloud (Fig. 1) derived about literature on Agri-food SCC suggest that Agri-food, Supply Chain Management, Blockchain Technology, information sharing, trust, IoT, smart contract, traceability, Quality and Safety Controlling, and application have been the frequently used words in 272 collected articles. It is also depicted that there is less citation on model so there is gap in the literature to discover the model of Agri-food SCC with the integration of BCT. From the keywords, it is clear that the selected research papers are more relevant to the proposed research work on Agri-food SCC.

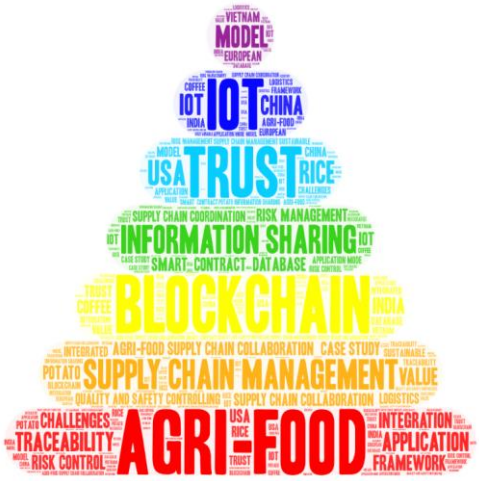

Fig.1 Word Cloud based on 272 articles

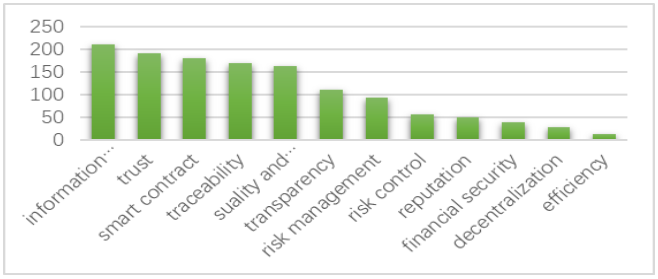

Fig. 2 Key Fitting Points of Agri-food SCC and BCT

Summarize the key fitting points of applying BCT to realize the agri-food SCC, mainly including: information sharing, trust, smart contract, traceability, quality and safety controlling, transparency, risk management, risk control, reputation, financial security, decentralization, efficiency. As shown in Fig. 2, the top five words frequently used in the previous literature are: information sharing, trust, smart contract, traceability, quality and safety controlling. This paper attributes the characteristics of traceability to trust and quality and safety controlling to illustrate.

III. Literature Review Classification Based on the Fitting Point of Agri-food SCC and BCT

A. General Literature Review of Agri-food SCC with the integration of BCT

According to [8], [9], [10], and other scholars, Agri-foods have lots of characteristics. (a) Agri-foods generally have a long production cycle and cannot increase or decrease yield in a short period of time. Once planted, the intermediate controllability is poor. (b) Affected by factors such as price fluctuations, natural disasters, and artificial speculation, the supply and demand of Agri-foods have a significant degree of randomness. (c) When the sales season approaches, Agri-foods are prone to an imbalance in supply and demand. (d) The perishability of Agri-foods requires high logistics conditions, otherwise it can damage freshness and cause significant losses. (e) The changes in quality and quantity of agricultural inputs, as well as the randomness of yield. (f) The need for specialized attributes such as traceability and transparency.

BCT was regard as a block chain data storage structure linked according to time order and verified by encryption algorithm [11][12]. Reference [13] viewed BCT as a decentralized underlying data protocol that stores data through encrypted block chain structure, updates data through distributed formula algorithms, and programs and operates data through smart contracts in a broader sense of data storage system. This study believes that the BCT is an open network database system in which different nodes participate. Instead of relying on intermediaries to provide trusted endorsement proof of data, it is a decentralized distributed database that uses cryptography and mathematical algorithms to ensure data security.

BCT applications in agriculture enhance diverse aspects include food safety [14], food security [15], food quality monitoring and control [16], traceability for waste reduction [17], reliable operational data analysis [18] and efficient contract exchanges and transactions to reduce economic costs [19], thus supporting small-scale farmers [20]. Reference [21] analyzed the application of BCT in agriculture field under four research dimensions namely traceability, architecture and security, information systems and others. As in [22], the behavioral and organizational antecedents that influence the application of BCT in SCM were examined.

Many scholars have designed and built the operation architecture of the SC through the BCT architecture from a technical angle. For example, Reference [23] proposed the logical architecture of the Agri-food SCC based on the BCT; Reference [24], [25], [26] and others designed the technical functional architecture and certification traceability process of BCT embedded in the quality and safety management of Agri-food SC. Decentralization, transparency, fairness and openness of BCT were combined in [27] with the concept of energy Internet, and analyzed the feasibility of BCT application in food SCC from different angles such as function, subject and performance. As in [28], it was investigated how BCT can impact Agri-food SCM and how a BCT-based network can be formed. A research framework was proposed in [29] to explain how an organization can build SC resilience and enhance SC performance with the help of BCT. A complete model of a BCT based Agri-food SC traceability system was proposed to provide quality, integrity and traceability of the entire SC process in [30].

On the other hand, some scholars analyzed and deduced the application logic of BCT in specific scenarios from the perspective of BCT application. The market potential and feasibility of BCT was deeply analyzed in the development of SC finance [31]; The intelligent management mechanism formed by the BCT coupling SC from three different angles was discussed in [32]: efficiency, fairness and sustainable development; Several specific scenarios where BCT embedding in the field of Agri-food circulation can solve the application pain points was summarized [33], including: cross-border Agri-food trade alliance chain, cross-border Agri-food logistics alliance chain, Agri-food traceability alliance chain, agricultural financing BCT that can efficiently transfer value, etc. As in [34], the institutional arrangement of the BCT was discussed, from a Network Chain Structure & Trust & Contract Framework to investigate how the network organization system based on the BCT is managed. They also described the possible situation of BCT-based Agri-food SCM from three aspects: network chain structure, trust mechanism, and contract mechanism. A comprehensive Agri-food SCC model was proposed in [35], based on IoT and BCT to solve the problem of complex SC processes relying on Intermediaries and lack of effective monitoring opportunities. So as to improve the SC and achieve security and traceability. The BCT-based Agri-food SC system can pinpoint the location of products, allowing for rapid detection and prosecution of theft.

There are also some scholars who conduct research on BCT-based Agri-food SCC from a comprehensive

perspective of technology, applications, and cases. Reference [36] proposed an approach for efficient transactions of soybean traceability in Agri-Food SC, which overcome the problems of centralized solutions and eliminates the need for a trusted third party. BCT was an appealing solution due to its immutability, transparency, security, and fault tolerance, at least for trust and traceability, and there were already many real use cases in the SC [37]. An end-to-end solution for BCT-based Agriculture and Agri-food SC was presented [38], and provided detailed information of proposed solution in terms of traceability, trading, delivery and reputation. A critical driver of BCT adoption in the Agri-food industry was food safety concerns [39]. A vertically coordinated ecosystem and tracking and tracing information are needed for successful implementations. the most relevant case studies of Agri-food SC traceability using BCT and other distributed ledgers technologies was discussed in [40]. They also suggested a logical scheme in order to favor the identification of the BC structure to be more appropriate for each Agri-food SC. As in [41], a framework was proposed based on the consortium and smart contracts to track and trace the workflow of Agri-food SCs, implement traceability and shareability, break down the information islands, eliminate the need for the central institutions and agencies and improve the integrity of the transaction records, reliability and security. Reference [42] described the working principle of BCT for data recording and tracking, summarized the collaboration models for the current BCT applications on Agri-food. They discussed specific utilization of BCT to enhance safety and quality of Agri-food in four aspects: enhance the data transparency, realize data traceability, improve the food safety and quality monitoring, and reduce the cost of financial transactions. systematic literature review approach was used in [43] to analyze the findings of existing literature, focusing on fundamental research themes, research gaps, and the direction of future research on the impact of BCT adoption in the Agri-food SC. They found that key factors of BCT utilizing in Agri-food SC mainly because the BCT can solve these problems of Agri-food, such traceability and transparency, safety and security, supply and logistics, integrity, environmental awareness, and waste.

The study believes that Agri-food SCC is a subject with cross disciplinary characteristics, which can be literally divided into three aspects: Agri-food, SC and collaboration. The three aspects of different combinations, different perspectives, and different focuses interact and integrate with each other, resulting in ever-changing research and achievements. With the development of technology, researchers have found that the application of BCT is more direct and efficient in breaking through the Agri-food SCC problems. However, due to the fact that BCT integration has not formed an Agri-food SCC model, which still needs systematic breakthrough.

B. Key Fitting Points

The integration of BCT into Agri-food SCC offers a plethora of opportunities for enhancing transparency, traceability, and efficiency. Here are some key fitting points of Agri-food SCC and BCT from the statistics of the third part.

(a). Smart Contract

The self-executing contracts with the terms of the agreement directly written into code can automatically enforce and execute specific actions when predefined conditions are met. This can reduce the need for intermediaries, streamline operations, and ensure contractual obligations are met in the agri-food SC [44]. Through the comparative institutional analysis at the micro-level, reference [45] pointed out that the production and sales of Agri-food SC should be dominated by the quasi market (quasi enterprise) in the form of intermediate organization, rather than pure farmers, enterprises or governments. The organization evolution of Agri-food SC in the modes of Enterprise & Farmer and Quasi-integration was regarded as an institutional change [34]. Based on contract management, the contract types of different Agri-food SC organization modes were compared, and believed that commodity contracts were more suitable for loose Agri-food SC organization modes than factor contracts [46].

Smart contract is unique because it may be programmed with self-executed code [35]. A smart contract is a commitment between parties involved in a transaction that keeps each party responsible and ensures the contract is enforced. Smart contract is automatically activated when specific criteria is met. It can assist BCT overcome shortcomings of transparency, tracking, efficiency, and security [47]. During Agri-food SCC, there were multiple levels of transactions, each level with different terms and conditions [48]. Different kind of Agri-foods has diverse characteristics and functions, which are collaborated in a SC, including food processing, transportation, storage,

and distributors [49]. All these processes maintain a record. Smart contracts can assist in simplifying the whole process and enhance transparency throughout the SC [35]. Integrated with BCT, smart contracts enable tracking ownership rights changing across the SC [49]. Besides this, smart contracts enable companies and customers to determine the quality of the food products by tracing back all the information [50]. The characteristics of smart contracts, acquired from the core BCT, enable their use in diverse applications [48].

(b). Trust

In the relationship management of Agri-food transactions, the trust level of farmers and enterprises plays an important role in the stability of cooperation [51]. Trust is considered to be one of the core elements of Agri-food SCM. It can increase trust among SC entities through the design of multiple mechanisms such as participant certification, incentives and constraints, increase management flexibility and reduce transaction costs [52] [53]. Trust is a cornerstone in any SC. BCT inherently offers trust as all participants have access to the same version of the ledger, and any changes made are transparent to all [54]. By citing BCT, using the unique properties of BCT, such as decentralization, trustlessness, non-modification, and traceability, in a business society that does not trust each other, the profit distribution of SC partners is more fair and reasonable[55], the cost of trust is minimized, and the use of resources is maximized, and finally a business society with transparent information, simple transaction process and mutual trust is built within the Agri-food SC. a review and evaluation was conducted in [56] on the conditions and functions of trust in the Agri-food SC, and evaluated the trust level in different stages of the Agri-food SC.

An increasing number of studies have proposed BCT-based solutions for tracing transactions and items along the SC [57]. Through its traceability mechanisms, BCT could become a source of change in today's conventional ways of extracting and delivering value by acting as a new means for achieving trust among partners and stakeholders [58]. Based on interviews with SC experts, reference [59] argued that traceability through BCT can enable information sharing and build trust among stakeholders along the SC. The implementation of Agri-food SCC traceability, by means of BCT, would also help establish a relationship of trust between consumers and producers by guaranteeing transparency on the origin of Agri-food [60].

(c). Quality and Safety Controlling

With the increasing concerns over food safety, BCT can ensure real-time monitoring of products throughout the SC. By integrating IoT devices with BCT, details like temperature, humidity, and other crucial parameters can be monitored, ensuring product quality [61]. It was considered that the root cause of the frequent quality safety accidents of Agri-food in China was the lack of good governance and management in the Agri-food SC under the asymmetric quality information [62]. The quality and safety management of Agri-food SC can improve the control level of Agri-food quality and safety through the organization mode of Agri-food SC. Different organization modes have different impacts on Agri-food quality and safety. The more closely organized the Agri-food SC, the higher the controllability of Agri-food quality and safety [63] [64]. Reference [65] addressed the uncertainty of the quality and safety of Agri-food, and the introduction of BCT can improve the credibility of traceability information on the quality and safety of Agri-food. The operation process from each operation link of the Agri-food SC was analyzed in [25], and it explored the application of BCT in the Agri-food SC quality management system to establish a traceable food safety management system to ensure the quality and safety of Agri-food.

From Agri-food enterprises perspective, BCT can improve the food safety failures by quickly identifying and linking outbreaks back to their specific sources [66]. Everyday an enormous amount of data is generated in the Agri-food SC and recognizing methods to abstract the vital material from diverse sources would assist in bacterial risk evaluation [67], infection source tracking [68], which empowers food safety and quality assurance. In the Agri-food SCC based on the BCT, concurrent supervision [69], RFID tag, GPS, and QR code like digital labeling and improved traceability throughout storage and distribution are a few out of numerous benefits, which can add to the Agri-food SCC safety [49]. BCT and IoT have potential of boosting Agri-food reconnaissance frameworks and performing synergistically by AI-based big data evaluation towards food safety outbursts [70][71]. It is expected that BCT will enhance the privacy and security of Agri-food SCC.

BCT has the potential to alleviate risks and uncertainty and enhance SC with the help of its characters of immutability, traceability, risk management and smart contracts [72]. BCT favors sustainability and fairer SC with better food traceability [73]. According to the European Union General Food Law EC 178/2002, food traceability is the capability of tracking and tracing food in all phases of production, processing, and sales. Traceability in Agri-food SC is becoming more complex since ASCs are getting longer with expanding globalization and increasingly intense competition [74][75]. Empirical studies have found that consumers consider food origin as the most important information to be traced [76][77].

(d). Information Sharing

Efficient SCs are built on seamless information flow. Information sharing is the key to the collaboration of Agri-food SC. Advanced information technology means and organization incentive design for information sharing can optimize the information sharing of Agri-food SC, and ultimately increase organization trust, reasonably share risks and distribute benefits [78]. The application expansion of IT not only improves the information sharing level of Agri-food SC, but also optimizes the Agri-food SCM through the organization evolution induced by technological progress. BCT facilitates real-time sharing of information among all participants, ensuring that all stakeholders have the same, up-to-date information [59]. The research of [79][80] and other scholars shows that on the one hand, network IT can enhance the organization function of Agri-food SC and help to flatten the organization; On the other hand, to some extent, it will produce the effect of alternative organization and de organization. As the development and application of IT continue to deepen, it was believed that the Smart Agriculture based on the IOT and other new generation network technologies will drive the SC of Agri-food to achieve new changes [81]. A BCT-based solution was proposed in [82] to address knowledge sharing problems among the enterprises in a SC so as to ensure responsiveness to market conditions and improve overall SC efficiency. An empirical test was conducted on 367 fruit farmers' research samples and found that SC partners could positively adjust the collaborative management and operation performance in the SC through information sharing [83].

From consumers perspective, BCT addresses concerns about the safety, quality, authenticity and environmental friendliness of Agri-food [84]. This guarantees consumer having access to traceable and transparent Agri-food SC, so as to getting reliable data about how Agri-food is both produced and distributed [60].

IV. A Comprehensive Analysis of Agri-Food Like Rice SCC in China

A. DongNan Rice Description

DongNan Village, located in Changzhou City, Jiangsu Province, China. It has successively established Agricultural Machinery Service Professional Cooperative Commune and Organic Rice Planting Cooperative Commune in the past 10 years. DongNan Rice Smart Farm has been established, relying on BCT and organic rice planting industry as the main body. Local farmers are responsible for planting organic rice and taking care of it. The Village is responsible for collecting and selling uniformly. The series of soft rice produced by DongNan Village has created the Xiashu brand and has successively passed the certifications of Organic Products and Green Food. DongNan Rice Smart Farm has become a pioneer in the application of BCT in the field of Agri-food SC in China. This study takes DongNan Rice Smart Farm as an example to analyze Agri-food SCC with the integration of BCT. DongNan Rice adopts a BCT & Agriculture cloud service platform, coupled with various information technologies such as the IoT, big data, visualization, AI. It innovatively creates a BCT based rice SCC system.

B. Case Analysis

In the production process of farmers, DongNan Rice matches farmers with BCT-based planting management IoT devices. Farmers can automatically obtain basic data in the rice planting process through smart sensing equipment, and automatically obtain data geo-stamping and time stamps. Farmers can also manually judge the changes in seedlings based on experience and supplement the input data. In addition, in the business aspect of farmers, DongNan Rice has developed an APP that meets the business needs of farmers. The APP can conduct integrated, digital and intelligent management of pre-production input purchasing, planting management, sales, financial services and other content required for farmers' operations. At the same time, the operation and

management data are simultaneously uploaded to the DongNan Rice system. Consumers can order rice grown by farmers online through the DongNan Rice system. Farmers can track orders through the APP. Once a sale is made, the rice is inspected and delivered, the BCT-based smart contract will automatically distribute the proceeds to farmers.

DongNan Rice is equipped with mobile IoT terminals for Agri-food production management in the farm, which can conduct comprehensive management of farm land, production materials, and farmers' planting behavior. Data sharing between each APP and mobile IoT terminals. If the data uploaded by farmers and the data collected by farm inspectors meet the standards, it will be uploaded to the system through digital signature confirmation, and a Quality Stamp certified by the DongNan Rice system will be generated, and the rice can be further processed, packaged and sold.

In the downstream processing and circulation links of the rice SC, DongNan Rice has developed an APP for sales. Its data is also shared with other node devices. The data includes rice planting and harvesting data, distribution data, warehousing data, processing and packaging data, etc. Each rice product will be stamped with a BCT-based Geographic Stamp, Time Stamp, and Quality Stamp to ensure the quality and safety of rice products throughout the SC.

DongNan Rice has changed the traditional Agri-food SC model in terms of organizational structure, solved the problems of irregular planting, processing, and circulation in traditional agriculture, and guaranteed the Agri-food safety and quality from the source. The production, logistics, processing, warehousing, social services and other aspects of rice have formed an autonomous and trusted SC ecology with decentralization, distribution according to work and resource sharing in the BCT-based Agri-food SCC. It solves the collaboration problem of partis in the Agri-food SC in a distrustful environment.

Research Gap

A close study of prior literature on Agri-food SCC has revealed that lot of research literature exist on SCC practices of different Agri-food based on BCT [43]. However, these studies all focus on the technical application of BCT, or problems encountered in the Agri-food SCC. There is not much work on the model of Agri-food SCC with the integration BCT. Likewise, little research has been conducted on the important aspects of BCT for fresh Agri-food such as rice in the Chinese context [85]. Furthermore, there is a negligible amount of research on the problems faced by different parties in rice SCC [86], especially technical safety and security problems [87] for farmers, Agri-food processors, marketing enterprises, and consumers. In this context, research work is carried out to explore the model of Agri-food SCC with the integration of BCT, as well as the technical safety and security problems of different partis in each link of SC, and to derive specific solutions [88].

Conclusion

To put on a nutshell, integrating BCT into the Agri-food SCC can address many of its inherent challenges and revolutionize the way it operates. This paper conducts a comprehensive literature review on Agri-food SCC with the integration of BCT, so as to pinpoint the fitting points of the two domains. The study counted articles from major databases and publications in the past 10 years. The study found that most journals or books on this topic mainly focus on theoretical research. Only a few articles really focus on the practical aspects of Agri-food SCC with the integration of BCT. This study analyzes the literature from the overall perspective and four fitting points of Agri-food SCC and BCT, namely smart contract, trust, quality and safety controlling, and information sharing. It has been observed that Agri-food SC application based on BCT mainly focuses on the technical development and problem research of BCT, and noteworthy research also includes the model of Agri-food SCC integrating BCT. However, important practical model problems related to Agri-food SCC implementation based on BCT are rarely covered, such as the various partis in SCC and the technical safety and security problems faced by each party. These require further in-depth research.

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