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Application of Digital Solutions to Improve the Operation of Short Food Supply Chains

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Abstract

Short food supply chains (SFSCs) are today widely promoted due to the positive impact on social, economic and environmental sustainability. However, short chains face several specific challenges (e.g., meeting the requirements of consumers and ensuring optimal operations). The application of innovative solutions and digitalisation can support the actors of SFSCs to achieve these goals.
Solutions and methods were collected based on the innovativeness and applicability of SFSCs. Systematic analysis of the needs of SFSCs for technological and non-technological innovations was carried out by partners of the SmartChain project. Based on the research, recommendations were made for the participating SFSCs regarding potential innovations.
A significant proportion of the identified solutions have digital elements that were collectively assessed as a suitable solution in the case of the studied SFSCs. The current work provides an overview of the potential implementation of the collected innovative solutions having digital elements and addresses the primary needs and issues of SFSCs where the application is relevant. Highlighted areas of performance are marketing, communication, packaging and labelling, and logistics.

Keywords: SFSC; Innovation; Digitalisation; Digital solution

1 Introduction

Digitalisation and the application of related technologies have a massive impact on the economy and processes globally. However, the digitalisation process in the agri-food sector needs support due to the sector's special characteristics. SFSCs have a significant role in the transition towards the creation of a sustainable food system in the European Union. Therefore, exploitation of the opportunities provided by these emerging technologies is of great importance to improve the competitiveness of SFSCs.
According to the European Union's rural development regulation, "short supply chain means a supply chain involving a limited number of economic operators, committed to cooperation, local economic development, and close geographical and social relations between producers, processors, and consumers" (REGULATION (EU) No 1305/2013 of 17 December 2013).
Short food supply chains (SFSCs) are coming into focus nowadays as an alternative to the conventional long food chains and to satisfy the increasing consumer demand for the products and services of SFSCs (Aggestam et al., 2017; Varsányi et al., 2020). However, SFSCs are still being labelled as a niche market for conscientious consumers (Aggestam et al., 2017).
An SFSC contributes to closer communication and increased collaboration and community building thus strengthening local identity (Vit-

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Nomenclature

SFSC	Short Food Supply Chain	NTI	Non-technological innovations
TECI	Technological innovations		

tersø et al., 2019) and supporting rural communities and food culture, social sustainability and tradition.

Today, the food system faces significant social, economic, and environmental challenges (Vittersø et al., 2019), including the lack of trust among actors in the food chain, unfair distribution of incomes (Short Food Supply Chain, 2019), overuse of land and water resources, biodiversity loss, pollution, climate change and food waste. SFSCs could contribute significantly to the solution of issues related to these challenges. Global challenges faced by the food industry can be met with the support of information technologies (Demartini et al., 2018).

SFSCs are widely promoted since they are considered important actors for the sustainable transition of the food system. Nevertheless, instead of replacing long chains with short chains, the coexistence of the different food networks is present in the agri-food sector (Thomé et al., 2021).

Sellitto et al. (2018) studied the critical success factors of SFSCs, in other words, adopting procedures that enhance value and promote local characteristics. The identified success factors included environmentally friendly operations, direct and ethical relationships between producers and consumers, food safety and traceability, and cultural heritage. The study also found that despite producers having strived to embrace cultural changes through SFSC implementation, the primary motivation is still economic, in other words, cutting costs of transportation and eliminating intermediary agents that posed heavy operational expenditures to the food supply chain.

Several types of short food distribution channels exist, including traditional, direct ways (e.g., producers' market, on-farm sales and pick your own) and innovative new methods (e.g., online platforms) besides the long, conventional mass food distribution channels (Malak-Rawlikowska et al., 2019).

Depending on the product, distribution system and network characteristics, SFSCs can have several logistics solutions. Specific weaknesses identified by previous research, such as organisational and coordination difficulties and high logistics and transportation costs compared to conventional distribution, can be mitigated through logistics improvement. Potential ways for improvement can be optimising the location of supply chain nodes, improving distribution routes, restructuring the supply chain and making environmentally sustainable food distribution choices (Paciarotti & Torregiani, 2021).

SFSCs are often developed and implemented by local and small actors with limited IT knowledge (Paciarotti & Torregiani, 2021). Though smart farming has had appreciable attention in the past years, the integration of digital technologies in SFSCs has not yet been achieved (Lioutas & Charatsari, 2020). The study of Lioutas and Charatsari (2020) showed, though SFSCs participants have positive attitudes towards smart technologies (e.g., use of connected farm machinery, sensor networks, Internet of Things (IoT), automation systems, farmbots and drones), smart farming is considered a threat to both the quality of the farmer-consumer relationship and the optimally distinct character of SFSCs. SFSCs represent an alternative to "industrialised agriculture" and customers consider smart technologies as belonging to the "industrialised universe", thus estranging consumers who prefer the unconventional character of short food schemes. Their findings also indicate the need for policies to support investment in the development of lower-scale smart technological solutions for farmers

who follow alternative production and/ or distribution routes.

2 Materials and Methods

A systematic analysis of the needs of the SFSCs for technological and non-technological innovations was carried out.
The 18 case studies involved in the SmartChain project provided detailed information on the explicit needs of SFSCs and the developed or applied innovations. Primary data collection was based on a questionnaire consisting of 3 parts:
Part 1 consisted of general information on their activities (entity types, products, services).
Part 2 was a thorough description of the actual operation of the SFSCs selected as case studies through 12 questions. This part of the questionnaire collected information on:

- the main and side activities, and the efficiency of those activities,
- the explanation of the applied innovations,
- issues to be solved,
- IT system,
- experiences and difficulties in the application of innovative solutions,
- resources used for the application of innovative solutions (human, financial and other resources),
- unsolved problems and their causes.

Part 3 described the planned innovations to improve or upscale the activity and sources of innovations.
The annex of the questionnaire served as a basis for identifying innovative solutions. A template for "Short summary findings on SmartChain case studies" has been elaborated to analyse the filled-out questionnaires. The project partners analysed the questionnaires in an agreed and unified way using the template.
Technological (TECI) and non-technological (NTI) innovations have been collected and described based on the survey results and an analysis of the literature. These innovations can be used to solve the problems of SFSC actors and enable their development plans. Figure 1 shows the process flow for preparation of the inventories with links to the work packages of the SmartChain project:

WP1 Conceptual and analytical framework,

WP2 Technological and non-technological innovations,

WP3 Social innovations,

WP4 Food- related consumer behaviours,

WP5 Integrative sustainability assessment,

WP6 Innovation platform,

WP7 Business and policy recommendation,

WP8 Dissemination, communication and exploitation,

WP9 Coordination and management.

2.1 Identification of the explicit and hidden needs of the SFSCs of innovation

The explicit needs of the SFSCs for technological (TECI) and non-technological innovations (NTI) were identified by analysing the information received from the 18 cases of SFSCs from 9 countries participating in the project through a questionnaire survey: Switzerland (Biofruits, Chevrément Bon), Germany (Landwirtschaftskammer Niedersachsen, Solidarische Landwirtschaft), France (Association Gersoise pour la Promotion du Foie Gras, Couleurs Paysannes), Greece (Gaia, Allotropon), Hungary (FoodHub, Zala Termál Völgye), Italy (Arvaia, Alce Nero), the Netherlands (Vleesh& Co, Local2Locad), Spain (Lantegi Batuak, La Trufa de Alava), Serbia (Polo Cacak, Association of companies for the processing of fruits and vegetables).
Based on the similarities and gaps between the research and innovation needs of the food chains in general and the specific, exact requirements of the SFSCs represented by the case studies, the

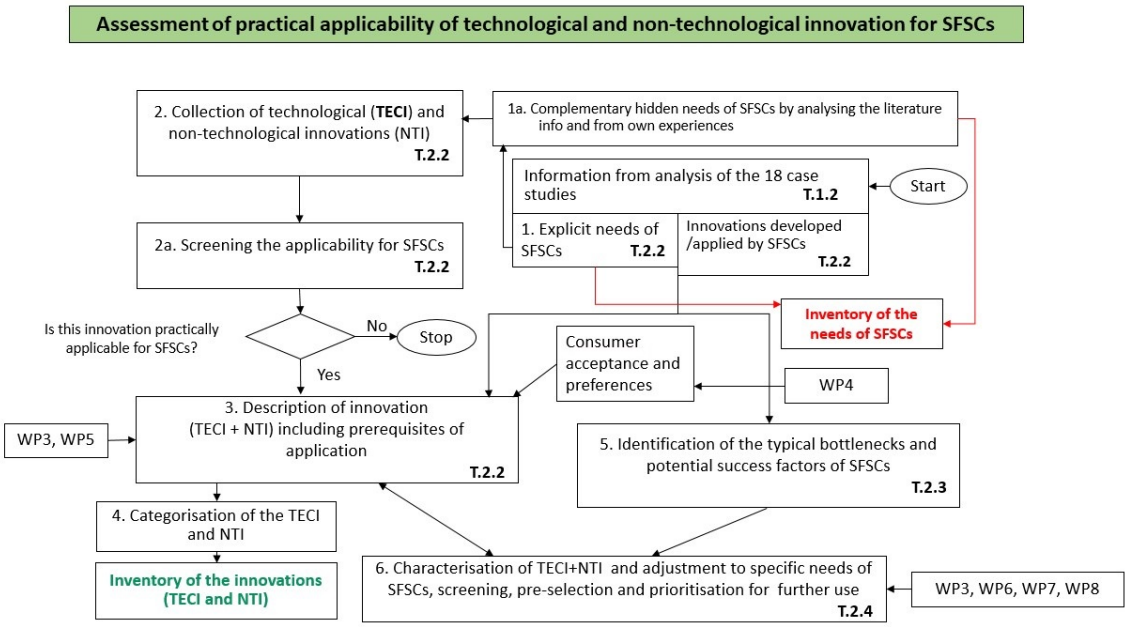

Figure 1: Process flow for preparation of the inventories

potential hidden needs of SFSCs were identified in addition to the explicit needs.
The explicit and hidden needs were organised into an inventory of needs of the SFSCs.

2.2 Collection and description of technological and non-technological innovations for SFSCs

Innovative methods, solutions and systems were collected based on the innovativeness and applicability of SFSCs by using a template from a wide range of sources, including the 18 case studies in the SmartChain project, the knowledge and experiences of the project partners participating in this task, publicly available information, literature review, results of other projects such as SKIN (2019), TRUEFOOD (2010), I-CON (2019) and CapinFood (2014). Technological (TECI) and non-technological innovations (NTI) were described for the individual steps of the SFSCs and SFSCs as a whole and for the needs of consumers and chain actors.
The short summaries were used to identify those innovative solutions developed by the case studies to tackle their problems and to improve the performance of their SFSCs. Additional innovative solutions were also collected to tackle those problems described by the cases that were not known, nor mentioned nor used by the cases, and for the hidden needs of the SFSCs.

2.3 Descriptions of each specific innovative solution, which were kept after the first screening

The critical information on each innovative solution was described and the description of these innovations were organised into an inventory of innovative solutions following the structure of 9 subtasks.

T2.2.1 Agriculture and primary production

T2.2.2 Food safety and hygiene aspects, and regulatory issues related to technological and non-technological innovation

T2.2.3 Food quality aspects

T2.2.4 Food preservation and other processing technologies, including preservation of freshness and nutritional value, and packaging form

T2.2.5 Logistics, accessibility of the product and short food chain channels

T2.2.6 Food integrity, traceability, transparency, certification, voluntary labelling, food chain management and networking

T2.2.7 Marketing concepts and communication tools

T2.2.8 Structural and economic aspects, enhancing collaborative short food supply chains

T2.2.9 Modern information and communication technologies (ICTs)

A brief description tool of innovative solutions was prepared for each innovation, which contained:

- the reference number of the subtask,
- reference to the analysed case study or source of information,
- the title of the technological or non-technological innovation,
- prepared by,
- the description of the need or problem,
- the description of the technological and non-technological innovation.

2.4 Categorisation of TECIs and NTIs into the overview matrix

The collected innovations were categorised as those that serve the needs of the consumers (food safety, food quality, trust, ethical aspects, accessibility) and the needs of the chain actors (fair price, increased negotiating power, shared use of available resources, product development support, access to markets and consumers, access to infrastructure). They were allocated to different individual steps of the SFSCs (farming, primary production, transport, processing and packaging, storage, logistics, sale) and to the food supply chain, as a whole (product integrity/authenticity, transparency, marketing concepts, food chain management and networking for enhancing co-operation among chain actors, business modelling, policy environment, legal requirements, labelling).
The availability of the appropriate innovative solutions for the different needs of the SFSCs was reviewed and the gaps were identified.
Based on the analysis of the short summaries, typical problems and needs of SFSCs were identified. Altogether, 129 innovative solutions were identified that were collected into the inventory of innovative solutions.

3 Results and Discussion

3.1 Proportion of innovations having digital elements

Fifty of the collected 129 solutions have digital features, representing 38.6% of the innovations. Figure 2 shows the proportion of digital solutions by subtask. They represent a significant part in agriculture and primary production (55.5%), food quality (61.5%), logistics (33.3%) and marketing concepts and communication tools (33%).

3.2 Applicable innovative solutions having digital features by the individual steps of the SFSC

At different stages of the SFSCs, specific innovations could be applied. The proportion of innovative solutions having digital features by the individual steps of the SFSC can be seen in Figure 3.
A significant amount of the solutions can be used in sales processes (29), followed by food chain

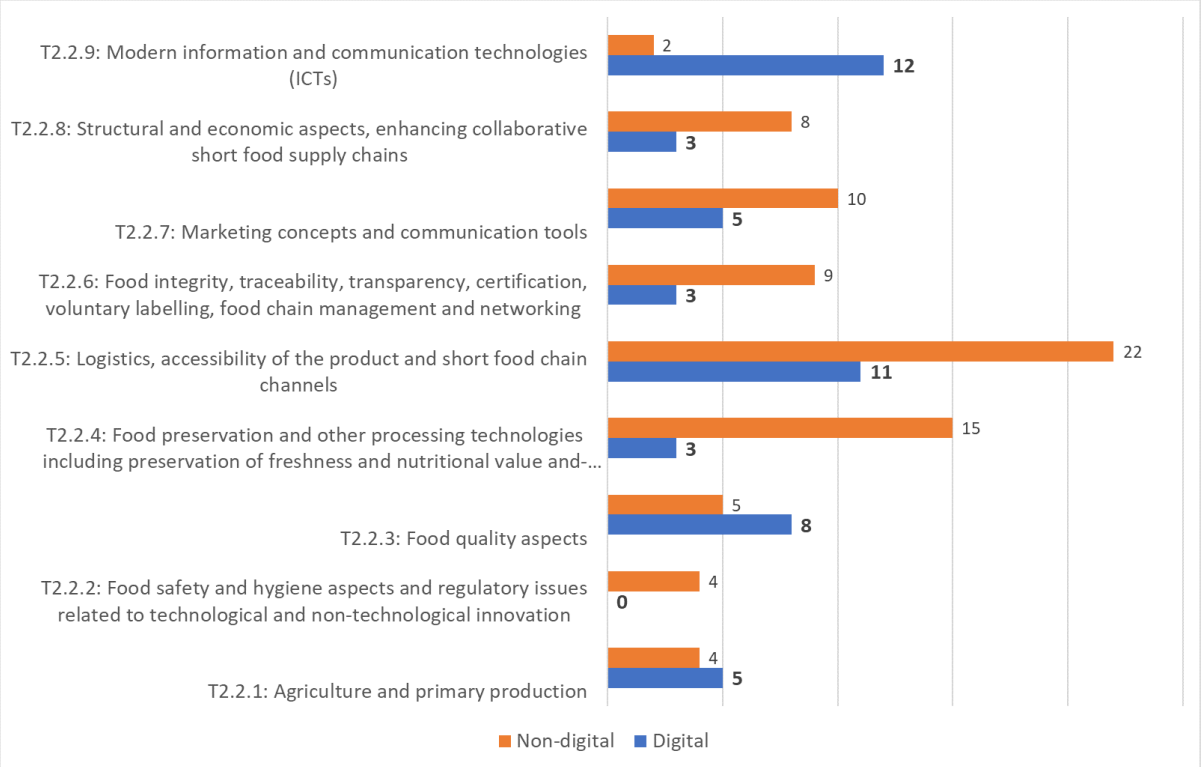

Figure 2: The proportion of digital and non-digital solutions by subtask

management and networking for enhancing cooperation among chain actors (26). Numerous digital solutions support the communication between actors represented in these categories. These are followed by applications for logistics (15), storage (15) and innovations related to marketing concepts (15).

3.3 Fulfilling the needs of the chain actors using innovative solutions having digital features

The proportion of innovative solutions having digital features by the needs of the chain actors can be seen in Figure 4. The highest amount of the opportunities is related to food quality (35), followed by access to markets and consumers (27), trust (24) and accessibility (20). A high proportion of innovations easing information flow between SFSCs and consumers can be observed in the latter three categories.

Food quality as one of the main issues in the food sector is highly represented (24%) though only 6% of the innovations provide solutions regarding food safety. Food safety is the most critical topic for every actor in the food ecosystem, therefore mostly conventional solutions are applied in this field according to regulations at national and international level. There is a development in this direction (novel technologies in sensing, application of IoT systems), however, in the case of the current inventory of solutions, the proportion of innovations is low (6%).

3.4 Recommendation of solutions having digital elements

Ninety-eight from the current 129 innovations of the "Inventory of TECIs and NTIs" were used

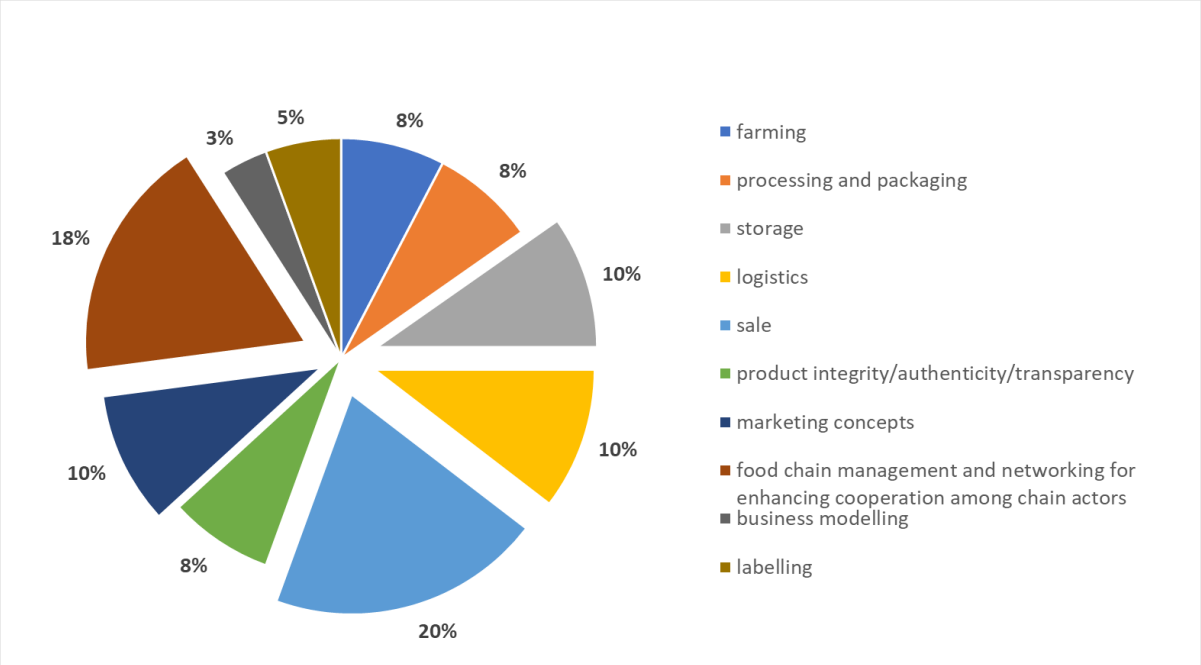

Figure 3: The proportion of innovative solutions having digital features by the individual steps of the SFSC

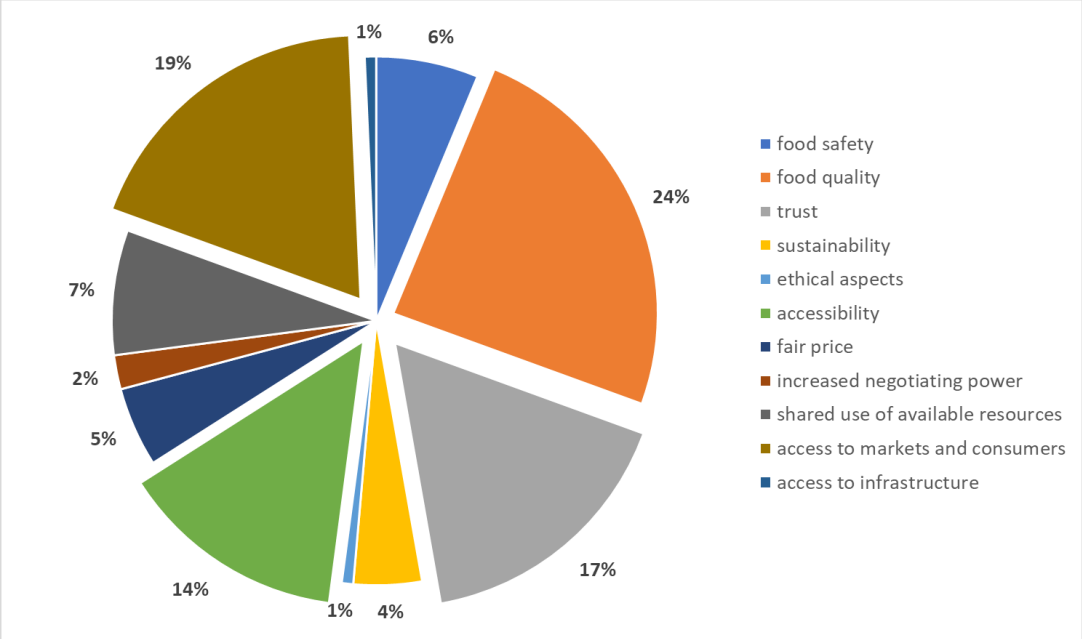

Figure 4: The proportion of innovative solutions having digital features by the needs of the chain actors

Table 1: The most frequently proposed digital innovations for the 18 case studies

Reference and title from the inventory	Number of presences
T2.7.1D Social media marketing	15
T2.5.5D Diverse direct marketing	10
T2.3.13D Food labelling and nutritional analyses without lab tests	8
T2.4.14D Biodegradable active packaging	8
T2.6.2D Platform for Short Food Supply Chains	8
T2.7.3D Marketing tools	8
T2.3.11D Temperature Monitoring Labels	7
T2.5.2D Multi-channel sale	7
T2.5.22D Involvement of the consumers	6
T2.8.12D Platform in collaboration	6
T2.9.3D Smart label	6

and proposed for the 18 case studies to operate more effectively and innovatively, including 34 innovations having digital elements. There are innovations that may be widely applicable and can offer a solution for many SFSC organisations.
The most frequently recommended digital innovations are summarised in Table 1. Among the most frequently recommended solutions, there are different marketing tools and concepts (T2.7.1D Social media marketing , T2.5.5D Diverse direct marketing , T2.7.3D Marketing tools) which can be broadly and universally applied. A trustworthy company identity can be created through their implementation and a high number of consumers can be reached at a cost-efficient price.
Many of the solutions (T2.5.5D Diverse direct marketing , T2.5.22D Involvement of the consumers) can help to overcome some of the identified problems of the SFSCs, including the poor direct access/links to consumers, in other words, low awareness and lack of trust of consumers.
A specific aspect regarding SFSCs is the logistics due to the geographical proximity and the limited number of intermediaries. Several solutions have been proposed to support these processes by tracing and monitoring the parameters of containers or products (T2.9.11.D Babbler , T2.9.13D Tsenso , T2.9.10D PerishABLE) or by enabling proper information flow management (T2.9.12D Qifresh).
Packaging and labelling were also important areas where several solutions can be implemented (T2.3.13D Food labelling and nutritional analyses without lab tests , T2.4.14D Biodegradable active packaging , T2.3.11D Temperature Monitoring Labels).
Digital solutions can ease communication and collaboration between the actors of SFSCs and support the empowerment of communities. The unity of small producers enables a common strategy for marketing and logistics, and eases access to consumers. One of the identified main hurdles of SFSCs, the low negotiating power, can be overcome by the organisation of communities and collaboration.

4 Conclusions

SFSCs have a highlighted role within Europe in the transition towards a sustainable food system, preserving cultural heritage and the development of rural areas. Nowadays, there is a growing number of innovative solutions in the agri-food sector that can be adapted in the case of SFSCs. The promotion of the short supply chains needs effective methods which can be easily adapted and accessible for small-scale producers. The appearance of digital technologies enables significant development in many sectors. Additionally, in the prepared inventory of technological and non-technological innovations, there are several examples of innovations that can be implemented without considerable investment or expertise.

The awareness-raising actions are essential to the actors of the SFSCs regarding the opportunities these innovations can provide to increase the competitiveness of SFSCs. The inventory of technological and non-technological innovations collected in the framework of the SmartChain project can be a practical tool for the improvement of SFSCs and to find answers to the most problematic questions of actors. It is continuously updated and available on the website of the project: https://www.smartchain-platform.eu/en/innovation-inventory.

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Further information is available on the SMARTCHAIN online platform:
https://www.smartchain-platform.eu/.

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