

# REVERSE LOGISTICS IN AGRI-FOOD SUPPLY CHAINS: A SYSTEMATIC LITERATURE REVIEW

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## ABSTRACT

*This paper aims to explore, through the analysis of 153 scientific articles (1998-2023), how reverse logistics contributes to reducing food and packaging waste, decreasing greenhouse gas emissions and improving agri-food supply chain efficiency. The research pays particular attention to reverse logistics' role within a circular business model in a) reducing food waste, and b) mitigating the system's contribution to climate change by reducing greenhouse gas emissions. The main subject areas related to reverse logistics, analyzed in the literature, include waste management, inventory optimization, packaging management and the perishable nature of food products. The review highlights the growing importance of reverse logistics in reducing food waste, managing packaging, and addressing the challenges related to the perishable nature of food products. The findings also highlight reverse logistics as a key tool for applying circular economy strategies, pointing to challenges that require greater integration across the different food supply chains, collaboration between different economic agents of the agri-food system and stakeholders, and policy support. The study identifies key barriers such as inadequate infrastructure, high costs, and a lack of coordination among supply chain actors. In response, the literature suggests solutions including investments in cold chain systems, improved traceability, and supportive public policies.*

## KEYWORDS

*reverse logistics; agri-food supply chains; food waste; circular economy; sustainability*

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## INTRODUCTION

Nowadays, climate change is one of the world's most critical environmental challenges. The effects of climate change caused by human activities require a fast and significant review of all human activities, including those related to the agri-food system (Accorsi et al., 2022; Nellemann et al., 2009). While agriculture provides significant benefits, such as contributing to the socio-economic growth of many countries and reducing poverty, it is also one of the major drivers of global emissions, accounting for about 10–12% (Nsabiyeze et al., 2024). According to the latest IPCC Report (2023), the global temperature has already risen by about 1.1°C compared to the time before industrialization. This increase is having a stronger impact on food and water security in the most vulnerable regions. Agriculture, forestry, and land use account for approximately 22% of global greenhouse gas (GHG) emissions. This data underscores the urgent need to participate in food systems not only at the production stage, but also across the supply chain. In this context, reverse logistics can reduce emissions by minimizing food waste and optimizing the return and reuse of materials, particularly packaging and unsold products. Moreover, unsustainable agricultural practices can cause air and water pollution, soil erosion, and biodiversity loss (Horrigan et al., 2022). In addition, how food is produced, distributed, consumed, and food waste is managed are closely connected to issues such as water scarcity, land degradation, and climate change (Araújo et al., 2023). In particular, several studies (Urugo et al., 2024) demonstrate that food waste significantly contributes to GHG emissions, land degradation, water scarcity, and energy inefficiency. This highlights the importance of reducing the environmental impacts of food waste.

These environmental problems show how closely the agri-food system is connected to major global challenges. Because the food system is so complex and connected to many issues, the whole food system needs to evolve and to adapt to changing circumstances, including climate change, and mitigate the various negative impacts it can cause. Hence, the entire food system must adapt to the evolving social and environmental challenges brought about by climate change (IPCC, 2023).

This transition of the agri-food system towards a more sustainable model also involves the evolution from a linear to a circular model. In this context, it is also necessary to adapt distribution and logistics activities, which in more developed countries significantly influence the organization of agri-food supply chains. In this scenario, reverse logistics assumes a strategic function. In fact, reverse logistics, in the last decade, has gained significant global attention due to challenges such as climate change, environmental protection, resource scarcity, sustainable business practices, and social responsibilities (Agrawal et al., 2015; Govindan & Soleimani, 2017; Govindan et al., 2015; Kazancoglu et al., 2020).

Reverse logistics involves processes such as returns, collection, recovery, repairing, refurbishing, recycling, remanufacturing, or disposing of products that

are used, unconsumed, or have reached the end of their life cycle (Ilgın & Gupta, 2010). It plays a crucial role in helping businesses achieve sustainability goals by making their supply chains more environmentally friendly. Reverse logistics focuses not only on optimizing profits and costs, but also on following green principles and environmental regulations. Its primary goals include minimizing waste and making efficient use of resources at every stage of the supply chain (Mutingi, 2013; Kazancoglu et al., 2020).

The concept of reverse logistics has been adopted in different industries, including manufacturing, electronics, and garments (Islam & Huda, 2018; Tan & Kumar, 2006; Kazancoglu et al., 2020). In the food sector, reverse logistics activities are crucial to reduce food waste and to ensure efficient logistics operations. Food waste and loss negatively impact the environment and contribute to higher GHG emissions and pollution (Kazancoglu et al., 2020). These impacts can be reduced by minimizing unnecessary transportation (Frei et al., 2020). Integrating reverse logistics into the food supply chain can help reduce food waste and losses.

Reverse logistics activities are critical to maintaining high quality and food safety because of products' rapid spoilage and short shelf life (Vlachos, 2014). Moreover, reverse logistics activities in food supply chains with perishable products represent a key focus in supply chain management (Deng et al., 2019).

This review helps to better understand the role of reverse logistics in supporting circular economy strategies in agri-food supply chains. Instead of seeing reverse logistics only as a way to manage waste, this study shows that it can help companies become more efficient, innovative, and sustainable. Policymakers and managers can use these ideas to make agri-food systems more circular and resilient. Researchers are encouraged to consider reverse logistics an essential part of the circular economy, not just a separate activity.

Based on the reviewed literature, this paper suggests the following research questions (RQs):

- RQ 1: Does reverse logistics help improve the sustainability of agri-food supply chains by reducing food waste and GHG emissions?
- RQ 2: Does reverse logistics help face challenges such as waste management, inventory routing, packaging, product perishability, and the need for strong collaboration among actors in agri-food supply chains?

The paper is structured as follows: Section 1 introduces the concept of sustainability in agri-food supply chains. Section 2 presents the aim, materials, and method used for the systematic literature review. Section 3 reports the main results of the review, organized into five thematic subsections: waste management (3.1), inventory routing (3.2), packaging (3.3), the perishable nature of food products (3.4), and a discussion of challenges and strategies in reverse logistics in agri-food supply

chains (3.5). Finally, Section 4 concludes the paper by summarizing key insights and outlining implications for policy and future research.

## 1. SUSTAINABILITY IN THE AGRI-FOOD SUPPLY CHAIN

The OECD (2023) defines sustainability in the agri-food sector as an approach to agriculture that preserves environmental balance through the responsible use of resources and production methods. According to this definition, sustainable agriculture is based on three key pillars: resource sustainability, economic sustainability for operators, and health sustainability for operators. These three pillars (dimensions) of sustainability are significantly influenced by the specific characteristics of the agri-food system and its dynamics.

Indeed, agri-food supply chains face various sustainability challenges. Key issues include losses during pre- and post-harvest stages, imbalances between demand and supply, rising prices, consumer demand for safe and high-quality foods, nutritional security concerns, and the impacts of climate change. Additionally, unsustainable practices in the use of land, water, and energy further intensify these challenges (Bhat & Jōudu, 2019). From an environmental perspective, these issues extend to waste management and handling food industry waste (Bhat & Jōudu, 2019; Headey, 2013). These operational and environmental inefficiencies highlight the urgent need to reorganize agri-food supply chains to better match supply and demand, generate added value, and reduce environmental impacts. This can be achieved by reducing the use of raw materials and resources and promoting the reuse and valorization of food industry by-products and waste (Govindan, 2018). The sustainable transformation of these materials into value-added products can play a key role. Efficient valorization helps mitigate environmental issues by reducing pollution and overuse of resources (Ben-Othman et al., 2020).

A helpful strategy to address these sustainability challenges is the circular economy, which offers an alternative to the traditional model of production and consumption. Rather than focusing only on end-of-life waste management, this approach emphasizes the reuse and valorization of by-products and food waste across the entire supply chain (Chiaraluca et al., 2021). The circular economy can support a more resource-efficient and resilient agri-food system in this context.

Yet today, only 8.6% of the global economy can be considered circular (Hamam et al., 2021). The low percentage of circularity in the worldwide economy underlines the need for a transition towards a more circular and sustainable economy. Circular economy focuses on the responsible production and reuse of natural resources, while considering medium- and long-term impacts on the environment and society (Araújo et al., 2023).

An approach in line with the circular economy model (Ellen MacArthur Foundation, 2013) bases its sustainability paradigm on the three “R” principles: Reuse, Reduce, Recycle. “Reuse” refers to extending the shelf life of food products and accessory products such as packaging and pallets for transportation; “Reduce” refers to minimizing resource consumption, packaging, product losses along the supply chain (food loss), and the purchase of unused products (food waste); and “Recycle” refers to the recycling of non-reusable waste, such as packaging from perished or expired food products (Gonçalves & Maximo, 2022; Miranda et al., 2021).

This approach and others include different interventions to mitigate environmental impacts on both the demand and supply sides concerning agricultural activities (Scherer & Verburg, 2017), the food industry, and the entire supply chain. Within this circular economy approach, reverse logistics plays a key role by enabling the return, recovery, and redistribution of products and materials throughout the supply chain (Frei et al., 2020), including the agri-food sector.

In circular economy systems, reverse logistics is becoming more critical as a key strategy for improving sustainability, despite challenges related to its organizational efficiency across the supply chain. Both industry operators and researchers from different disciplines are exploring how to implement closed-loop supply chains, which are defined as “the design, control, and management of a system to maximize value creation throughout a product’s entire lifecycle, with dynamic value recovery from different types and volumes of returns over time” (Govindan et al., 2015). In this context, the circular economy has become a helpful approach in agri-food supply chains, aiming to reduce environmental impact and improve resource efficiency.

Reverse logistics plays a crucial role in this transition, enabling the collection, reuse, and recycling of products and materials across the supply chain (Sonar et al., 2024). As such, it represents a practical way to apply circular economy principles in the agri-food sector.

## 2. AIM, MATERIALS AND METHOD

This study describes the current state of reverse logistics systems in agri-food supply chains, focusing on their role in supporting sustainability and circular economy practices.

This review follows the main steps suggested by the PRISMA 2020 guidelines (Page et al., 2021) to make the research process more transparent and easier to follow. Although the review was not formally registered and no risk-of-bias assessment was carried out, the standard PRISMA stages -identification, screening, eligibility, and inclusion - were followed.

The literature search was carried out using the Scopus database, where we applied a set of keywords: “reverse logistics”, “food”, “agri-food”, “food waste”, “food

loss”, and “packaging”. Boolean operators (AND/OR) were used to combine the keywords and filter the results. This search returned 172 articles published between 1998 and 2023, written in English and from peer-reviewed journals or selected conference proceedings.

In addition to these articles, we manually selected 49 further papers from Google Scholar. These articles were not collected through a systematic keyword search but rather identified as relevant by reading titles and abstracts from a much larger set of results. They were added because of their thematic relevance and contribution to the topic of reverse logistics in agri-food systems.

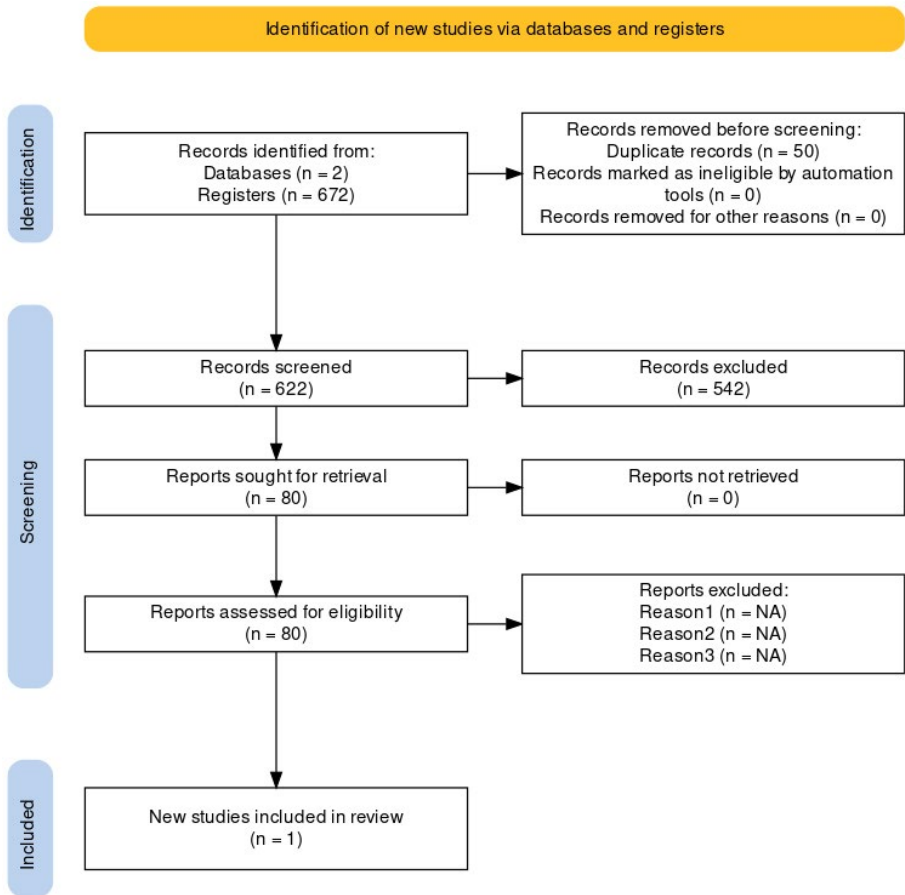
The total number of articles considered for initial screening was 221. A two-step screening process was applied to select the final set. In the first step, titles and abstracts were reviewed, and 68 articles were excluded for being out of scope (for example, studies focused only on medical topics or not related to reverse logistics). The exclusion criteria were: 1) studies not focused on reverse logistics, and 2) articles related only to the medical field.

In the second step, we assessed the full texts of the remaining articles and selected 153 studies for the final synthesis. The inclusion criteria were: 1) articles in English, 2) peer-reviewed journal articles, and 3) studies about reverse logistics in the food or agri-food sector.

Each article was analyzed using a qualitative and thematic approach. The studies were grouped by: 1) type of research (conceptual, empirical, case study, review); 2) main topic, such as optimization methods, food waste, waste recycling, packaging, perishable goods, GHG emissions, food safety, food security, environmental, economic, social and institutional aspects; 3) geographical area, and 4) whether they contribute to sustainability or circular economy practices.

The method used in this review is similar to other systematic literature reviews on reverse logistics, such as the ones by de Paula et al. (2020) and Prajapati et al. (2019). While our review does not include quantitative synthesis or use bibliometric software like NVivo or VOSviewer (de Paula et al., 2020), it follows a comparable structure for organizing and thematically analyzing the literature. Like Prajapati et al. (2019), we applied a thematic approach to review the literature on reverse logistics. While their work focuses on research techniques and industry sectors, our review focuses on contributions to sustainability and the circular economy in agri-food supply chains. The PRISMA checklist and a simplified flow diagram (Figure 1) show the selection process. The PRISMA 2020 checklist was adapted for this qualitative review. Items not applicable to non-quantitative systematic reviews (e.g. effect measures, meta-analysis, risk-of-bias assessment) were omitted.

Figure 1. - PRISMA Scheme for retrieving the relevant articles.



Source: Authors' elaboration

### 3. RESULTS

In recent years, there has been growing scientific interest in reverse logistics within agri-food supply chains. Between 2019 and 2023, 63% of analyzed papers were published in this field, indicating an increasing focus on this topic. Case studies are primarily found in Europe (39%) and the Americas (29%), with many of them from South America (70%), especially Brazil. Among the European countries, Italy has the highest number of case studies. Several studies on this topic have also been conducted in Asia (22%) and Africa (10%). The analyzed topic adopts a multidisciplinary approach, with most publications appearing in fields such as management and business, engineering, and environmental sciences. The prevalent issues that

emerged are food waste management, technical aspects, like transportation and cost optimization, packaging, the perishable nature of food products and environmental issues. These topics are often interconnected in the analyzed literature. The economic and environmental dimensions are the most analyzed areas in the papers, while the social dimension is the least addressed aspect of sustainability.

A summary of the key studies reviewed for each thematic area is provided in Appendix 1 (Tables 1–4).

### 3.1. WASTE MANAGEMENT

The increasing concern about landfill waste, especially food waste, strongly motivates food manufacturers and distributors to adopt reverse logistics strategies to optimize waste management. These strategies help reduce environmental impact and generate value from waste.

One relevant contribution is from Vijayan et al. (2014), who investigated the adoption of reverse logistics in Malaysian supermarkets. The study highlights that the Malaysian food retail sector is worth 15 billion USD and is expected to grow by 10% annually. However, the sector remains fragmented, with 56% of outlets being small grocery stores and 43% supermarkets or hypermarkets. This fragmentation is one of the key barriers to the broad adoption of reverse logistics. The study identifies essential drivers and obstacles and highlights the role of reverse logistics in improving waste handling and supporting sustainability in the food retail industry. Among the most significant barriers are consumer indifference toward green retail practices, lack of expert guidance, absence of government policies, lack of tax incentives, and the fact that reverse logistics adoption is not mandatory for retailers.

Gholipour et al. (2023) present a design for a closed-loop supply chain (CLSC) for the pomegranate sector in Iran, where about 1.5 million tons of waste are produced annually. The proposed model uses reverse logistics to convert wasted pomegranates into valuable products such as bioethanol (used as fuel) and compost (used as fertilizer). This system reduces environmental damage, improves profitability for producers, and promotes circular economy principles.

Beheshti et al. (2022) focus on urban food waste recycling. Their model involves using reverse logistics to collect expired or unused food from urban sources, such as restaurants and stores and transporting it to recycling facilities located outside the city. The study introduces a Quantity Flexibility (QF) contract model to improve coordination between the actors involved. This contractual mechanism allows the buyer to adjust the initially agreed quantity based on actual demand or recovery levels, reducing the risks associated with over- or under-utilization of recycling capacity. The approach has been shown to increase profits for waste collectors by up to 30% while supporting more efficient planning and reducing food waste disposal in urban areas.

Another significant study by Lagarda-Leyva et al. (2023) integrates reverse logistics with dynamic modelling to improve waste management in the food service provider sector. Dynamic modelling is applied to simulate and analyze complex systems to understand how key variables interact over time. In the field of waste management, it supports decision-making by generating different scenarios and identifying the effects of policy or operational changes (Lagarda-Leyva et al., 2023). In their case study, if 35% of the waste is reused, the recovered value reaches €35,000 per month from biofuel (11,000 liters), €13,100 from compost (7.5 tons), and €69,600 from soap (1,960 liters). The study supports decision-making by generating different waste management scenarios and shows how reverse logistics combined with modelling can help reduce waste and create new business opportunities.

These studies show that reverse logistics, combined with the right tools and policies, can play a key role in improving waste management in the agri-food sector while also supporting economic and environmental sustainability.

To improve clarity and allow comparison across the reviewed studies, Table 2 summarizes the main features of each contribution. It presents the context, methods, key results, and sustainability impact related to reverse logistics in waste management.

### 3.2. INVENTORY ROUTING

The inventory routing problem (IRP) is a central issue in the optimization of reverse logistics, especially when dealing with the collection of returns, donations, and waste. Inventory and routing decisions should be made simultaneously to minimize both inventory and transportation costs while ensuring efficient recovery operations (Shirzadi et al., 2021). Key goals include determining optimal routes, shipment quantities, and inventory control strategies over time (Wang et al., 2019; Nair et al., 2018; Mehrbakhsh & Ghezavati, 2020).

Gutiérrez-Sánchez and Rocha-Medina (2022) conducted a taxonomic review of Vehicle Routing Problem (VRP) variants applicable to donation collection logistics. They analyzed 133 papers and classified them into models such as VRPTW (with time windows), VRPB (with backhauls), and PVRP (periodic vehicle routing problem). Their findings underline the logistical complexity in food donation routes due to limitations like vehicle capacity, time windows, and product perishability. For example, a donation collection route involving perishable (e.g., food) and non-perishable items may need to visit up to 14 donors per day, with route distances and donor availability significantly impacting the feasibility and cost-effectiveness of operations. The use of customized VRP models has been shown to reduce operational costs and support circular practices especially when perishable items are involved.

In the Italian context, Bottani et al. (2019) assessed different reverse logistics scenarios for the collection of packaged food waste (PFW) in the Emilia-Romagna region. Their study modeled the recovery of 38.056 tons per day of PFW from 1,557 retail stores (RS) using a routing and location model based on real geolocation data and vehicle capacity constraints. The results showed that collecting waste from all RSs is more expensive than landfill disposal—with a logistics cost of approximately €123 per ton, compared to a disposal cost of €110–€120 per ton—but it is environmentally preferable due to the avoided greenhouse gas emissions, as confirmed by their life cycle assessment. The study also demonstrated that optimizing the number and location of distribution centers (DCs) could significantly reduce travel distances and overall logistics costs. For instance, using 7 to 9 strategically placed DCs reduced total transport distance by over 30% compared to a single centralized collection point. These findings highlight the environmental and economic benefits of network optimization in agri-food reverse logistics systems. These studies show that better inventory and routing planning helps lower costs and emissions and also makes agri-food reverse supply chains stronger and easier to expand.

### 3.3. PACKAGING

Reverse logistics plays an important role in the sustainability of packaging systems within the agri-food supply chain. In Brazil, a study by Guarnieri et al. (2020) analyzed the implementation of a national sectoral agreement for reverse logistics of packaging. This agreement aimed to support the transition to a circular economy and included the active participation of waste picker cooperatives. The study revealed that around 90% of recyclable waste in Brazil is collected by waste pickers, who are considered essential actors in the return and recycling processes. Baruffaldi et al. (2019) explored a reusable packaging system for fruits and vegetables in Italy. Their study evaluated different transport scenarios using a decision-support tool based on real supply chain data. The results showed that switching to intermodal transport (such as rail and sea) in a closed-loop network led to a 9.2% reduction in CO<sub>2</sub> emissions and an 11.7% reduction in transportation costs. This evidence supports the idea that logistics optimization in reusable packaging systems can result in significant environmental and economic benefits.

González-Torre et al. (2004) investigated reverse logistics practices in the glass container supply chain in Spain and Belgium. The study surveyed over 400 companies and found that Spanish firms use reusable containers more frequently, while Belgian firms design packaging more often for recyclability and reuse. The study also highlighted that effective collaboration with suppliers and customers, such as joint campaigns or standardized recovery systems that were crucial in achieving successful recycling practices.

Overall, these studies demonstrate the importance of reverse logistics in improving sustainability in packaging systems.

### 3.4. PERISHABLE NATURE OF FOOD PRODUCTS

Reverse logistics in agri-food supply chains faces important challenges related to the short shelf life of many products. Perishable goods require fast and controlled return processes to avoid waste and ensure food safety (Baranau & Lisec, 2020). The authors reported that fresh produce and animal products often deteriorate within a few hours if not properly stored, creating additional pressure on logistics systems.

Fasihi et al. (2023) studied the fishing supply chain, focusing on the management of fish by-products. Their model showed that converting by-products into fishmeal and animal feed could reduce CO<sub>2</sub> emissions by 22% and increase profit margins by 18%, while also improving sustainability through recycling. Trienekens et al. (2017) analyzed the logistics of online food retail and highlight how last-mile delivery is significantly influenced by the perishability of food products. According to the authors, last-mile activities can account for up to 75% of total supply chain costs in urban food logistics. Challenges include short delivery windows, fragmented inventory management, and the need for real-time temperature control to maintain product quality. For example, preparing an online order may involve picking 60–80 items across three temperature regimes and delivering them within a 1–2 hour time slot, which significantly increases operational complexity and costs. The study also reports that 67% of surveyed consumers still prefer physical stores for perishable products, mainly due to the importance of appearance and freshness in purchase decisions. While faster delivery improves customer satisfaction, it also leads to higher logistics costs and more complex coordination.

Moisidou et al. (2019) investigated the use of Reusable Plastic Containers (RPCs) in the logistics of fresh fruits and vegetables within a large Greek retail chain. Their study shows that inappropriate packaging and cold chain interruptions are among the main causes of product losses during transport and storage. The use of RPCs is presented as a sustainable solution that helps reduce waste and maintain product quality thanks to better ventilation, temperature control, and ergonomic design. The research, based on interviews with logistics managers and suppliers, highlights the logistical and environmental benefits of reusable packaging systems, such as reduced damage, better shelf appearance, and lower logistics costs. Minor issues include poor coordination between partners and higher initial investment costs compared to disposable packaging.

Together, these studies show that reverse logistics for perishable products should combine speed, environmental control, and appropriate recovery strategies to reduce waste, losses and support circular practices in agri-food systems.

### 3.5. DISCUSSION

Reverse logistics in agri-food supply chains faces several challenges that need to be addressed to ensure sustainability and efficiency.

One of the main difficulties is the perishable nature of food products, which requires rapid handling, specialized storage, and controlled temperature along the return process. These requirements increase costs and complexity (Baranau & Li-sec, 2020; Fasihi et al., 2023; Moisdou et al., 2019).

Another challenge is the lack of adequate infrastructure, especially in rural areas or in developing countries, where cold chains and collection centers are limited (Fonseca & Vergara, 2014). In addition, many food supply chains are fragmented and include small producers or retailers who often lack the financial or technical capacity to implement reverse logistics solutions on their own.

To overcome these barriers, several strategies can be applied. First, investments in cold chain infrastructure can improve efficiency (Moisdou et al., 2019). Second, cooperation between actors is essential. Vertical collaboration between producers, distributors, and retailers can lead to more coordinated and shared systems (Guarnieri et al., 2020). Third, public policies and incentives may be necessary to support the adoption of reverse logistics, particularly for small and medium-sized enterprises (SMEs) that often operate with limited resources and may not have access to the infrastructure or knowledge required to implement these practices effectively (Vijayan et al., 2014).

In addition to organizational and infrastructural aspects, digital technologies are emerging as enabling tools to support reverse logistics. Recent studies have highlighted the potential of digital technologies to support the implementation of reverse logistics in agri-food systems. For instance, Mohajeri et al. (2021) propose an integrated model that combines IoT, mobile apps, and smart composting devices to manage food waste at the household level. Their system enables real-time traceability, citizen participation, and more efficient planning of collection and recycling activities. Similarly, Gholopour et al. (2023) explore the application of blockchain in agri-food supply chains, emphasizing its role in improving transparency, data sharing, and trust among supply chain actors. These tools, although still emerging, could help address key barriers in reverse logistics by enhancing monitoring capabilities, supporting decentralized systems, and fostering stakeholder collaboration.

In summary, addressing these challenges requires a combination of technological innovation, logistical planning, and supportive regulation. Without tackling these issues, the potential of reverse logistics to support sustainability in the agri-food sector remains limited.

#### 4. CONCLUSIONS

This review highlights the essential role of reverse logistics in tackling the environmental, economic, and operational challenges faced by agri-food supply chains. In modern food systems, logistics is key to coordinating flows and ensuring efficiency. Reorganizing logistics operations through circular economy principles, including reverse logistics, is a crucial step toward building more sustainable and resilient supply chains. Reverse logistics contributes to waste reduction, resource recovery, lower GHG emissions, and improved logistics performance. These benefits make it a valuable strategy for supporting climate action and sustainable production. However, its implementation is not without obstacles. Key challenges include managing perishable goods, lack of infrastructure, limited awareness, and insufficient attention to the social dimension of sustainability.

Importantly, the transition toward circular and sustainable food systems involves distributional challenges that have to be addressed. Large retailers and logistics operators often have the resources to adopt reverse logistics systems, while small-scale farmers and SMEs may struggle due to limited funding, technical skills, or access to infrastructure.

To ensure a just transition, it is essential to support these actors with targeted policies, training, and financial incentives that enable their participation in circular practices.

Raising awareness through education and promoting collaborative approaches across the supply chain are also key to increasing adoption. Transportation planning, digital traceability, and policy support are all necessary elements of a successful reverse logistics system.

Future research should further explore the social impacts and equity dimensions of reverse logistics, as well as develop scalable models that can be applied in different territorial contexts. Overall, this review emphasizes the need for continued innovation, public engagement, and institutional support to fully leverage the potential of reverse logistics in achieving a sustainable and inclusive agri-food transition.

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## APPENDIX 1

Table 1. Overview of reverse logistics applications for waste management in the agri-food sector

Study	Context	Method	Key Results	Sustainability Impact
Vijayan et al. (2014)	Food retail sector in Malaysia	Empirical study (survey & analysis of barriers and drivers)	Identified main barriers and success factors in adopting reverse logistics strategies.	Improves waste handling, logistics efficiency, and supports sustainable practices.
Gholipour et al. (2023)	Pomegranate supply chain in Iran	Optimization model for closed-loop supply chain	Transforms pomegranate waste into bioethanol and organic fertilizer; reduces disposal risk.	Promotes circular economy and renewable energy.
Beheshti et al. (2022)	Urban food waste collection	Mathematical modelling	Optimal facility rental strategy increases profit by 30%; reduces food waste in cities.	Reduces environmental impact and improves cooperation among supply chain actors.
Lagarda-Leyva et al. (2023)	Food service provider sector	Dynamic modelling & reverse logistics integration	35% of food waste reused: biofuel (€35k), compost (€13.1k), soap (€69.6k).	Supports waste valorisation and new circular business models.

Table 2. Overview of reverse logistics applications for inventory routing in the agri-food sector

Study	Context	Method	Key Results	Sustainability Impact
Wang et al. (2019)	Inventory and pricing decisions in green supply chains	Optimization model with remanufacturing and government subsidy	Optimal inventory policies identified; green product preference increases with consumer awareness	Supports green growth by reducing pollution and encouraging recycling
Nair et al. (2018)	Food rescue and delivery in Sydney, Australia	Scheduling and routing model	Efficient pickup and delivery schedules for perishable food; improved resource utilization	Reduces food waste and supports equity in food distribution to vulnerable populations
Mehrbakhsh & Ghezavati (2020)	Closed-loop green supply chain with uncertain demand	Multi-objective model	Balanced inventory-routing model minimizes costs and emissions; emphasizes recovery and reuse	Reduces GHG emissions, raw material use, and promotes circular economy practices
Gutiérrez-Sánchez & Rocha-Medina (2022)	Collection of donations (food, clothing, recyclables)	Taxonomic review of VRP models	VRP models reduce operational costs and inefficiencies	Supports environmental sustainability through waste reduction
Bottani et al. (2019)	Food waste collection in Emilia-Romagna (Italy)	Custom model for logistics routing	Improved planning reduces costs and GHG emissions	Promotes more efficient and greener transportation

Table 3. Overview of reverse logistics applications for packaging in the agri-food sector

Study	Context	Method	Key Results	Sustainability Impact
Guarnieri et al. (2020)	Packaging waste system in Brazil	Case study on national sectoral agreement	Identified key role of waste picker cooperatives	Promotes recycling, inclusion, and circular economy
Baruffaldi et al. (2019)	Reusable packaging for fruits and vegetables in Italy	Decision-support tool and scenario analysis	Intermodal transport reduces CO <sub>2</sub> by 9.2%, costs by 11.7%	Improves transport efficiency and reduces environmental impact
González-Torre et al. (2004)	Glass container supply chains in Spain and Belgium	Survey of over 400 companies	Collaboration improves recycling	Encourages sustainable design and collaboration

Table 4. Overview of reverse logistics applications for perishable nature of food products in the agri-food sector

Study	Context	Method	Key Results	Sustainability Impact
Baranau & Liseć (2020)	Reverse logistics for perishable agro-food products	Analysis of operational issues and logistics practices	Highlights challenges due to food perishability: safety risks, high costs, and disruptions in logistics processes	Emphasizes the need for tailored logistics, improved tracking, and cold chain infrastructure to reduce waste
Fasihi et al. (2023)	Fish by-products reuse in fisheries	Optimization model	By-products reused reduce CO <sub>2</sub> by 22%, increase profit by 18%	Reduces emissions, waste, and improves resource recovery
Trienekens et al. (2017)	Last-mile logistics for online food retail	Review of urban delivery challenges	Fast delivery increases complexity and costs	Identifies trade-offs between convenience and sustainability
Moisidou et al. (2019)	Reusable Plastic Containers (RPCs) in fresh produce	Interviews with logistics managers and suppliers	Better ventilation and temperature control reduce losses	Improves food quality and reduces waste