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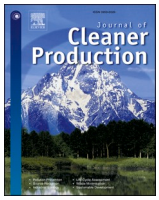

Investigating Co-Innovation strategies to prevent food loss in the fruits and vegetables sector

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ABSTRACT

The transition towards sustainable food systems implies the exploration of drivers and challenges for the adoption of innovative solutions by the operators on the value chains. The development of innovative approaches is critical to improve the collaboration of different stakeholders on sustainability topics. The Q-methodology combines qualitative and quantitative analysis to navigate subjective stakeholder perspectives, aiming to find shared strategies and enhance collaborative approaches on complex topics. This study employs Q-methodology to investigate stakeholders' viewpoints on reducing food losses in the Italian fruit and vegetable sector, focusing on the upstream phases of the supply chain. The aim is to explore the perspectives of producers, experts, and institutional representatives towards sustainable innovations in food losses prevention and management practices. The integration of technological innovation is described as a key factor, but the adoption process is hampered by structural supply chain burdens. The results enforced the adoption of sustainable technologies by operators, reporting that collaboration can enhance efficiency, quality management, and sustainability during fruit and vegetable production and distribution operations. Innovative solutions to mitigate food losses risk are driven by resource-efficiency network strategies that should imply a positive environmental and social performances. The application of the Q-methodology allows for a deeper understanding of the emerging challenges during the adoption of food loss reduction strategies. The findings reported the significance of collaboration, technological innovation integration, and sustainable practices across the supply chain. This research contributes to the development of effective, stakeholder-supported strategies and informs policymakers in the fruit and vegetable sector about different solutions to mitigate food losses.

1. Introduction

The production of fresh fruits and vegetables (FFV) is a key activity in the European agri-food sector. In 2022, the value of fruits and vegetables produced in Europe was estimated at 73.4 billion €, being more than 14% of all agricultural production (European Commission, 2023). At the same time, almost half of the total FFV produced and/or distributed for human consumption is lost or wasted due to value chain inefficiencies and the scarce collaboration of value chain actors, causing environmental, social, and economic issues (Caldeira et al., 2019). Moving towards sustainable and effective value chain management systems has been reported to produce a wide positive impact to improve food safety, reduce waste, and enhance the collaboration of different value chain members (Smith, 2008; Aramyan et al., 2021). Nonetheless, addressing the various challenges towards the transition to sustainable agri-food systems is a complex topic that requires shared approaches, economically viable innovations, and a supportive policy framework (Krishnan et al., 2021). The life cycle of FFV products typically develops along five stages of an organized value chain, including: production, post-harvesting, manufacturing and distribution, retailing, and consumption. Post-harvest losses and waste happens during all these phases and are related mainly to inefficiencies during the inventory management of fresh products, like fast perishability, quality preservation, cold-chain management, and demand volatility that is closely linked to price volatility (Notarnicola et al., 2017). A relevant fraction of waste has also been reported during the intermediate phases, like packaging, storage, and transportation, due to a lack of investment to improve the efficiency of operations (FAO, 2019; Tort et al., 2022). The challenges during the production and commercialization of FFV products, combined with contextual differences among operators, enveloped a lack of

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common goals and shared approaches, making FFV products a particular challenge for the transition towards sustainable value chains, especially when operators have to deal with the prevention of food losses and waste (Bossle et al., 2016). The term "food loss" refers to edible foods that do not reach the retailer phase, while the definition of food waste can be applied in the case of discarded products during the remaining downstream stages, including the final consumption (Directive 2008/98/EC). Instead, "food surplus" refers to raw, semi-finished, or finished items produced throughout the supply chain that, for a variety of reasons, are not being sold or consumed (Garrone et al., 2014; Teigiserova et al., 2020). Food surplus can be collected and redistributed for human consumption purposes (Garrone et al., 2016), provided that it meets all hygienic and safety stadards (Pietrangeli et al., 2023b). The present research paper aims to explore the subjective perspectives of upstream stakeholders (from the harvesting stage up to, but excluding, retailers) in the Italian FFV value chain about the adoption of sustainable innovations to prevent food waste and reduce the volume of food losses. Examining the relationships between distinct viewpoints of upstream stakeholders about the efficacy of strategies and policies put in place could provide additional information for the political implications of waste prevention and surplus management by the development of co-innovation approach based on shared solutions (Doukidis et al., 2007).

2. Literature review

The collaboration of different value chain members, especially during the upstream phases, can improve the performance of the whole value chain as a driving force for the adoption of sustainable innovations and shared practices, defined also as “co-innovation” (Benyam et al., 2021). The concept of co-innovation refers to collaborative approaches to innovation that involve multiple stakeholders working together to create novel solutions or improve existing practices (Krishnan et al., 2021). This topic has been reported by different authors as effective in the prevention and reduction of food loss and waste (FLW), but since this topic has only gained interest in recent years, only a few relevant studies exist that address this topic (Magalhães et al., 2022; Krishnan et al., 2021). Surucu-Balci and Tuna (2022) evaluated different collaboration measures across near-stakeholder groups in the Türkiye FV value chain. The authors reported not only specific problems to tackle in each phase of the supply chain but also differences in the perspectives of the stakeholders about the best approach to tackle FLW generation. In the same way, Matzembacher et al. (2021) pinpointed that the complex causes behind FLW require collaboration and coordination efforts from different stakeholders, but it is still crucial to clarify which entry level of the value chain plays a key role in FLW prevention activities. Ishangulyyev et al. (2019) reported that the identification of opportunity trough linkages among the distinct stages of a food value chain is a key element for the adoption of effective solutions to reduce FLW. At the same time, the institutional and research sector should facilitate and improve the knowledge and tools available to operators. In this regard, Mourad (2016) described different approaches to implement sustainable innovations in food value chains by assessing two distinct national policy contexts, concluding that prevention measures are not effectively implemented if they are not shared by the stakeholders in charge of the implantation. Therefore, to effectively adopt practices and innovations to reduce FLW, it is essential to target stakeholders who can have a considerable influence on reduction activities and discuss collaboration-related mitigation strategies also according with their closer stakeholders on the chain (Avolio et al., 2014; Schanes et al., 2018). The topic of collaborative approaches from the viewpoint of relevant players in the FFV value chain can be explored directly with the involvement of the operators and an assessment of their subjective point of view (Vellema and van Wijk, 2015). The aim of this study is to report and discuss the point of view of upstream operators towards sustainable innovations to prevent and reduce the generation of FLW using an empirical approach that can be replicated in other contexts. Indeed, investing in co-innovation and circular business models may increase knowledge on the topic of FLW prevention and facilitate the transition towards sustainable value chains (Ciccullo et al., 2021). At the same time, a general exploration of the drivers and challenges for innovation adoption is needed to better design future policy development to reduce food losses and waste, thus providing a reference for tailoring policies and strategies in the field (Magalhães et al., 2022).

3. Methodology

The investigation of subjective viewpoints towards co-innovation approaches to prevent and reduce FLW is performed by establishing a Q-methodology study (Webler and Danielson, 2009; Mandolesi et al., 2015).

3.1. Q-methodology

The Q-methodology was developed in the 1930s by W. Stephenson, adapting his master Spearman’s approach to factor analysis (Brown et al., 1980), shifting from variable factor analysis, R-methodology, to person factor analysis, Q-methodology. Stephenson’s approach considers participants as variables providing a by-person rather than by-item factor analysis (Webler and Danielson, 2009). It offers a useful tool for the methodical investigation of subjectivity through the examination of intercorrelations and patterns across individuals (Brown, 1993; 1996). Q-methodology has extensively been used in a variety of fields, including educational, behavioural, and health sciences (Webler and Danielson, 2009), and its popularity has recently grown in environmental and agricultural sciences (Dieteren et al., 2023; Mandolesi et al., 2015). The Q-methodology combines qualitative and quantitative methods for data collection and analysis, so it can be viewed as a “discourse analysis technique” based on a mixed method (Brown, 1996). The theme or topic under investigation is defined as *concourse* (Brown et al., 1980; Watts and Stenner, 2012). The development of the concourse, which Brown (1993) defines as “*the flow of communicability surrounding any topic*", is a collection of all the statements relevant to the topic of the study, organized to form the Q-sample. A Q-study involves the sorting of written and/or graphical Q-statements, defined as individual units of measure that shall cover the full range of opinions or feelings about the subject. During the data collection process, each participant is invited to order the statements, according to his personal agreement with the stimulus provided, and describe their personal preferences, enabling the identification of common patterns inspired by their own words (Watts and Stenner, 2012). The participants in a Q-study are part of the P-sample (participant sample), which is typically made up of a specific segment of society. The selection of participants is not random but strategic, targeting individuals who can provide insight into the specific attitudes, beliefs, or opinions being investigated (Mandolesi et al., 2015). As suggested by Webler and Danielson (2009), the analysis should include subjects with knowledge and/or roles coherent with the topic. Indeed, Q-participants are selected to reflect the range of opinions within a target sample rather than the distribution of beliefs within a community (Watts and Stenner, 2012). Q-participants are also selected to reflect the varied and well-developed social viewpoints within a given population. So, individuals who have well-formed beliefs will find it easier to perform the Q-sort and are likely to produce a more robust sort (Dieteren et al., 2023). Factor analysis techniques, like principal component analysis (PCA) or Centroid, are used to analyse collected data. The Q-researcher’s objective is to identify patterns in the Q-sorts of the participants, indicating that there may be common intersubjective orderings of beliefs among individuals. This leads to the notion proposed by Brown (1993) of “social perspectives”, since many people’s subjective expressions are covered (Brown, 1993; Webler and Danielson, 2009). The aim of the Q-researchers is to develop a narrative that describes each social perspective revealed, thus discussing social

viewpoints. The goal is to uncover an explanation that describes a narrative related to the research topic (Dieteren et al., 2023). This is particularly relevant in the case of sustainable innovations considering the complexity of different viewpoints that hamper the possibility of cooperative agreements (Iñigo and Albareda, 2016). The Q-methodology has proven useful in connecting the effects of individual preferences and knowledge with the variables influencing the process of innovation adoption and the drivers of FLW reduction through environmental sciences innovations (Webler and Danielson, 2009; Sneegas et al., 2021; Dieteren et al., 2023). Other authors adopted this methodology to interpret insights into the factors that influence upstream stakeholders' decision-making and the complexities involved in a topic (Dieteren et al., 2023). Moreover, the Q-methodology has proven to be a reliable tool to understand complex topic and explore stakeholder perspectives in the European agri-food sector. D'Amato et al. (2019) employed the Q methodology to distinguish between circular, green, and bio-economies within growth models. Their findings indicated a general mistrust of the growth-oriented bioeconomy suggesting a policy shift towards synergistic, non-growth-focused approaches. In Italy, Mandolesi adopted the Q-methodology to examine farmers' attitudes towards sustainable innovations, revealing varied viewpoints and informing potential strategies to integrate sustainable food practices (Mandolesi et al., 2015). Other research in Italy focused on the adoption of precision agriculture, emphasizing farmers' preferences and the influencing factors in technology adoption for advancing agricultural productivity and sustainability (Iofrida et al., 2018). Relevant literature reviews are also available in scientific literature to assess the strong and weak points of setting a Q-methodological study to uncover complex topics (Sneegas et al., 2021; Dieteren et al., 2023).

3.2. Study design and development

The five steps involved in the implementation of Q-methodology include: concourse development, Q-sample creation, P-sample selection, Q-sorting, and Q-factor analysis. The focus of this study is on the Italian stakeholders' viewpoints about the concourse: sustainability innovations and best practices to enhance the management of surplus and prevent FLW during the upstream phases of the Italian FFV value chain (following the harvesting stage and up to, but excluding, retailers). Pertinent sources such as scientific research, grey literature, and transcripts of public talk, together with one-on-one interviews with consultants and experts, were analyzed to develop the narrative around this topic (Webler and Danielson, 2009). After the inspection of the research materials, over three hundred written statements were collected, sorted, investigated, and eventually included in the Q-sample. A factorial design was used to be sure that the Q-sample fully represented the concourse and to include all the relevant statements (Watts and Stenner, 2012). A deductive approach was adopted for developing a 9-cell sampling matrix composed by theoretical categories derived from patterns observed during the collection phase (Dieteren et al., 2023). Inspired by the waste hierarchy concept, three categories of measures – representing food surplus prevention, food surplus optimization, and food loss recycling and recovery – were defined to categorize the statements (Papargyropoulou et al., 2014). Then, three categories of innovation were used to finalize the grouping of the relevant statements. Considering the traditional concept of innovations, technology and product innovations are related with development of new products or services generally related to technological advancements; organizational innovation refers to the implementation or the development of new organizational methods and the enhancement of new ideas or behaviours internally or externally to the firm; marketing innovations represent different approaches developed to marketing products to potential or existing customers (OECD, 2018; Lam et al., 2006; Salunkhe and Wu, 1974). The final Q-sample is composed of thirty-four written statements selected to represent the entire concourse. Table 1 shows the sampling matrix developed for this study reporting the number of statements for each category. The number of statements is not equally distributed between the theoretical categories developed, but the authors observed that additional statements would not improve the accuracy of the Q-sample (Watts and Stenner, 2012).

Table 1
Sampling matrix.

Class of innovation	Technology & Product Innovation	Organizational Innovation	Marketing Innovation
Measure			
Food surplus prevention	4	4	4
Food surplus optimization	4	4	4
Food losses recycling and recovery	3	4	3

The Q-sample was developed and administered in Italian. For the sake of the study, the statements are translated in English (see section 4). A pilot test was conducted in December 2022: the list of statements was refined, reworded, and reorganized to include all feedback. Fig. 1 illustrates the complex interactions between the several actors of a typical supply chain model in the fruit and vegetable sector. The diagram is segmented into layers that represent different stages of the value chain: at the core of the supply chain are placed Producers' Organizations (PO) & Association of Producers' Organizations (APO), which are pivotal in aggregating efforts and resources of producers, supported by public funding and the collaboration with research and public institutions (Diaz-Ruiz et al., 2019; Gutiérrez and Macken-Walsh, 2022). They are linked to other key actors such as farmers, brokers, buyers, wholesalers, and retailers through a network of interactions representing the flow of goods and information, denoting the activities involved during the price formation process, indicated by arrows. Each activity is represented by specific icons characterizing raw materials, FFV products, and logistics. By focusing on the upstream stages, the study intentionally excludes retailer interactions, directing instead on addressing inefficiencies and reducing FLW among the primary producers and intermediaries. This approach supports the research objectives, aiming to enhance food waste and losses prevention activities through improved coordination among producers, experts, and institutions.

As reported in Table 2, the P-sample consists of eighteen participants, among which 40% are women, equally composed by representatives of POs and their closest stakeholders. The age range and experience in the sector is wide, with most participants having over 10 years of experience in the sector and distinct roles in the innovations' adoption process (Table 2). Those directly involved in the final decision about the adoption of an innovation are considered adopters (Knickel et al., 2021). They can be seen as the link between the strategic vision of the planners and the practical adoption of innovations (Al Zaabi et al., 2013). Their role is critical in ensuring that innovative ideas are not only adopted but also effectively integrated into existing systems and practices (Gutiérrez and Macken-Walsh, 2022). Adopters in the agri-food sector need to navigate the trade-offs between different values and perspectives (e.g., economic viability vs. environmental sustainability) (Tort et al., 2022; Batterink et al., 2010). Planners participate in the higher-level decision-making processes and are responsible for setting the course for how innovation is approached and implemented within the organization (Batterink et al., 2010). They bring a top-down perspective to innovation, focusing on aligning innovative practices with broader organizational goals and strategies (Knickel et al., 2021). Innovation brokers play a pivotal role in the innovation ecosystem (Boons et al., 2013). They act as intermediaries who facilitate the transfer and sharing of knowledge, resources, and technologies between different entities (Howells, 2006) (Fig. 1). The diversity of roles within the P-sample is considered relevant for a comprehensive understanding of the theme underneath the analysis (Brown, 1996). Each participant adds a subjective perspective,

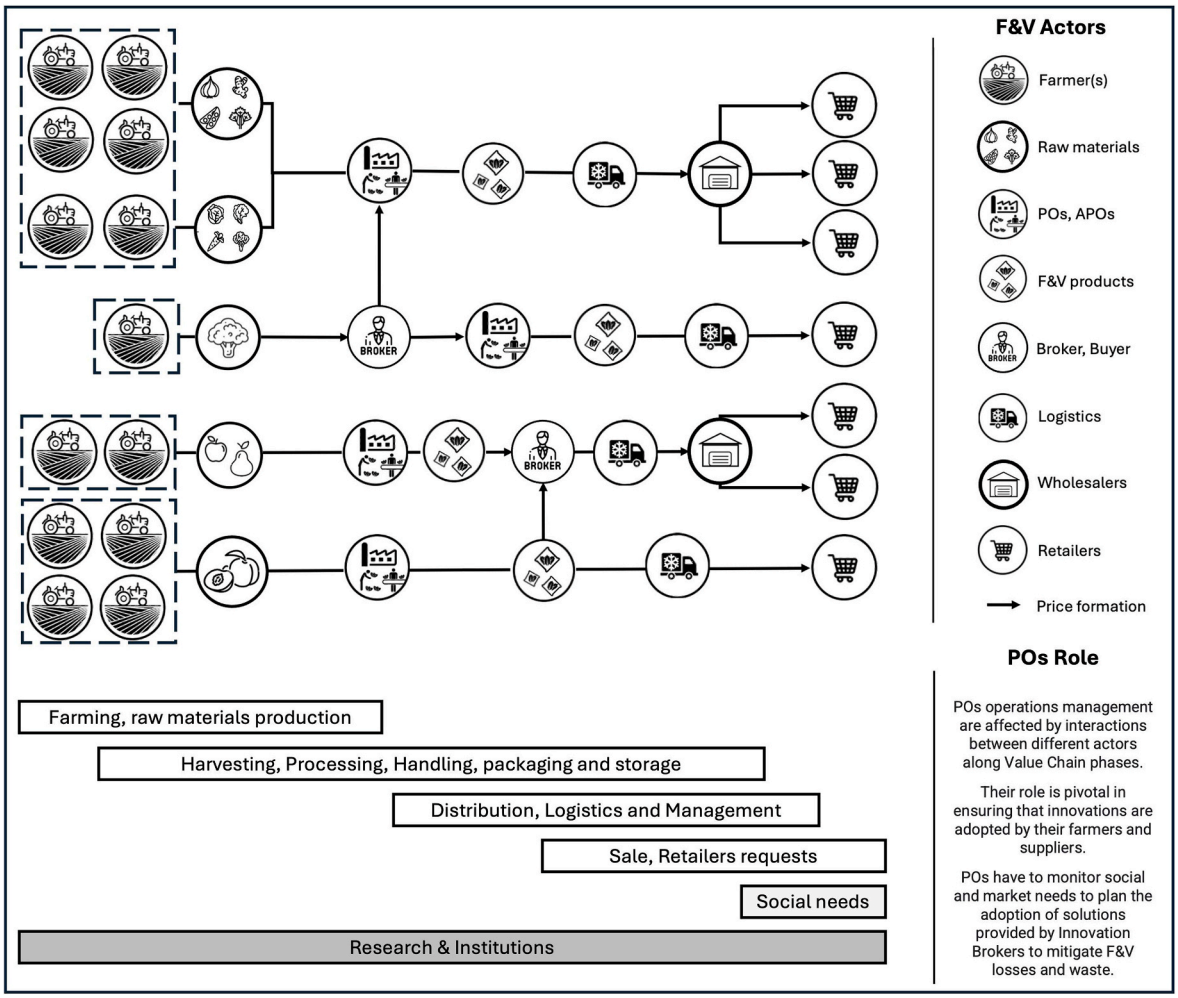


Fig. 1. Supply chain dynamics in the fruit and vegetable sector.

Table 2
P-sample.

Role in the adoption process	ID	Membership organization	Role in the organization	Gender of the Q-sorter	Age	Experience in the sector
Adopter	APO2	APO	Operative Programs Manager	M	50–55	>10 years
Adopter	PO2	PO	Organization Manager	F	40–45	>10 years
Adopter	PO3	PO	CMO Manager	F	40–45	>10 years
Adopter	PO4	PO	Market Withdrawals Manager	F	35–40	>5 years
Adopter	PO5	PO	President	M	60–65	>20 years
Adopter	EXP4	Institutional	Expert	F	40–45	>15 years
Adopter	EXP5	Institutional	Agronomist	M	40–45	>15 years
Innovation broker	PO7	PO	Commercial and Controlling Manager	M	40–45	>10 years
Innovation broker	PO8	PO	Operative Programs Manager	F	45–50	>10 years
Innovation broker	PO9	PO	Agronomist	M	45–50	>15 years
Innovation broker	EXP2	Research	Expert	M	30–35	>5 years
Innovation broker	EXP3	Research	Agronomist	F	30–35	>5 years
Planner	APO1	APO	Organization Manager	F	40–45	>15 years
Planner	PO1	PO	Operative Programs Manager	M	60–65	>20 years
Planner	PO6	PO	Commercial and Controlling Manager	M	35–40	>10 years
Planner	EXP1	Commercial	Buyer	M	45–50	>15 years
Planner	EXP6	Commercial	Expert	M	35–40	>5 years
Planner	EXP7	Research	Buyer	M	40–45	>15 years

shaped by his/her experience and position within the value chain. Therefore, the P-sample involved professionals with expertise at the upstream stages of the value chain (Dieteren et al., 2023). Since the characteristics of the membership organizations might influence the interviewees' subjective perspectives, it was decided to include in the P-sample a diverse range of organizations that operate at local, national, and international levels, market fresh fruit and/or vegetable products, and have previously engaged in research projects or implemented innovations in collaboration with research bodies or institutions. Annex 1 provides additional details on the participants included in the study and information about their membership organizations.

3.3. Data collection

The Q-sorting process involved the data collection organized by one-to-one remote interviews. The online tool Miro® (https://miro.com/it/) was used to present the statements included in Q-sample in the form of digital cards and to perform the sorting of each one on the Q sorting grid (Table 3). Two rounds of interviews were held during March–May 2023 and October–December 2023. All interviews followed the same structure (see Annex 2 for a list of descriptive questions asked in the interview). The first part of the interview was focused on a general description of the participant and their membership organization the interviewees read all statements and a warm-up discussion is conducted before beginning the Q-sorting process. The cards were divided into three groups: the statements with which they mostly agreed, the statements with which they mostly disagreed, and the statements with which they felt neutral. Then participants were asked to sort the thirty-four cards (e.g., statements), following the sorting condition: "*For each statement, indicate, based on your preferences, if you agree, disagree, or* feel *neutral to the effectiveness of the practice or innovation for the management of production surpluses and preventing food losses,"* from the "mostly agree" (+9) to the "mostly disagree" (+1), starting from the extremes. The employment of a solely positive scale in the Q-sorting grid, ranging from +1 to +9 as delineated in Table 3, was decided after the feedback obtained through the pilot test. The positive concourse under examination suggests that evaluating such progressive elements should naturally involve positive ratings (Mandolesi et al., 2015). The researchers noted that participants perceived the Q-sorting task as more straightforward when utilizing a scale with exclusively positive values, rather than a scale ranging from negative to positive. Therefore, the use of a positive scale not only makes the sorting process easier but also more accurate when the positive impact of the innovations to tackle FLW being studied (Diaz-Ruiz et al., 2019). Using this approach, a neutral feeling about what communicated by a statement is represented by placing the card in a cell of value (+4, +5, +6). Negative values correspond to (+1, +2, +3) and positive value correspond to (+7, +8, +9). Finally, during and after the Q-sorting process, the participants were invited to describe their personal point of view. As clearly stated to the participant, the goal of the Q-sorting is to rank the statements according to which solution they believe is more effective to prevent and optimize FFV products. The shape of the grid in Table 3 is also relevant since respondents are "forced" to classify the statements of the concourse in a normal distribution to set up the data analysis (Mandolesi et al., 2015).

The study assumed a basic understanding of the concourse, along a broader comprehension of the participants' operational context (Addams and Proops, 2000). For this reason, the distribution of the Q-grid is steep, leaving more free space for ambiguity and uncertainty. After the Q-sorting process is completed, all participants are asked to review the Q-sorting grid and discuss with the researchers the statements placed on the extremes of the distribution. Questions about the topic raised during the Q-sorting and other broad questions were discussed at the end of the Q-sorting to improve the availability of information and improve the overall quality of the outcomes (Brown, 1993; Webler and Danielson, 2009).

Table 3
Q-sorting grid.

Mostly Disagree			Neutral			Mostly Agree		
+1	+2	+3	+4	+5	+6	+7	+8	+9
+1	+2	+3	+4	+5	+6	+7	+8	+9
	+2	+3	+4	+5	+6	+7	+8	
		+3	+4	+5	+6	+7		
			+4	+5	+6			
				+5				

4. Data analysis

The analysis of the Q-sorts was conducted using the KadeQ® software (v. 1.2.1). The Q-sorts were subjected to factor analysis using principal component analysis (PCA) to identify the number of significant Q-statement combinations, or factors, to be extracted from the distribution (Watts and Stenner, 2012). Each factor can be referred to as "idealized sorts" because they are generated by the analysis rather than the participant (Brown, 1993). The decision about the number of significant factors to be extracted was made according to the relevant suggestions available in the scientific literature (D'Amato et al., 2019; Dieteren et al., 2023). A first decision can be made considering those factors that present an eigenvalue >1 (Watts and Stenner, 2012). After the PCA, more than seven factors satisfied this condition, but the authors observed low variation in the explained variance by adding supplementary factors after the fourth. Therefore, the scree plot test facilitated the final decision: this analysis is based on the observation of a typical "elbow" when plotting the eigenvalues of each factor (Watts and Stenner, 2012). This analysis confirmed the choice of four factors to be extracted and examined, representing 60% of the explained variance (Table 4).

Table 4 reports the number of defining variables, e.g., participant (or Q-sort), for each factor and their relative eigenvalues. A percentage of the overall study variance is explained by the statistical relationships between each factor and Q-sorts (Watts and Stenner, 2012). As recommended by other researchers and for data analysis purposes, the scale used for data collection was converted into a negative-to-positive scale ranging from (−4) to (+4) (Mandolesi et al., 2015). On this scale, Q-sort values in the middle of the distribution, such as (−1), 0, and (+1), indicate neutrality. The statements that are particularly relevant for the discussion are those ranked at the extremes of the scale, indicating disagreement (−4, −3, −2) and agreement (+2, +3, +4) with the topic under investigation (Table 5). These statements highlight distinct viewpoints and will be further analysed to explore the stakeholder perspectives represented by each factor (Barry and Proops, 1999).

Varimax is an algorithm designed to maximize the amount of variance explained by each factor without compromising the accuracy of the data (Webler and Danielson, 2009; Watts and Stenner, 2012). This analysis is performed by analysing the factor loading values (which represent the correlation between Q-sorts in Table 6) and deciding which solution maximizes the variance explained by the extracted factors (Naspetti et al., 2009). Selecting statistically significant factor loading is done by applying the Brown rule (Brown et al., 1980). Each Q-sort is related to each factor, and the decision on the number of Q-sorts to be rotated is based on the value of the factor loading that was statistically significant at the 0.05 level ($\pm 1.96 \times 1/\sqrt{n}$. of statements, e.g., ±0.34). In cases of significant loadings on more than one factor, the authors decided to flag the factor with the highest loadings (Loučanová et al., 2017). For each factor, rotated Q-sorts and their relative factor loadings are reported in Table 6. Assessing which Q-sort is related to each factor is also crucial for detecting patterns between the participants (Cuppen, 2012).

The discussion concerning the social perspective contained in the four factors can be expanded by examining the Z-scores. The Z-score is a value calculated during the analysis that indicates where, on average among the participants of each factor, the statement was placed on the scale from −4 to +4 (Watts and Stenner, 2012). One of the possible approaches is to assess the value of Z-scores for each statement, taking

Table 4
Eigenvalues and variance explained.

	Factor 1	Factor 2	Factor 3	Factor 4
No. of defining variables	6	4	4	4
Eigenvalues	4.5489	2.7933	2.0579	1.4980
% Explained variance	25	16	11	8

Table 5
Factor arrays.

Measure	Statement	Factor 1	Factor 2	Factor 3	Factor 4
Pr	1. Investments to reduce the risk of contamination between products during conservation in fridges	−1	**−3**	0	**4**
Pr	4. Innovations to monitor the quality of products during sorting phases	**2**	1	−1	−1
Pr	8. Investments to improve efficiency during transport phases	1	0	0	**−3**
Pr	12. Investments to maintain the cold chain from harvesting to retailers	**4**	**2**	**−2**	**−3**
Pr	13. Diversify the portfolio of customers to optimize the logistical efficiency of the volumes delivered	−1	**−2**	**−2**	**2**
Pr	20. Innovations for monitoring commercialization phases and warehouse flows	1	−1	0	1
Pr	23. Facilitate access to European and national funds	**3**	0	1	3
Pr	25. Improve the cooperation with institutions through projects and initiatives	0	**−2**	**2**	**−2**
Pr	26. Implement long-term action plans to address the climate crise	0	**2**	0	1
Pr	28. Use of innovative packaging during the storage and transport phases	**−2**	**−4**	**−2**	**−3**
Pr	29. Improve contracts with large-scale retail by providing incentive in the case of activation of practices that prevent FLW	−1	**−4**	**4**	0
Pr	32. Promote commercial campaigns for the sale of products with aesthetic defects	**2**	−1	**4**	3
Op	2. Develop “short supply" chain business models	**−3**	**3**	**−4**	**−2**
Op	3. Innovations in automation and robotics for the sorting of products	0	0	0	−1
Op	6. Use of innovative packaging for freshly harvested products	**−3**	**−2**	1	−1
Op	9. Software to optimize sales forecasting	**−2**	**−3**	**−3**	**3**
Op	10. Preservation of products with innovative chemical compounds	**−2**	**−3**	−1	1
Op	14. Allocate the surplus to charitable activities at a production cost	**4**	1	1	**2**
Op	16. Promote personal initiatives over collaborative actions	**−4**	1	**−4**	**−2**
Op	17. Participation in digital platforms to improve surplus' allocation	**3**	0	1	−1
Op	18. Improvement of agricultural production Decision Supporting Systems	**3**	**3**	**−2**	1
Op	21. Sale of fresh fruit and vegetables by digital platforms	**−3**	**−2**	**−3**	−1
Op	22. Setting up physical or digital spaces for training activities and exchange of good practices	0	1	−1	**2**
Op	27. Increase the portfolio of product with sustainability and/or quality labels	**2**	−1	**2**	**2**
Re	5. Organization of farms for investments in a common biodigester*	**−4**	0	**3**	**−4**
Re	7. Develop business models considering a “biorefinery” perspective	**−2**	−1	**−3**	**−4**
Re	11. Training of experts for the management of food surplus and waste	0	**2**	−1	0
Re	15. Transformation of fresh surpluses close to deterioration into long-life finished products*	**2**	0	0	**4**
Re	19. Use of discards and waste to produce energy and animal feed	1	**4**	**2**	1
Re	24. Development of collective composting facilities at distribution centres level	1	1	**2**	0
Re	30. Investments to optimize the management of FV product at distribution centres level	1	−1	−1	**−2**
Re	31. Increase knowledge and communication on tools to manage and reduce food surpluses	0	**3**	1	0
Re	33. Development of a shared protocol and guidelines to valorise FV surpluses management	−1	**4**	**3**	0
Re	34. Investments for the measurement of the volume of FV surplus and waste generated	−1	**2**	**3**	0

Please note that the letter in Column 1 “Measure” in Table 5 are referring to: **Pr**: Food surplus prevention; **Op**: Food surplus optimization; **Re**: Food losses recycling and recovery.

Table 6
Rotated factor loadings.

ID	Factor 1	Factor 2	Factor 3	Factor 4
APO1	0.8689*	0.1967	0.1107	0.2209
APO2	0.5530*	−0.0103	−0.0316	0.2509
PO1	0.3963	0.2687	−0.0285	0.4097*
PO2	0.8547*	0.2034	0.1020	0.1521
PO3	−0.0158	0.6365*	0.3233	0.1230
PO4	0.1135	0.0309	0.2419	0.5879*
PO5	0.5646*	0.0835	0.0788	−0.4408
PO6	0.4498*	0.0525	0.4317	0.1632
PO7	0.5594*	−0.0126	0.3901	−0.2851
PO8	0.2237	−0.1184	0.1021	0.7848*
PO9	0.0094	0.2750	0.2159	−0.4802*
EXP1	0.1630	0.8681*	−0.1031	−0.1348
EXP2	0.4363	−0.1699	0.7128*	−0.0082
EXP3	0.0846	0.2461	0.7723*	0.0503
EXP4	0.0763	−0.1175	0.8609*	0.1053
EXP5	−0.1271	0.3928	0.6003*	−0.0773
EXP6	0.1937	0.8047*	−0.0476	0.0267
EXP7	0.0866	0.8441*	0.1120	−0.2464

into consideration the category assigned during the construction of the Q-sample (Table 5 – See also Annex 3). It is possible to sum Z-scores by category and standardize the aggregate to the number of Q-statements in that category to compare salience across categories (Webler and Danielson, 2009; D'Amato et al., 2019). Table 7 shows the normalized mean Z-scores calculated for each factor in relation to the given type of

Table 7
Normalized Z score.

Type of measure	Factor 1	Factor 2	Factor 3	Factor 4	Mean
Food surplus prevention	0.2967	−0.4892	0.2117	0.1733	0.0481
Food surplus optimization	−0.1983	−0.0183	−0.5292	0.1283	−0.1543
Food losses recycling and recovery	−0.1180	0.6070	0.3810	−0.3610	0.1272

measure, as:

$$Z - score_m \ : \ \sum \frac{Z\text{–}score_i}{M}$$

m: category of measure
i: ith statement.
M: number of statements in the category of the measure.

The four factors resulting from the PCA represent the individualized opinions that emerged after the analysis of the Q-sorting (Mandolesi et al., 2015). Each factor represents a subjective point of view shared by the participants with a similar Q-sorting (Zabala et al., 2017). A graphical representation of the mean normalized Z-score for each factor in relation to their relative category of statement is provided in Fig. 1. The graphs in Fig. 1 illustrate the mean Z-scores for Factor 1 to Factor 4. Each of the spikes in the triangles represents the measure described by the statement according to categories defined during the design of the analysis (see section 3.2).

The graphical representation of the results facilitates the interpretation of the revealed stakeholders' perspectives after the analysis. These reflect the subjective point of view shared by the participants in the same factor about the best approach to reduce FLW in the FFV value chain (Jaitiang et al., 2022). Defining the social point of view described by each factor is made taking into consideration the sorting of the statements for each factor (Table 5) and reporting relevant comments from the participant (Annex 4).

5. Results and discussion

The findings of this study provide four stakeholders' social points of view on reducing FLW in the FFV sector, adding significant implications in light of sustainable transition and the sector's structural and commercial vulnerabilities (Thyberg and Tonjes, 2016). The viewpoints' convergence and divergence provide insightful information to optimize the matching of stakeholder priorities for future policy formulation (Surucu-Balci and Tuna, 2022). A a clear claim emerges from operators, stakeholders, and researchers, calling future policies to be tailored to support the sector's sustainability and resilience (Al-Obadi et al., 2022). The analysis of statements and the resulting Z-score analysis provide a clear view of where stakeholder opinions converge and diverge (Fig. 2). In Table 8, it is highlighted the distribution of distinguish statements across the four factors relating to the three categories of measure aimed at preventing FLW within the fruit and vegetable sector. Following the framework of the study, the measures are categorized into three distinct types: Food Surplus Prevention, Food Surplus Optimization, and Food Losses Recycling and Recovery, and are analysed across the factors. This is crucial for identifying the topic of the measures stressed by each factor and the importance of developing policies that are well-suited to the different and sometimes opposing priorities of stakeholders (Pancino et al., 2019). Inside the Food Surplus Prevention category, Factor 2 is predominantly associated with negative viewpoints. Conversely, the other factors present a balanced range of opinions regarding the adoption of innovations or investments proposed in the statements. For the Food Surplus Optimization category, Factor 3 exhibits the greatest disagreement, with a general inclination towards agreement in the opinions of Factor 1 and Factor 4. In the category of Food Losses Recycling and Recovery, Factors 2 and 3 display the strongest preferences towards this type of measure. However, Factor 4 contrasts with substantial disagreement, suggesting that there are divergent point of views in this category that require further considerations.

5.1. Factor 1 – innovation and digitalization

Factor 1 underscores the importance of using technology and digitalization to enhance efficiency, reduce waste, and contribute to social causes. This viewpoint represents a perspective that prioritizes the use of innovative strategies to manage surpluses and optimize supply chain operations (**14**, +4) supported by digital tools to improve operations (**17**, +3). Indeed, the Q-sorts in this factor highlight the need for technological advancements and digital platforms to manage surpluses and improve supply chain efficiency. This stresses the importance placed on infrastructure to preserve the quality of products from producer to consumer, emphasizing quality maintenance (**12**, +4). On the opposite,

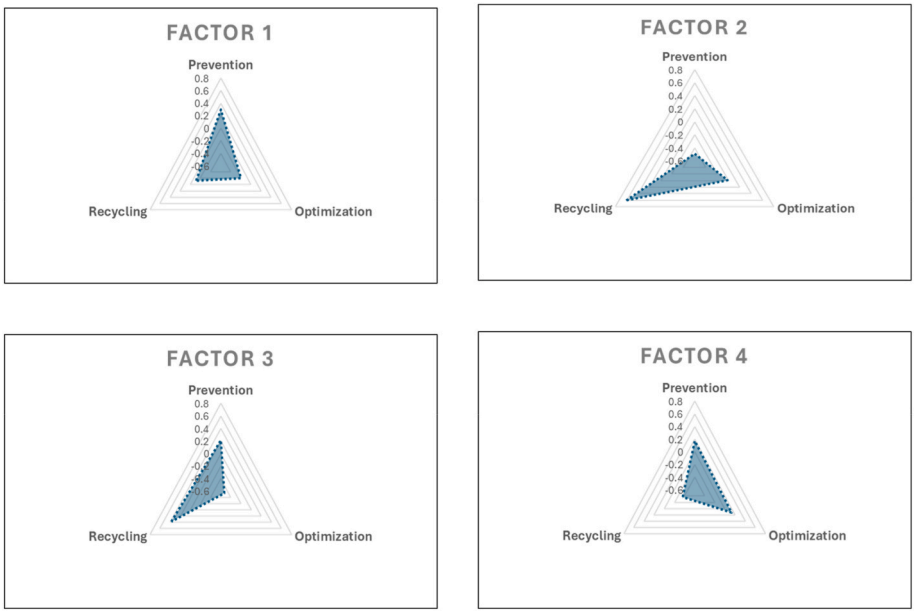
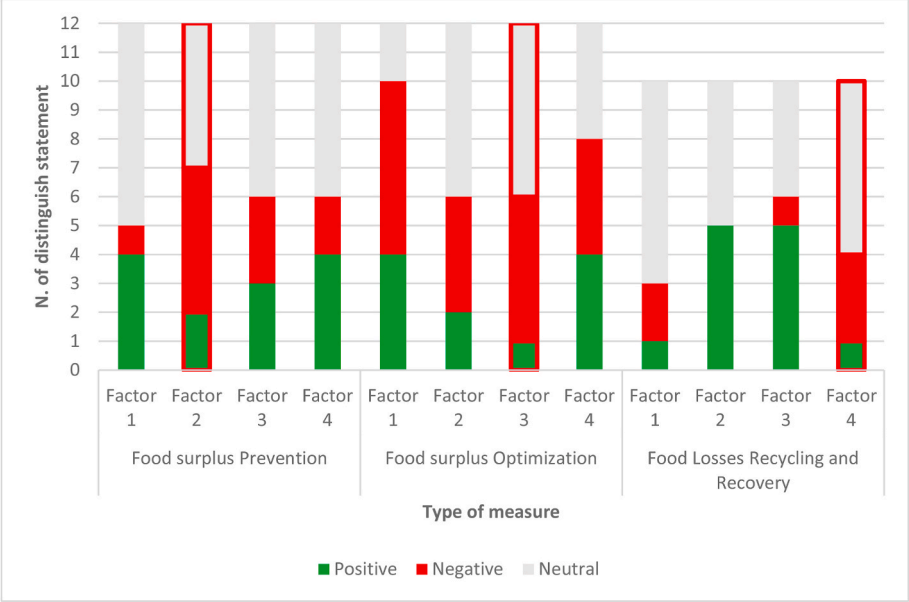


Fig. 2. Normalized Z-score for each factor.

Table 8
N. of distinguish statement for each factor grouped by type of measure.



the interviewees seem not convinced about the effectiveness of utilizing digital platforms for the sale of fresh fruits and vegetables (**21**, −3), pointed out by a "*preference for traditional marketing channels and a lack of readiness for digital marketplaces among the target customers*" [**APO1**]. The negative values associated with the organization of farms for common biodigester investments (**5**, −4) and the promotion of individual-level actions (**16**, −4) suggest a critique of these approaches.

5.2. Factor 2 – sustainable resource valorisation

Factor 2 emphasizes sustainable practices and the importance of effective communication and education campaign regarding waste management. This perspective is characterized by a claim for enhancing knowledge and establishing protocols to manage and valorise food surpluses (**33**, +4), underscoring the importance of structured approaches and education in achieving sustainability goals. Despite this, there's a clear endorsement of the "short supply chain" concept (**2**, +3) and the utilization of surpluse for energy (**19**, +4), reflecting a commitment to local economies and already consolidated circular economy practices. This factor also indicates a resistance to incentivized contracts for reducing waste in retail (**29**, −4), due to "*doubts about their practical implementation due to the strong market power of retailers*" [**PO3**]. In general, Factor 2 disagrees with the use of novel packaging and chemical preservation (**28**, −4); in the opinion of the participant, "*these approaches are viewed as non-essential and less effective compared to other actions.*" [**EXP6**].

5.3. Factor 3 - market-oriented prevention strategies

Factor 3 reflects a viewpoint that emphasizes the need for campaigns to market surplus products and the importance of discussing novel contracts with retailers to incentivize economically the adoption of sustainable surplus management practices (**32**, +4; **29**, +4). This perspective is supported by the high ranking of the statements related to the development of protocols to valorise surplus and waste (**33**, +3), indicating a strategical approach towards secondary raw materials and resource recovery. The negative perception of the "short supply chain principle" (**2**, −4) reflects "*concerns about the scalability and inclusivity of such models and a belief that broader systemic changes are necessary for meaningful impact*" [**EXP5**]. Factor 3 portrays a social-oriented perspective that emphasizes collective action and systemic change over individual initiatives (**16**, −4), suggesting that social and environmental responsibility are seen as inseparable.

5.4. Factor 4 - investment in value adding and supply chain optimization

Factor 4 is centred on the importance of investments in risk management and the optimization of value chain operations. The agreement towards statements related to the transformation of perishable surpluses into long-life products (**15**, +4) and for mitigating contamination risks (**1**, +4) reflects a strong emphasis on extending the lifecycle of FFV products and safeguarding quality. Also, the promotion of commercial campaigns for products with aesthetic defects (**32**, +3) further represents a progressive attitude towards reducing food waste and enhancing market opportunities for all producers, while also taking into consideration the damages to crops related to climate change. Conversely, Factor 4 shows a pronounced disagreement towards investments solely focused on the cold chain and transport efficiency (**8**, −3), suggesting a critical view of these areas as either "*sufficiently addressed within current practices*" [**PO8**] or "*less impactful compared to other interventions*" [**PO1**]. The negative values assigned to the organization of farms for common biodigester investments (**5**, −4) and the development of biorefinery business models (**7**, −4) suggest some reluctance towards these cirular economy approaches.

5.5. Discussion on shared insights

Factor 1 and Factor 4 mainly represent the point of view of POs and APOs, suggesting agreement in those innovations converging in the prevention area, by using different approaches. In general, these factors disagree on the development of biodigesters at the farm level (**5**; F1: +4; F4: +4) and the promotion of personal initiative over collaboration approaches (**16**; F1: +4; F4: +2). The focus on innovation and digitalization highlighted in Factor 1 aligns with the need for technological advancements in the sector and all the factors tend to agree on the allocation of surplus product to charitable organizations using digital platforms (Tort et al., 2022). Innovations like novel packaging products and optimized logistics are seen as relevant to reduce waste and enhance

competitiveness (Mylona et al., 2018; Aramyan et al., 2021). However, the investment costs and risks associated with innovations are reported as barriers to their adoption, as also discussed by other authors (Ghisellini and Ulgiati, 2020). The strong emphasis of Factor 2 and Factor 3 is towards innovations focused on the recycling of FLW and this could stand for a clear economic opportunity to valorise surplus and discards (Klewitz and Hansen, 2014). Comparing the four perspectives that emerged from the analysis is indeed relevant when discussing the four social perspectives emerged from this study (Reina-Usuga et al., 2020). To this aim, it is possible to consider the mean Z-score obtained from the individual statements within the factors to identify the so-called "*consensus statements*" (Annex 5). Consensus statements point to areas where all participants can agree on a way forward through conflict. (Webler and Danielson, 2009). Indeed, the exploration of statements with a high Z-score for each category shall suggests additional shared insights on particular topics during the adoption of sustainable practices, useful for producing advancement in the sustainable transition (Bryngelsson et al., 2016). In the Food Surplus Prevention Category, the use of innovative packaging during storage and transport (**28**, Z-score: 1.06) did not receive a strong endorsement due to "*the perceived cost required that is often related to commercial choices imposed by the retailers*" [**EXP1**]. On the other hand, promoting commercial campaigns for the sale of aesthetically flawed products (**32**, Z-score: 0.94) has been sorted on top, highlighting that imperfection and defect do not compromise the quality of the product (Pietrangeli et al., 2023a). Current regulatory frameworks about the use of novel packaging materials to preserve food products emphasize sustainability and reduction of environmental impact. European regulations, for instance, encourage the adoption of recyclable and reusable packaging materials to minimize waste (European Commission, 2023). These legislative measures not only aim to address environmental concerns but also align with consumer expectations for sustainable practices. Nonetheless, the high costs associated with implementing environmentally friendly packaging solutions can be a significant barrier, especially for smaller producers who are often bound by the commercial demands of larger retailers (Afif et al., 2022). For the food optimization category, the idea of promoting actions or innovations at the individual actor level rather than at the supply chain level (**16**, Z-score: 1.11) was not favoured. This also reflects a homogenous preference of the sample for systemic advancement over individual solutions. The disposition of unsold goods for charitable activities at production cost (**14**, Z-score: 0.925) was more welcomed, highlighting a societal inclination where businesses engage in social welfare and the agreement with institutional measure in case of crisis (Sundin et al., 2023). This confirm the agreement towards the European regulatory framework during crises event in the agricultural sector, highlighting the potential for enhancing regulatory reforms to encourage redistributions by facilitating the bureaucracy which is often mentioned as a barrier. Finally, the distinguish statements that fell under the Food losses recycling and recovery domain offers insight into the community's valuation of circular economy principles. The development of business models with a "bio-refinery" approach (**7**, Z-score: 1.1575) received a less favourable score, potentially indicating a general disagreement or perceived impracticality of implementing such business models at the present time (Bauer, 2018). Conversely, the utilization of losses and waste for energy and feed production (**19**, Z-score: 1.03) was viewed more favourably, suggesting a general endorsement of consolidated recycling strategies that directly convert waste into useful resources in line with circular economy principles (Klewitz and Hansen, 2014). Therefore, the preference for more immediately implementable solutions reflects a pragmatic approach to sustainability in the agricultural sector, prioritizing initiatives with quicker returns on investment and simpler integration into existing practices (Smith, 2008).

6. Conclusions

The application of the Q-methodology has disclosed the perspectives of stakeholders on strategies to mitigate FLW in the Italian fruit and vegetable sector. After analysing the responses from a sample of eighteen operators from the upstream phases of the FFV value chain, four distinct viewpoints were identified, emphasizing varied approaches to adopting innovations that prevent and optimize the management of fresh fruits and vegetables loss. A key theme is the preference for collaborative efforts over individual advancement, indicating readiness among stakeholders to participate in a structured and sustainable food system. The outcome from the operators outlines the need to tackle organizational challenges to promote digitalization, enhance the value of domestic products, and foster sustainable practices. However, the adoption of novel technologies is often hindered by high investment costs and perceived risks, highlighting the need for supportive policies to facilitate the access to public funds. This is also crucial for fostering dialogue and partnerships to develop solutions aligned with environmental, economic, and social goals. The need for developing co-innovation approaches based on shared objectives and dialogue among parties emerged also as a crucial theme. It was reported that the influence of commercial choices by retailers on the adoption of sustainable innovations by upstream actors is significant, directing investments that may not always meet producers' needs, reflecting trends highlighted in recent literature. This is particularly evident in the discussion concerning the adoption of novel packaging materials. Scientific research strongly supports the introduction of sustainable packaging, yet several significant challenges persist, as both Producer Organizations and experts have identified, even if from different perspectives. A primary concern is the question of who will bear the allocation of additional costs associated with packaging changes and their management. In a market dynamic where POs face difficulties negotiating on equal terms, these costs are predominantly borne by them. This financial burden represents a critical element within the supply chain, as underscored also by experts. Moreover, POs often raise a concern that can be encapsulated by the phrase "*it's not worth it.*", since they do not receive a direct economic benefit from this choice. This perspective fundamentally relates to their responsibility for organizing and managing new packaging solutions in a global context that is increasingly moving towards de-packaging initiatives. The study highlights that differing stakeholder perspectives on innovative packaging are a significant area of discussion. The core of collaborative decision-making relies on the stakeholders' ability to establish an integrated framework for actions that addresses broader needs beyond their immediate concerns. Engaging in dialogue among stakeholders can prompt a revaluation of existing practices, such as the introduction of shared strategies on packaging, which can serve as a focal point for future discussions. These interactions offer a compelling opportunity to redefine the dynamics of industrial decision-making power, particularly among those stakeholders with substantial contractual influence. Our final suggestion is that future Q-methodology studies could further explore these emergent topics, deepening insights into the sector's complexities and guiding more effective interventions.

6.1. Recommendations to foster Co-innovation actions

The insights from the Q-methodology study clearly point towards co-innovation strategies as pivotal for tackling the challenges in the Italian fruit and vegetable sector. Co-innovation, involving collaborative efforts that integrate diverse stakeholder contributions, emerges across all identified factors, emphasizing the necessity of joint actions to enhance sustainability and efficiency. The convergence and divergence of viewpoints provide valuable insights to encourage co-innovation as subsequent to informed policy development, particularly in refining strategies to align with stakeholder priorities and facilitate cross-sector collaboration, ensuring that technology providers, agricultural producers, educational institutions, and policymakers are not only aligned but also actively engaged in creating solutions. Participants agreed with solutions that merge technological advancements with traditional practices,

suggesting a strong inclination towards collaborative systems that enhance supply chain sustainability. To promote sustainable food business models where technology, policy support, and stakeholder engagement converge it is crucial to enhance co-innovation approaches and efficiency. Strengthening public-private partnerships can facilitate the effective implementation of sustainable value chains. Moreover, educational campaign aimed at aligning all parties toward common goals are central, ensuring that each stakeholder not only contributes to, but also benefits, from the collective efforts is needed. Our results support that adopters are ready to include prevention and optimization innovations in their businesses but despite the recognition of the potential benefits from innovations, such as novel packaging and optimized logistics, the high costs and perceived risks remain significant barriers. Areas for improvement and discussion are still related to the scalability of innovative practices, the economic viability of modern technologies, and the need for comprehensive policy support. Stakeholders also highlighted concerns about the actual implementation of collaborative strategies across different levels of the supply chain, which can be hindered by varied interests and the power dynamics among large and small players. Finally, there is an ongoing need to address the educational gaps that exist regarding the benefits and practical applications of sustainable innovations to develop a framework that ensure a fair widespread of sustainable innovations.

6.2. Limitations

A benefit of a Q-methodology study is that it clarifies the positions held by stakeholders and allows experts to use this knowledge constructively. It gives insight into the ways stakeholders see the issue, revealing the logic behind their position and putting the most critical issues in context, thus provides a valid representation of the potential range of the main relevant perspectives in the general population. However, the findings cannot be generalized to the population because they are only specific to the participants. The P-sample is composed primarily of representatives of POs and APOs since the authors' interest was in exploring upstream stakeholders' points of view about innovations and policies. Also, during the Q-sorting process, the operator was the one in charge of moving the statement on the grid shown on the software. This may have somehow influenced the decision of the interviewee. Future studies should also consider the point of view of other stakeholders in the FV value chain, including the point of view of retailers. A future Q-methodology study on this topic should involve a sample including the downstream phases of the chain, with a specific suggestion for the retailer phase and representative of wholesale markets, in addition to consumers. Finally, it is relevant to claim that the inclusion of a statement in each specific category has been conducted on the experience and knowledge of the authors and is considered only for the purposes of this study. The categories were created to qualitatively represent the results.

CRediT authorship contribution statement

Marco Nasso: Writing – review & editing, Writing – original draft, Supervision, Methodology, Data curation, Conceptualization. **Emanuele Blasi:** Writing – review & editing, Validation, Supervision, Resources, Methodology, Formal analysis, Conceptualization. **Flavio Pezzoli:** Validation, Investigation, Data curation. **Clara Cicatiello:** Writing – review & editing, Validation, Supervision, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2024.142984.

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