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From farm to fork: Examining the differences between local and global food supply chains

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ABSTRACT

Food contamination varies in frequency and severity. Differences between local and global food supply chains were identified with regard to seven drivers of change contributing to uneven emergences of food safety risks. Results revealed that local food supply chains were considered more environmentally friendly than global food supply chains, case-by-case assessment was advised to evaluate sustainability, and global food supply chains were considered to have enhanced food safety measures, higher adoption of advanced technology, higher levels of traceability, provide greater food security, contribute more to economic growth and integrate more sophisticated data management systems compared to local food supply chains.

1. Introduction

Food travels from the producer to the consumer through different stages in the supply chain such as farming, harvesting, processing, distributing, retailing and consumption. Local food supply chains (LFSC) generally refer to food supply chains with proximity between producers and consumers with food being sourced from nearby farms and distributed through few intermediaries. LFSC are short and medium-sized food chain systems with a direct or closest possible relationship between producer and consumer, and refer to three types of systems: where consumers buy a product directly from the producer, where products are sold close to where they are produced and consumers are aware of the local nature of the food products at retail level, and where production and point of sale are not necessarily local but information about the place of production and the producer is communicated to consumers (Augère-Granier, 2016). In contrast, global food supply chains (GFSC) are large-sized food chain systems that involve several intermediaries or touch points throughout their supply chain, considered to provide large amounts of foods that are produced and distributed through points of sale which are globally distributed (Grabs & Carodenuto, 2021).

LFSC are presented as an alternative to GFSC. Consumers perceive local food products as preferable to global food products; however, scholars have impugned this statement because it is mainly based on perceptions rather than on evidence (Polleau & Biermann, 2021; Schmitt et al., 2017). Therefore, it is important to systematically evaluate aspects that affect both food supply chain concepts either positively or negatively to determine whether LFSC perform better than GFSC or whether performance should be evaluated for each criterion separately.

There are a number of issues in food supply chains such as foodborne pathogens, food contamination, cross-border disease transmission, food insecurity and food fraud which are pivotal to consider and control for ensuring consumers a safe food product. Despite policies, regulations, and control processes such as the Hazard Analysis and Critical Control Points (HACCP) that have been adopted to reduce risks in food products, frequent contamination incidences caused by microbiological hazards such as *Salmonella* spp., chemical hazards such as antibiotic residues and pesticides, and physical hazards such as pieces of metals or wood reveal that these food safety issues are still occurring and cause harm to consumers of both local and global food products (Machado Nardi et al., 2020). Antimicrobial resistance (AMR), for instance, is a global public health concern and food safety threat that caused 4.95 million deaths in

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2019 and according to WHO it could cause 10 million deaths each year by 2050 (Murray et al., 2022; WHO, 2023).

Additional challenges for food business operators are the adoption of certain technologies to support their supply chain management, keeping on with the competitive market demands and fulfilling food related legal requirements or regulations. The decision of food business operators to adopt new technologies or migrate from basic to more sophisticated technologies, is largely driven by the needs of their consumers, their budget and their resource allocation (Davies & Garrett, 2018). In this regard, quality and food safety controls make food supply chains traceability a worldwide societal concern. The more intermediaries and the longer distances in a food supply chain, the more complex and challenging traceability becomes for the actors in the supply chain and the less transparent it may be for the consumer (Charlebois et al., 2014). Control strategies with basic technologies and processes might not be precise enough to trace issues like cross-border diseases or cross-contamination in the food supply chain, making more sophisticated traceability systems or tools necessary to ensure accurate and real-time monitoring of movement patterns across countries and multiple intermediaries.

Environmental disruptions and variability also impact food supply chains at local to global scales. These environmental issues may affect food availability, affordability and acceptability. For instance, low rainfall can cause local shortages of certain foods in key producing regions that supply exports to larger economies; in other words, a local environmental variability could affect global-scale food trade networks and impact geographically distant locations and populations (Davis et al., 2021).

Food supply chains are becoming more complex and food security that tends to become prevailing faces a great challenge to be delivered effectively and efficiently (King et al., 2017). Projections of economic growth based on future food demand are subject to uncertainty and not easily predictable. However, according to the latest forecast by the Food and Agriculture Organisation (FAO), food production would need to increase by 54–70 % between 2005/07 and 2050 to feed a world population of 9.1 billion people (Galhena et al., 2013). Therefore, there is a projected global economic growth of about 2.9 percent annually that would benefit local and global food supply chains but at the same time request them a larger production to satisfy the food demand (FAO, 2009; Valin et al., 2014). Sustainability assessment of food supply chains is often associated with environmental dimensions and rarely considers the social, health and ethical dimensions; hence justified findings are less easy to capture (Brunori & Galli, 2016). In this sense, local food products have been marketed as a diverse and sustainable alternative against the standardized global food products.

Inadequate data management and information inaccuracy create inefficient supply chains, a pivotal issue in agri-food chains (Kamble et al., 2020). Nowadays food supply chains are becoming more data-driven and digital. Data is collected at different steps of the supply chain and therefore, data management systems are fundamental to ensure compliance with regulations, quality of data and support identification of the sources of food contamination in case of foodborne outbreaks or pro-active recalls (Astill et al., 2019; Galvez et al., 2018).

Within the framework of the European Union's Horizon Europe Research and Innovation programme, the FoodSafeR project aims for the development of future-proof tools to support proactive and holistic food safety management systems with a key focus on emerging microbiological or chemical hazards and associated risks (FoodSafeR, 2024). It is pivotal to acknowledge the differences of LFSC and GFSC and their strengths and weaknesses to provide support with results-oriented resources such as designing tools to targeting deficiencies of each food supply chain. For the abovementioned reasons, a literature review was conducted to provide an overview of how food security, food safety compliance, digital technologies in food production, environmental protection aspects, economic growth, sustainability, and data management determine and influence the performance of LFSC and GFSC to provide evidence-based support in their supply chain processes.

2. Methods

As part of the EU FoodSafeR project, a qualitative review of the scientific and grey literature was conducted, focusing on seven drivers of change that influence main characteristics and peculiarities of short, medium and large size food chain systems and could contribute to the occurrence of food safety risks in local and global food supply chains.

Selection of drivers of change:

Within the EU FoodSafeR project, an online workshop on "Drivers for emerging food safety hazards" was carried out in work package 1 in April of 2023, in which drivers for food safety risk emergence were analysed aiming for improvements in the management of European food systems. Characterization and prioritization of selected drivers were performed based on volatility, impact, probability and severity of associated hazards. The workshop gathered 19 academic, research and industry organizations from across Europe as well as the 22 global multi-actors of the EU FoodSafeR Advisory Board, a hub that encompassed scientific, national and international business partners, food safety authorities and stakeholders, technology small-to-midsize enterprises and start-ups from the food system. The EU FoodSafeR Advisory Board members include representatives from the Agrifood Systems and Food Safety Division of FAO (ESF); the Joint Research Centre of the European Commission; the U.S. Department of Agriculture (USDA); FAO/WHO Codex Alimentarius; the China National Center for Food Safety Risk Assessment (CFSA); the Academy of National Food and Strategic Reserves Administration (Academy of NAFRA); the U.S. Food and Drug Administration (FDA); the consumer organisation 'Testaankoop' in Belgium; the Food Research Division of Health Canada; the Singapore Food Agency (SFA); Agriculture and Agri-Food Canada (AAFC); the International Institute of Tropical Agriculture (IITA); the International Life Sciences Institute (ILSI); FoodDrinkEurope; the Federal Agency for the Safety of the Food Chain (FASFC) in Belgium; the Thammasat University (TU); the Babcock University; the Kansas State University; the National University of Rio Cuarto (UNRC); the Michigan State University (MSU); Arbeitsgruppe Zukunft Landwirtschaft in Austria; University of Nairobi (UON) and the European Food Safety Authority (EFSA). The outcomes of the workshop revealed that respective sub-drivers and indicators were necessary to identify barriers and trends of food safety risks and to determine measurable factors that point to or are related to the occurrence of hazards and associated risks (Neuberger et al., 2024).

For the purpose of this study and taking into account the EU FoodSafeR project and Work package 1 focusing only on the food safety aspect, a key driver analysis centered around the idea of the influence that specific fields (drivers of change) have on a particular area of interest (targets) was performed (Gell, 2023). The key driver analysis along with a qualitative scientific and grey literature review of the following seven drivers of change: food safety compliance, food security, digital technologies in food production, environmental protection aspects, economic growth, sustainability, and data management was carried out to qualitatively assess and rate them based on comprehensive information found on the literature, and to determine the differences in terms of performance between LFSC and GFSC. These two models of food supply chains were considered the targets and the drivers of change were selected based on the participatory approach of scholars made in the EU FoodSafeR Work package 1 workshop and the frequency of occurrence observed in the literature search. This analysis was executed to achieve one of EU FoodSafeR Work package 2 objectives, to addressing microbiological hazards and related risks with a focus on pathogenic bacteria, viruses and antimicrobial resistance traits, from short supply chains and conventional supply chains.

Literature search:

Keywords; drivers of change "food safety compliance", "food security", "digital technologies in food production", "environmental protection aspects", "economic growth", "sustainability", "data management"; and targets "local food supply chains", "global food supply chains"; were systematized by a conceptual literature review utilizing Google Scholar, Web of Science, EUR-Lex and Eurostat databases for an optimal search to guarantee adequate and efficient coverage of literature. Additionally, keywords of relevant derivative concepts e.g. "food-related incidents" and "smart food traceability system", were searched to cross-reference and deepen results. The selected articles underwent a qualitative content analysis consisting of condensing the material to the essential findings without restricting content.

Evaluation of drivers of change:

Drivers of change were evaluated qualitatively using an Importance-Performance matrix, also known as key driver analysis matrix, in which the drivers' relative importance was attributed to the horizontal axis while the vertical axis represented the drivers' performance. 6-point importance and performance scales, with a qualitative rating of low, mean and high, and 1 to 6 numeric values, were elaborated for rating and positioning the drivers of change in the Importance-Performance matrix. The 6-point importance scale is described as follows: (1) driver of change never comes into consideration as it is of low importance, (2) driver of change does not usually come into consideration as it is of low importance, (3) driver of change comes less often into consideration as it is of low importance, (4) driver of change comes more often into consideration as it is of high importance, (5) driver of change comes usually into consideration as it is of high importance, and (6) driver of change comes always into consideration as it is of high importance, whereas the 6-point performance scale follows this description: (1) driver of change has consistently low performance, (2) driver of change has usually low performance, (3) driver of change has less often low performance, (4) driver of change has more often high performance, (5) driver of change has usually high performance, and (6) driver of change has consistently high performance. The exact position of each driver of change, considered as a term, was agreed by the authors based on the term frequency found in the literature followed by the opinion of experts contributing to the EU FoodSafeR Work package 2 for consistency and validity of the rating and to address modifications when needed, hence to ensure transparency of the drivers' assessment process. As the drivers of change and targets were the independent and dependent factors, respectively; the greater the relative importance, the greater a driver's contribution to influencing the target (IfM, 2016; Survalyzer, 2023). The outcomes of the evaluation of drivers of change could be displayed in a 2 x 2 quadrant chart, and interpreted as follows: the key weaknesses are placed in the bottom right quadrant containing drivers of change that are important but poorly rated and the most relevant quadrant to focus on, the key strengths are placed in the top right quadrant containing drivers of change that are important and highly rated, the unimportant weaknesses are placed in the bottom left quadrant containing drivers of change that are not important and poorly rated, and the unimportant strengths are placed in the top left quadrant containing drivers of change that are not important but highly rated (Figs. 1 and 2) (Klein, 2023).

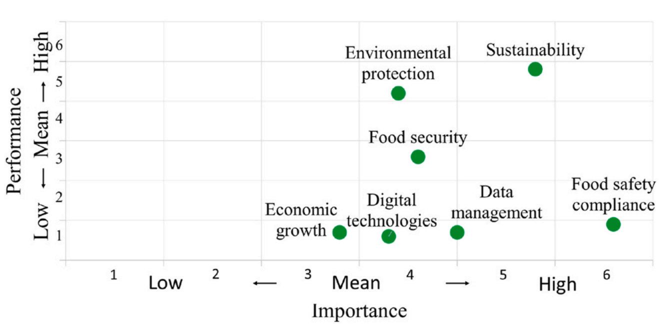

Fig. 1. Drivers of change influencing performance of LFSC.

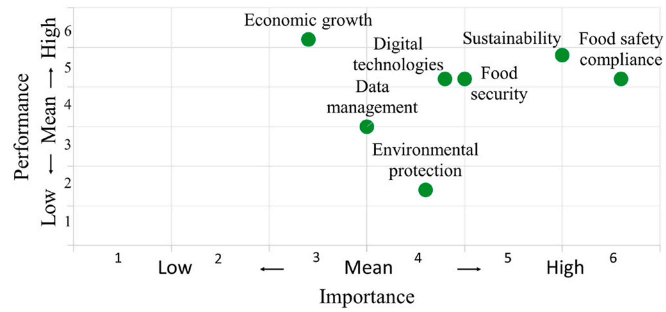

Fig. 2. Drivers of change influencing performance of GFSC.

3. Results and discussion

A qualitative review was carried out to provide an in-depth analysis of drivers of change that influence the performance of LFSC and GFSC.

3.1. Food safety compliance

Literature showed that many LFSC producers struggle with a lower rate of food safety compliance, mainly due to lacking established procedures like Good Manufacturing Practices (GMP) and Good Agricultural Practices (GAP) to avoid food hazards along the supply chain (Macieira et al., 2021). GMP and GAP along with HACCP are essential components of a food safety management system (FSMS) that contains best practices for the control of operating conditions within a food premise. An FSMS ensures the safety and quality of food products as they move through the production and supply chain. Food handlers use FSMS to handle food safety procedures properly and maintain a hygienic environment in their facilities, the processes used by the manufacturer and the personnel handling the food, to protect consumers from potential foodborne illnesses (Hasnan et al., 2022). LFSC do not always follow FSMS principles like HACCP due to being costly, perceived as an unreachable and burdensome process and not beneficial for them. This complexity in the processes as well as understanding obligatory regulations for food businesses like EC Regulation 178/2002 which is laying down the general principles and requirements for food safety or EC Regulation 852/2004 on the hygiene of foodstuffs, leads to reluctance and difficulties among LFSC to implement an FSMS which is more likely to result in food safety issues like food spoilage before the end of shelf life and foodborne illness due to products placed on the market linked to their supply chain, although foodborne outbreaks could be also caused by GFSC operating in nonoptimal conditions. In this respect, another major worldwide food related concern is the presence of antimicrobial resistant bacteria which could affect farmers, workers and consumers if exposed to contaminated food products (European Commission, 2002, 2004; Founou et al., 2016). Concerns are also raised about the safety standards of LFSC since food safety might be less efficiently monitored in products of smallholdings. In GFSC, where large quantities of products are handled, players in the system such as big retailers put pressure on food producers to meet all requirements for a safe food production and with regard to obtaining extralegal private certifications. In many cases, consumer organizations encourage purchasing healthy, safe, fair priced and sustainable, meaning regional foods without influencing on whether local or global products are better than the other one. Nevertheless, studies reveal that based on attitudes, behaviors and beliefs, consumers prefer local over global food products (Feldmann & Hamm, 2015). Traditional local markets are the selling points where the large majority buy their fresh foods (e.g. eggs, fruits, vegetables and fish) although formal regulation is challenging to enforce in such markets which therefore represent a major source of safety and health risks.

On the contrary, GFSC are required to implement an FSMS to comply with the principles and objectives of food safety proposed by Codex Alimentarius Commission. GFSC plan and incorporate FSMS as a systematic approach that focuses on regulatory and statutory requirements applicable to food safety, in which they follow national and international, public and private standards, regulations and guidelines (Kirezieva et al., 2015; Panghal et al., 2018). Furthermore, GFSC have a bigger geographical coverage compared to LFSC and therefore are influenced by and exposed to countries with more rigorous normative or cultural demands (Parasecoli, 2017; Quiñones-Ruiz et al., 2015; Santos-Larrazabal & Basterretxea, 2023). The adoption of these additional qualities supports GFSC to demonstrate their commitment to maintaining high standards of food safety and quality and strengthens trust and purchase behaviors and power in the consumers which in parallel encourages them to maintain or continuously improve their food safety practices (Machado Nardi et al., 2020). On the other hand, larger coverage and thus long-distance transport also implies the transportation of contaminants or infectious agents due to more intermediaries throughout the food supply chain (Chen et al., 2021). More distributed food supply chains, featuring a larger number of intermediaries each participating and responsible for a small portion of the end product, tend to have more problems with food safety risks as a result of contaminated food due to a greater exposure of the product to unsafe handling, and economically motivated adulteration that includes, for instance, the illegal use of antibiotics in animal productions and environmental and water contamination with heavy metals in farming environments (Chen et al., 2021; Hernández-Rubio et al., 2018). Significant large-scale foodborne outbreaks and recalls have been also linked to GFSC. In 2011, a foodborne outbreak produced by *Escherichia coli* O104:H4 in sprouted seeds imported from Egypt to Germany, resulted in 855 cases of hemolytic uremic syndrome (HUS), 2987 cases of bloody diarrhea and 53 deaths in Germany; and seven cases of HUS and four cases of bloody diarrhea in France; additionally to outbreak-related cases reported in other European member states, the United Kingdom, the United States and Canada (ANSES, 2011; RKI, 2011; WHO, 2011). In 2013, a multistate foodborne outbreak of hepatitis A virus implicated imported frozen berries as the vehicle of infection of the outbreak. Although Italy was the first member state declaring it a national outbreak of hepatitis A and despite coordinated and comprehensive investigations of the supply chain carried out at European level, owing its complexity, the type of the food item involved, and the epidemiological evidence available at that time, it was not possible to identify the origin of the contaminated berries. This outbreak resulted in 1589 cases and two deaths (Severi et al., 2015). Between 2015 and 2018, an outbreak of *Listeria monocytogenes* infections in Austria, Denmark, Finland, Sweden, and the United Kingdom was attributed to the consumption of contaminated frozen corn produced by a Hungarian food business which resulted in 47 cases of listeriosis and nine deaths (EFSA-ECDC, 2018; Sarno et al., 2021; Soon et al., 2020). The impact of microbial spoilage in the food industry is another issue for GFSC, considering that food spoilage due to high humidity, higher temperatures during storage, and the presence of air in packaged products, may affect, to a larger extend, foods traveling long-distance rather than locally sourced foods that are purchased and consumed more immediately. Fresh produce and processed fruit and vegetable products are particularly susceptible to spoilage with a range of challenges that include *Alicyclobacillus* and heat resistant mold in juice food businesses, *Pseudomonas* species in aerobically packaged meat and cheese, and lactic acid bacteria and *Brochothrix thermosphacta* in vacuum-packaged meat, and *Aspergillus* spp., *Fusarium* spp. and *Penicillium* spp. in cereals, grains and oils (Karanth et al., 2023; Pellissery et al., 2020; Snyder & Worobo, 2018).

Competition with other food businesses or economic gain may drive food fraud in food supply chains. While existing databases, like the Rapid Alert System for Food and Feed (RASFF) and HorizonScan, notify, record and report food fraud and some fraud incidents such as the horsemeat scandal in 2013 where undeclared horsemeat entered the beef supply chain and was found in burgers sold in the European Union, "Operation Weak Flesh" in 2017 where the largest meat food businesses in Brazil were found to selling rotten beef and poultry meat for export, changing expiration dates, meat adulteration, and overlooking of unsanitary hygiene practices, among other fraud incidents at global scale have been documented, undetected acts of fraud are continuously affecting GFSC (O'mahony, 2013; Robson et al., 2020). Although LFSC could also commit food fraud, it is more prevalent in GFSC as they are more challenging to monitor due to the diversity of intermediaries involved in the supply chain and therefore harder to trace, increased complexity and longer distances which provide more opportunities for fraudulent activities to occur and remain undetected (Soon et al., 2020). Hence, GFSC experience more challenges related to transport and a higher risk of cross-border spread of contaminants and transmission of infectious agents and food fraud than LFSC (Beltran-Alcrudo et al., 2019; Garcia et al., 2020). All in all, in regard to food safety compliance as driver of change, LFSC have a competitive disadvantage compared to GFSC. The delivery of a more likely hazardless food product supports GFSC and limits LFSC opportunities to tap even into the local markets, despite the perceptions and preferences of consumers, as LFSC compete with global food products supported by implementation with GMP and HACCP or certified with extralegal quality or food safety assurance programs.

3.2. Food security

The global issue of food insecurity has significantly increased since 2015, exacerbated by several factors including the COVID-19 pandemic, climate change, conflicts and deepening health and social inequalities (Borras & Mohamed, 2020; Drydakis, 2024). The United Nations (UN) and its 17 Sustainable Development Goals set its second goal "Zero Hunger", a world free of hunger by 2030 (UN, 2024). However, this represents a challenge for food supply chains, which are tending to become more complex, to deliver food effectively and efficiently (King et al., 2017). Food security requires a multi-dimensional approach to transforming food systems to achieve a more inclusive and sustainable world. In this respect, the current dominant agricultural production and food systems are embedded in GFSC, where the distance between producers and consumers has increased, where upscaling has led to rural-to-urban migration of people and food businesses, and where the vulnerability of people living in cities is such that they cannot access nutritious food if they disengage from GFSC (Donkers, 2014). GFSC are more geographically present and span over larger territories than LFSC. Food chains at international level provide food security, promote economic growth, employment opportunities and reduce prices in the market through trade of products from which all consumers benefit (Michel et al., 2024). GFSC substantially contribute to food availability with the import and export of food products assisting shortages of domestic supplies. Additionally, by promoting economic growth and reduced prices, GFSC enable consumers to an increased buying capacity, food accessibility and a more diversified and highly nutritive diet else not locally available. Moreover, GFSC support food stability and food utilization by creating a balance in case of seasonal or weather phenomena, the implementation of a new food regulation, changes in agricultural land use, among other scenarios (Ramankutty et al., 2018; van Berkum, 2021).

These advantages result in some countries with an import dependency for the vast majority of food product categories but at the same time with a variety of them. LFSC encounter more difficulties to provide food security to large populations, as usually found in urban areas. However, LFSC are crucial to the availability of food produced in rural regions and are fundamental to ensuring the stability of supply, even in situations of seasonal shocks and crises, as they are primarily responsible for establishing links to populations residing far away from the cities (Rodrigues Fortes et al., 2020). Diversity in food supply chains provides them with adaptative options and boosts their resilience to unforeseen disturbances and food shocks (Gomez et al., 2021). Though the significant influence of market power on some stages of the supply chain, particularly in GFSC, and over the foods that are to be produced, processed and distributed, the COVID-19 pandemic showed that LFSC offer a complementary alternative compared to GFSC, when the latter were challenged by logistical difficulties. Therefore, vulnerable LFSC due to market pressure would only reduce the diversity, thus resilience, of the food supply and increase food insecurity (Bingham et al., 2022; EFSCM, 2023). Concerning healthy and sustainable diets with less red and processed meat and with more fruits and vegetables, LFSC and primary productions could play a potential role on diversifying the global diet that depends on limited staple crops within a monoculture setting or animal production systems e.g. livestock productions, which are vulnerable to pests, diseases, resource scarcity and climate change (EFSCM, 2023). Consumption patterns changing to a more balanced diet between plant-based and animal-based source of proteins could be encouraged by creating awareness and informing consumers about the available, easily accessible, diverse, safe and nutritive products of LFSC and would improve the resilience of food systems in addition to the health and environmental effects. For the abovementioned reasons and by comparing the amount of food that is produced and later distributed, additionally to how far the food reaches and the fact that diversity in LFSC could be improved, GFSC have a more important role than LFSC to deliver food security.

3.3. *Digital technologies in food production*

The emerging application of digital technologies along the food supply chains could contribute to sustainable farming without a massive increase in food production, to the integrity of the value chain, to better nutrition and to the reduction and prevention of food waste (Hanson & Ahmadi, 2022; Strotmann et al., 2022). Big data analytics, 5G, sensors, artificial intelligence (AI), and traceability tools are some technological developments that GFSC already implement in their processes (Renda, 2019). Advanced analytics and big data open untapped potential for farmers, investors, emerging economies and other actors in GFSC. They could be utilized to reduce GFSC's environmental footprint, decrease food safety risks and optimize waste management. For instance, an online marketplace could connect supermarkets to consumers and non-governmental organizations, enabling supermarkets to provide food which according to the data is about to expire to people in need and at the same time reduce the burden of food waste. Big data analytics could estimate the need or effectiveness of interventions, analyze crop needs, forecast yields and use risk assessment tools to assess the impact of weather on soil conditions to allow farmers an efficient management of their fields and global food manufacturers to select optimal regions to source from (Magnin, 2016). Moreover, GFSC could evaluate which commodities should be produced at which season of the year, which could increase productivity and mitigate unpredictability or volatility of costs. Another opportunity for technological application in the agriculture and food sectors is the utilization of 5G, the new generation of wireless technology further supporting precision agriculture. Futuristic scenarios like fully autonomous farms, automatic spraying drones and driverless trucks and tractors would be possible by 5G connectivity (Van Hilten & Wolfert, 2022). GFSC would increase their productivity by transforming farms into cyber-physical management systems which are embedded networks that control and monitor physical processes while providing data and calculations (Majumdar et al., 2024). Despite the benefits of automated work in the field, GFSC would need to provide real-time data and continuous communication to the digital devices that in return will do the data transfer and the following day-to-day farming operations. A producer could receive a smartphone notification of current high soil humidity in its fields and heavy rains expected at a later time of the day. Prompt decision making would follow and production losses due to excessive irrigation could be reduced.

Sensing technology ensures food safety in the food supply chain processes as they could be integrated at any step of the entire value chain from farm to fork: in food transport vehicles, in refrigerators, chilling rooms and warehouses used for food storing. Sensing is already leveraged by GFSC to monitoring food products as they travel within and across countries (Huang et al., 2023). GFSC receive information on the location, quantity of the food expected at the destination point, temperature, pressure, humidity, and other parameters. Collecting this data informs the food business on the condition of the food in transit and if food spoilage is likely or has been detected. Hence control is never lost throughout the whole supply chain. Furthermore, AI is revolutionizing the food supply chain and leading to more efficient processes. AI analyzes and uses data generated e.g. by sensors, makes predictions, forecasts consumer behavior and supports decision making as an augmentation tool in process automation (Duan et al., 2019). Machine learning and computer vision are two of the most widely used AI disciplines in food supply chains, helping to improve inventory management in intelligent warehousing or energy efficiency in food preservation, and supporting food quality control by reducing errors and ensuring consistent product quality and traceability of food products for consumers (Monteiro & Barata, 2021). AI facilitates personalized interactions between food businesses and end-consumers through chatbots and virtual assistants. These digital technologies drive innovation and improve GFSC; nevertheless, they face governmental challenges to be widely accepted and implemented due to the potential risk of losing data security, privacy and integrity, particularly with the use of AI. LFSC do not encounter data privacy concerns due to not handling sensitive consumer data for personalized interactions and therefore they do not need robust data protection measures nor compliance with data regulations.

The provision of real-time information also facilitates food traceability. In this regard, there is a strong need to rely on companies or people who can guarantee trustworthy data and information, and the integrity and provenance of food products and goods in general. Moreover, due to the complexity of food supply chains, it is beneficial to have specialized entities overseeing each process in the supply chain. These entities would be responsible for the respective key steps in the food production process such as disinfection method, the addition of preservatives, type of production, sourcing of ingredients, and other aspects (Baralla et al., 2021). Although food supply chains play a pivotal role in ensuring safety of food products, food systems still lack traceability and transparency. Microbiological and chemical contaminants could be introduced at any stage of the food supply chain, even in GFSC with traceability systems in place for their productions, hence safety standards should be implemented and continuously be revised and updated to avoid vulnerability of food systems. *Escherichia coli* O157:H7 introduced to leafy greens from contaminated irrigation water and melamine added to milk to increase its nitrogen concentration and therefore the apparent protein content, are examples of microbial contamination and food fraud that were difficult to detect and to control (Chen et al., 2023; Schoder & McCulloch, 2019). Those are just two examples out of many food-related incidents that took a long time to be identified. The incorporation of sophisticated traceability systems helps for a fast identification of the source of contamination, allowing food businesses to take immediate actions, recall unsafe food, protect consumers and reduce the impact of foodborne incidents on health and economy (Magalhães et al., 2019). A smart food traceability system involves the leverage of portable sensors that work as indicators to collect more comprehensive, traceable, and timely data about food products, and the incorporation of emerging digital technologies like the internet-of-things (IoTs) and cloud computing (Yu et al., 2022). GFSC could improve their systems by implementing these advanced detection technologies for analyzing traceability data. However, LFSC often view these technologies as impractical due to limitations in their abilities, capacities and budget, together with the technical, flexibility and time demands. Additionally, the lack of knowledge concerning the benefits of such applications and the overlooking of free and open-source traceability instruments and support might determine LFSC on their decision to use traceability tools. As a result, these technologies are seen as neither attractive nor effective in improving farm-to-fork food safety in LFSC. LFSC might not consider these traceability tools due to several reasons: 1) the high cost of acquiring advanced devices to collect traceability data; 2) the vast and heterogeneous data generated, which can be challenging to analyze – requiring sophisticated tools to process data and trace contamination sources or to respond promptly to foodborne incidents; 3) compared to GFSC, LFSC products typically contain fewer ingredients and do not rely on multiple suppliers from different countries; and 4) LFSC have fewer intermediaries than GFSC and therefore their supply chains are less complex (Scholten et al., 2016).

GFSC take advantage of current traceability and detection technologies like portable spectroscopy, array sensors, wireless-based detection applications, data-assisted analysis for foodborne outbreak response, blockchain system (Cozzolino, 2025; Fernando et al., 2024), and software tools to manage processes such as product lifecycle management, warehouse management and resource planning (COHESIVE, 2020). GFSC benefit from the extensive volume and precision of traceability data which will be further enhanced by the use of sensors and indicators for portable detection, their integration in food packaging, and the availability of services to track food contamination using whole genome sequencing provided to food businesses operators by specialized support companies and service laboratories (Bhowmik et al., 2024). Some GFSC perform whole genome sequencing as part of their environmental monitoring requirements to identify contaminated niche locations within their production lines, hence reducing the number of potential contaminated foods entering the market (Brown et al., 2019). The implementation of genomics in their own food safety monitoring programs, in which highly discriminatory data provided by whole genome sequencing in centralized databases, can be used by GFSC to track the source of pathogen contamination to a supplier of ingredients or to a specific environmental niche in the process (Allard et al., 2016; Yu et al., 2022). The application of genome sequencing for the characterization of protected designation of origin and protected geographical indication olive oils has gained interest in food businesses as it detects oil adulteration which is fundamental in assessing the conformity of the corresponding official labels of origin (Agrimonti & Marmiroli, 2019). Whole genome sequencing and genome-wide association studies to examine the survival of *Campylobacter* spp. populations from various stages of the poultry production chain is another example of the use of genomics by the agri-food businesses for tracking and tracing purposes rather than for routine microbiological testing of foods (Yahara et al., 2017). Despite the applicability of genomics in the food industry, and the fact that these advancements will significantly improve the identification of the source of contaminations in foodborne incidents, its adoption and wider use in food supply chains could be facilitated by decreasing the costs of generating bacterial genomic sequences, capacity building for skilled workforce and improving infrastructure (Jagadeesan et al., 2019).

Additionally, IoT and cloud computing as wireless technologies, would enable real-time collection and analysis of traceability data, thus facilitating a quick identification of contaminations (Rucabado-Palomar & Cuéllar-Padilla, 2020). Another promising tool is the blockchain technology which is already used by multiple GFSC in many countries (Jangle & Sharma, 2024; Schilhabel et al., 2023) as well as a pilot blockchain ecosystems for food distribution in current food supply chains used by food safety authorities like USDA (Shew et al., 2022). Blockchain records trade transactions in a tamperproof way among many trading parties along the food supply chain. It enhances traceability, trust, transparency, deters fraud and improves response to contamination and foodborne diseases (Damoska Sekuloska & Erceg, 2022; Haskell, 2022). Blockchain partners transact without a central intermediary; therefore, food business operations of GFSC are protected. Moreover, by scanning the QR code on product packaging and label, consumers can instantaneously trace a food product back to its origin, having access to information on the conditions in which the food was produced and transported. As an example, the Food Safety and Inspection Service (FSIS), an agency of the USDA, aims to use blockchain to traceback and manage agricultural food exports like exported beef and poultry products; and at the same time implying a thorough inspection of the food products against both the national standards and the import country standards (FDA, 2021; USDA, 2022). Despite the opportunity for producers of LFSC to be integrated into a blockchain with higher transparency, equal treatment, better coordination between rural producers and more cost-efficient food products distribution than in traditional systems, blockchain demands LFSC stakeholders shifting to technology readiness, expertise and increasing their investments to adopt this technology. This represents the main limitation for small and medium sized food businesses to be part of the system (Jellason et al., 2024).

LFSC come across restraining factors to adopting big data analytics, 5G, sensors, AI, and blockchain technologies (Davies & Garrett, 2018). These factors include the high implementation costs of hardware, software and personnel training; the shortage of AI-skilled workforce in local food businesses to effectively implement and manage AI-solutions; and the migration from existing infrastructure and processes to a more complex and integrated system resulting in potential disruptions or delays in decision-making and operations. Thus, these technologies do not play an active role in LFSC which is seen as a challenge in this digital era, considering that technology has a significant role in the achievement of the second UN Sustainable Development Goal “Zero Hunger” by 2030, but as an opportunity for gaining consumer trust because of the transparent and more direct communication. Regarding technology as one of the drivers of change, in particular digital transformation and AI entrepreneurship seems a challenge.

3.4. Environmental protection aspects

Energy use or carbon footprint is often used as an environmental performance indicator for production activities. Higher energy use is often related to higher greenhouse gas emissions which are responsible for global warming and climate change (Bajan & Mrówczyńska-Kamińska, 2020). LFSC benefit from the proximity with consumers, hence are considered to have reduced fuel consumption, food miles and CO_2 emissions as well as fewer distribution phases. LFSC are therefore suggested to cause a smaller impact on the environment. Given that the carbon footprint estimates the CO_2 emissions generated from the beginning of the production process to its final use and disposal (Naresh Kumar & Chakabarti, 2019), LFSC have more acceptance from consumers and are perceived as performing more environmentally friendly than GFSC. An efficient logistic system is pivotal to achieving traceability in the food supply chain and to implementing environmental strategies which are considered a critical factor for the success of LFSC (Paciarotti & Torregiani, 2021). In this sense, it is essential to stress that LFSC with specific marketing strategies have less negative impact in the environment. Pillars of those marketing strategies are: direct on-farm sales, direct off-farm sales, sales through a retailer (only when a maximum of one intermediary is considered); LFSC food product sales exceeding 8 kg per costumer; and consumer round-trips shorter than 7.4 km (Delicato et al., 2019; Loiseau et al., 2020). LFSC with other characteristics like a higher number of intermediaries, larger geographical distances, and marketing strategies different than the ones previously mentioned could even generate a higher environmental impact per unit of production when measured in terms of food miles and carbon footprint compared to GFSC that have optimized their distribution routes and performance of logistics (e.g. larger quantities transported, larger vehicles and utilization of return-way transport) (Drut et al., 2021; Nsamzinshuti et al., 2017). Attributing the impact due to transportation from the place of production to the place of purchase is only a part of the total impact associated with the entire food supply chain. Overall, transport is a small contributor to CO_2 emissions and carbon footprint rather depends on the type of food product or the processing it has gone through than on transport (Ritchie, 2020).

The rapidly rise of food e-commerce, accelerated during the COVID-

19 pandemic, has led to environmental implications due to transportation, CO_2 emissions, increased packaging and food loss and waste (FLW). Food e-commerce interacts with the complexity of perishability to logistics, hence often circumvents brick-and-mortar stores which are energy and CO_2 emissions-intensive, compared to physical conventional retail stores which may have large fulfillments centers or warehouses to process greater volumes of food products than e-commerce. As e-commerce requires online pathways through which the food products get to the consumers, LFSC with sales through one intermediary, direct on-farm sales or direct off-farm sales would invest more, in terms of energy and transportation, to deliver their products as if they were offered in conventional retail, hence not benefiting from these online distribution channels. Nevertheless, the impact of food e-commerce in rural communities could also be seen as the replacement of multiple, long, consumer trips to the store that with more efficient delivery services could possibly reduce CO_2 emissions (Gee et al., 2020). On the other hand, GFSC take advantage of these digital food platforms where wholesalers and retailers may aggregate product offerings, thus sharing value throughout the network, and by offering highly customizable food products to the end-consumers. With more consumers purchasing foods online, GFSC direct their efforts to manage more frequent orders with rapid delivery times and invest resources e.g. in cold chain logistics providers, to ensure that perishable products can be delivered directly to end-consumers without compromising freshness or food safety (Suali et al., 2024). GFSC move their products between distribution centers which implies additional management, cold chain maintenance, packaging and pallets used for storing and assembling perishable food products (Chen et al., 2022). Energy consumed for food storage, the administration along the supply chain, and food packaging are essential elements that also generate an environmental burden and waste (Lu et al., 2024). On the other hand, LFSC use minimal packaging to protect and preserve their products during storage and transport which is a reason for consumers to choose them over GFSC products (Chakori et al., 2022). As LFSC travel shorter distances and have a more direct relationship with consumers than GFSC, extensive packaging is not essential. LFSC that avoid to use disposable plastic packaging for their products might induce more resource-efficient habits among consumers and suppliers (Beitzen-Heineke et al., 2017). This is also perceived as support to local farmers, better informed consumers and greater transparency along the food supply chain. However, the significant environmental and social benefits come with a limited supply efficiency and variety of food products.

Food packaging plays an important role in FLW along GFSC since its production, use and disposal are associated with environmental impacts. For instance, the use of inappropriate packaging causes FLW in retail stores and households. Difficulties in emptying packaging, damaged and oversized packaging are packaging-related issues to be addressed through the design of customized packaging sizes, proper storage conditions and consumer awareness and education, at GFSC worker and consumer levels, to mitigate FLW (Uhlig et al., 2025). During primary production and last mile, considered the first and last stages across the food supply chain, respectively, is generally when most FLW occurs and therefore potential reduction of packaging waste, particularly in the last mile delivery stage, could have a positive impact. Moreover, the recyclability of packaging could be affected by food leftovers, for example, when packaging is not easily emptied. Considering that large economies are focusing efforts and proposing legislations aiming at a more circular packaging by increasing recycling rates, boosting the uptake of secondary material by the industry, reducing FLW and promoting healthy life cycles, a clear understanding of the available recycling infrastructure and the suitability of food packaging to be reprocessed into a useful secondary material, stills needs to be approached by GFSC to bridge the circularity gap with societal and ecological objectives (De Wit et al., 2018). Sustainability assessments consider circularity as highly relevant for the environmental performance of packaging as it represents a major challenge to overcome; nonetheless, pivotal to improve packaging sustainability. Circular food supply chains, mostly related to large-sized food chain systems that handle large volumes of foods, could directly request the use of recyclable material to packaging producers and even influence on the use of renewable energies (Pauer et al., 2019).

Indirectly related to environmental protection aspects but potentially associated to food safety are the environmental disruptions and variabilities such as extreme precipitation, insufficient rainfall and adverse temperatures that impact food supply chains at local to global scales (Davis et al., 2021). An increased presence of indicator bacteria like coliforms, *E.coli* and Enterococcus, pathogenic microorganisms like *Salmonella* spp. and *Campylobacter* spp., and toxins in fresh produce, e.g. leafy greens, could be expected as a consequence of droughts, flooding and rise in temperatures (Castro-Ibáñez et al., 2015; Holvoet et al., 2014). Furthermore, environmental issues may affect food availability, affordability and acceptability (Brunori et al., 2016). Here, LFSC are more affected compared to GFSC because GFSC usually source large stocks of food supplies from different producing regions worldwide whereas LFSC depend directly on the production of a specific place or region so that environmental disruptions even at local-scale could impact LFSC substantially (Davis et al., 2021). All in all, LFSC are considered more environmentally friendly than GFSC. Nevertheless, the abovementioned peculiarities of LFSC should be taken into account as well as the emergence of food e-commerce as an instrument for food supply chain resilience in severe market disruptions. Impact of climate change can have both positive and negative impacts on contamination sources and pathways that influence microbial infectious agents and their survival or growth (Liu et al., 2013). To mitigate and respond to the impact of climate change, awareness of and strengthening of GAP, microbial water quality monitoring, personal hygiene requirements, and other control measures should be considered.

3.5. Economic growth

LFSC stimulate local economic development by creating jobs in regions where they produce and distribute their foods. They promote the demand for locally grown food products, meaning that consumers and food businesses like restaurants and caterers would spend a percentage of their budget on local food products (Coelho et al., 2018). Moreover, some governments encourage consumers to buy products of LFSC expecting to generate environmental, social and economic benefits in the respective regions (Thilmany et al., 2021), taking into account that the sourcing location is not only a matter of environmental impact but it may also affect social sustainability (Schaubroeck et al., 2018). In this regard, consumers prefer supporting LFSC and their own national economy. The consumption of local food is understood by many as reversing the effects and trend of globalization on local economies and favoring the local, in addition to the fact that economic activities such as tourism, are often stimulated by local and regional food products. While some governments do not develop mechanisms to strengthen LFSC and local food trade (Laforge et al., 2017), other governments deploy public policies and marketing measures to encourage local food consumption (Belfresh, 2025). Additionally, local and organic food products benefit local economies as the market prices of their products are higher what might leverage profits, although to a limited extend as the sales volume of organic products are limited to small quantities and less frequently sold. Another strategy of LFSC is to include the origin of the food product on the package as consumers prefer the idea that food is produced in harmony with nature, suggesting knowledge about the production methods as it could be traceable and can still be purchased at the nearest market (Reckinger, 2022). In this regard, a variety of labels includes information on protected designation of origin, protected geographical indication, traditional specialty guaranteed, certifications and organic production (González & Parga-Dans, 2020). LFSC feature their products through food festivals, regional cuisine fairs and other cultural-based strategies adding to the concept of “event gastronomy”. In general, LFSC contribute to economic growth but, compared to GFSC, of a small-scale effect, particularly in rural areas.

GFSC have a larger impact on employment and working conditions in the food supply sector. In 2024, 20.8 million people were employed in the sector in the European Union, representing 10.5 % of the total employment in the region (FoodDrinkEurope, 2024; OECD, 2024). Globally, food systems offer immense economic benefits to societies across the world. The net benefits are worth five to ten trillion USD per year, which was equivalent to four to eight percent of the global gross domestic product in 2020 (EU, 2020). GFSC outsource and relocate workforce to several locations around the world and relocate manufacturing and processing facilities to lower-cost regions. Therefore, the growth of food companies combined with the trend among GFSC to outsource to lower-cost destinations has located lower-and-middle income countries like India, for instance, as expected to exponentially grow in terms of food production, consumption and export. This results in more government support for large-scale export-oriented productions like subsidies offered to farmers encouraging export agriculture, more job opportunities for developing economies and, decentralized countries and international trade of endemic food products.

Despite the abovementioned strengths of GFSC, the proportion of labor force on farms decreased (Rye & Scott, 2018). Workers in agri-food businesses have shifted their work in the fields for work in factories or packaging plants. Farms became industrialized and due to the worldwide competition GFSC demand flexible labor and round-the-clock schedules as their terms of employment (Rodrik, 2018). Flexible labor usually involves a small group of permanent workers and a large number of temporary and casually contracted workers which allows GFSC to increase their own profitability, even when prices for their products are driven down by market competition in the supply chain (Surmeier et al., 2024). Development of GFSC also has an impact on labor migration both within and between countries (Siegmann et al., 2022). Migrant workers are widely used in the agri-food sector of industrialized countries, where many food businesses become immediately affected in case of shortage of this working force (Corrado et al., 2024). The effect of GFSC on the economic growth in the sector has implications for the type, quality and number of jobs, so any conclusion on whether they perform better than LFSC should be treated with caution. When considering only profitability and the large food production projected to satisfy the food demand of 9.1 billion people by 2050 (FAO, 2009), GFSC have a greater contribution to meet these requirements.

3.6. Sustainability

LFSC are considered to be sustainable and are therefore widely promoted in agricultural policies (Stein & Santini, 2022). However, many scholars challenge the claim that consuming local food is a sustainable solution, arguing that it is not based on evidence (Polleau & Biermann, 2021). Social, economic and environmental dimensions as well as case-by-case evaluations at consumer, policy and food business levels should be considered when assessing sustainability of food supply chains (Toussaint et al., 2021). Being an LFSC does not guarantee more sustainability than being a GFSC. The production and harvesting methods could determine whether food products were handled and processed in harmony with nature, season of the year and regional aspects. For instance, LFSC that include the utilization of hazardous pesticides that pollute soils and water and enter the food chain and display potentially toxic effect (Lykogianni et al., 2021), operate motorized machinery or equipment that damages the surrounding environment and quality of life of populations, or other procedures that do not take sustainability dimensions into consideration in their farming processes, could cause more negative impact if compared to GFSC. Although prioritization of food safety over sustainability is assumed, the achievement of the UN Sustainable Development Goals considers the integration of both drivers of change under the One Health approach which states that the health of humans, animals and the environment are closely linked and interdependent (Dye, 2022; EU, 2024). An efficient One Health approach is suggested to contribute to better health as well as improved food safety (López-Gálvez et al., 2021). In this regard, trade-offs between food safety, food security and sustainability are key and need to be carefully managed (Balié, 2020; Vågsholm et al., 2020) given e.g. the experiences with the use of antimicrobials to intensify food production, which contributes to the development and spread of antimicrobial resistant bacteria.

Sustainable food supply chains, and thus a sustainable future, require the shift from linear food systems to circular food systems that avoid cycles of nutrients in which pathogens or threats accumulate (Vågsholm et al., 2020). One of these threats are AMR bacteria. Limiting the emergence and spread of AMR bacteria is essential to preserve the ability of antimicrobials as critical life-saving medicines to treat diseases, to mitigate food safety risks, and contribute to the progress of the UN Sustainable Development Goals. Coordinated global actions applying the One Health approach to avert AMR include transforming agri-food systems to significantly reduce antimicrobial use while optimizing animal health and welfare (WHO, 2019). Strengthening health systems is also crucial including surveillance programs, prevention strategies such as immunizations, early diagnosis and prompt treatment, and environmental management of air, water, soil, food and vectors. Additionally, improving sanitation and hygiene of handlers and of equipment across sectors is essential; along with other interventions to tackle AMR at international, national, regional and local levels (Humboldt-Dachroeden & Degeling, 2023). Despite a necessary multi-stakeholder engagement to strengthen the One Health approach and increase AMR awareness among the public and scientists, there is the challenge of translating knowledge from scientific findings to decision- and policy-makers and, in a local context, to local actors (e.g. farmers). Ergo, sustainable agri-food systems should support food producers, combine regulatory and non-regulatory initiatives to make the entire food chain from production to consumption more neutral in its impact on the environment, and target the impact of food on individuals, the environmental and wider populations health (Kiran et al., 2023). In this regard, considering sustainability as driver of change, the superiority of LFSC over GFSC cannot be definitely stated, despite being perceived and promoted as a diverse and sustainable alternative to standardized GFSC. Instead, a case-by-case assessment of the individual LFSC is advised.

3.7. Data management

As mentioned earlier, food supply chains are evolving into data-driven digital systems where data is collected at different stages of the supply chain process. Consequently, effective data management systems are fundamental for ensuring regulatory compliance, maintaining quality of data and identifying sources of contamination during food-borne incidents (Astill et al., 2019; Galvez et al., 2018). Comprehensive data management enables food supply chains to achieve financial benefits, scalability, enhanced data access and control, rapid data retrieval and seamless information sharing. The primary difference between data management in GFSC and LFSC lies in the volume of data handled and the technology used to manage and process data. In LFSC, data is generated faster due to direct communication between actors in this supply chain. Although sourced from diverse channels, the overall volume of data is smaller, more limited and directly generated compared to GFSC. Consumer behavior, data of suppliers and producers as well as the information they share are generated as a straightforward and rapid input that could be further enhanced by using online applications and social media (Singh et al., 2018). On the contrary, GFSC produce larger quantities of data and the input might take longer to obtain because of the number of touchpoints and intermediaries in this supply chain, making it more complex than LFSC. Regarding the technology for data management, LFSC might only use basic technologies like spreadsheets, excel tables and local inventory software, to store and manage data (Gottschald, 2024). Moreover, these data are often unstructured, paper-based, and not machine-readable, limiting their use for purposes such as finance, audits, data transfer, data modelling, decision support and scientific research (Islam et al., 2022; Nurgazina et al., 2021). This lack of digitalization means lack of available records, slow tracing and complications to retrieve information. Instead, GFSC might use more sophisticated data management tools with an efficient data architecture that allows data analytics, supply chain optimization, data-driven decision making and cloud-based platform for real time monitoring and more (Accorsi et al., 2018). These technologies may also be combined with those mentioned in Section 3.3 (Digital technologies in food production).

Compliance with regulations and traceability are driving factors for GFSC to implement robust data management systems needed to ensure adherence to international regulations, quality standards as well as trade agreements. Additionally, GFSC need to have their data in standardized terminology and formats to guarantee consistent information exchange between actors of the supply chain through harmonized communication protocols. For instance, a GFSC with distribution focal points in Colombia, Belgium and Vietnam needs to at least standardize the communication and data entries in English and select a time zone and format at the moment of registering data and information. Data standardization is an advantage in both GFSC and LFSC. However, for LFSC it tends to be less crucial as LFSC are only subject to local regulations and compliance standards that might be complex to some extent, but are generally limited to the jurisdiction where the LFSC operate. The challenges and strategies to implement a data management system differ between GFSC and LFSC based on the nature of the food supply chain, where GFSC often adopt more robust, technologically advanced and elaborated systems compared to LFSC.

4. Conclusion

GFSC and LFSC could oppose but also complement each other and therefore they coexist. There is no clear superiority of one food supply chain concept over the other because for some attributes one food chain model works better than the other one. Rather than considering LFSC as an alternative to GFSC, an integrative assessment considering several drivers of change should address situations where complementarities and synergies between LFSC and GFSC occur.

The qualitative assessment of the performance of seven drivers of change revealed that products in LFSC were perceived more environmentally friendly than products in GFSC (Fig. 1), whereas GFSC were considered to provide greater food security, enhanced food safety measures, adoption of advanced technology, significant contributions to economic growth, higher levels of traceability, and integration of more sophisticated data management systems throughout their supply chain compared to LFSC (Fig. 2). Sustainability is suggested to be evaluated on a case-by-case basis. The findings of this study create a better understanding of issues resulting from different types of food distribution channels and indicate that LFSC demand more support and encounter greater challenges than GFSC regarding food safety management, digital technologies in food production and data management due to limited capacity; and that further research is needed to provide evidence-based support for optimization of LFSC processes e.g. via harmonized data structures or tailor-made software that include the revision and adaptation of existing tools for potential useful features for LFSC as well as to take a closer look at current policy instruments to identify ways to target LFSC to further minimize their disproportionate opportunities.

CRediT authorship contribution statement

Mariel Stefhanie Aybar Espinoza: Writing – original draft, Conceptualization, Methodology. **Annemarie Käsbohrer:** Writing – review & editing, Conceptualization. **Martin Wagner:** Writing – review & editing. **H.J. van der Fels-Klerx:** Writing – review & editing. **Mieke Uyttendaele:** Writing – review & editing, Supervision. **Marion Gottschald:** Writing – review & editing, Supervision, Conceptualization.

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Declaration of competing interest

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Data availability

No data was used for the research described in the article.

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