Food waste prevention along the food supply chain: a multi-actor approach to identify effective solutions

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Abstract

There is a large consensus highlighting the need to prevent the food waste volume along the food supply chain. However, there is currently a lack of understanding as to what the most effective anti-food waste measures to be implemented in fact are. The food waste puzzle can be considered from diverse perspectives depending on the stakeholder position on the chain. In view of this, the objective of this paper is to conduct a multi-actor approach to identify the most effective measures to prevent food waste. To do so, we combined in-depth interviews and the Delphi method and applied this to key agents along the food supply chain. The study was conducted in the Barcelona metropolitan region, and a total of 24 key stakeholders participated in the process. We identified 48 measures from the in-depth interviews. The Delphi method was used to evaluate stakeholders' perception of the effectiveness of each measure to prevent food waste and, the consensus and dissensus among the panel. In particular, we found different strong prevention measures, such as the increasing of diet valuation, weak prevention measures, such as building consumer awareness about food waste, and a set of redistribution measures. Finally, we discussed the importance of engaging as diverse a panel of stakeholders as possible when addressing food waste. The paper contributes to the incipient debate on how to examine the impact of multiple and diverse alternatives to food waste prevention.

Keywords: Barcelona, food losses, Delphi, food waste prevention, food redistribution, reduction

1. Introduction

The development of more sustainable alternatives to reverse the present food system scenario is one of the most important challenges society currently faces. There are numerous evidences highlighting the vast and increasing unsustainability of the agro-food system (Gamboa et al., 2016; Vinet and Zhedanov, 2010; Vivero-Pol, 2017; West et al., 2014). It is one of the most impactful human activities in generating greenhouse gas emissions, water consumption and soil utilization and depletion, among other notable effects, especially in the industrialized world (FAO, 2013; West et al., 2014). Moreover, despite having more nutrients available per capita than ever, there is both a significant percentage of people suffering from hunger (FAO et al., 2015) and an increasing percentage of people suffering from obesity and related illnesses (FAO-FAD-UNICEF-WFP and WHO, 2017). It is in this context that we must consider that one third of food produced is lost or wasted annually (Gustavsson et al., 2011). Food waste is emerging as a key symptom of the agro-food system that needs to be addressed. During the recent years, both policy bodies and research have devoted greater attention to the food waste phenomenon.

In the policy arena, food waste prevention is addressed at all levels: international, national, regional and local. From the international perspective, the United Nations outlines a specific target (12.3) within the Sustainable Development Goals to halve food waste volumes by 2030 (United Nations, 2015); to the regional and local levels where food waste prevention is gaining relevance in food systems sustainability debates (e.g. City Region Food Systems or the Milan Urban Food Policy Pact (MUFPP, 2017)).This, has been accompanied by a burst of research into food loss and waste in the last decade. Food waste studies have focused on quantifying the volume of food waste (e.g. Beretta et al., 2013; Buzby and Hyman, 2012; Chaboud, 2017; Ju et al., 2017; Willersinn et al., 2015), estimating the associated impact (e.g. Beretta et al., 2013; Brancoli et al., 2017; Campoy-Muñoz et al., 2017; Kummu et al., 2012; Mattsson et al., 2018; Vittuari et al., 2016), finding out the root of the problem (e.g. Canali et al., 2017a; Göbel et al., 2015; Parizeau et al., 2015; Thyberg and Tonjes, 2016) and, to a lesser extent, some research has been devoted to finding solutions to prevent and reduce the current volume (e.g. Mourad, 2016; Priefer et al., 2016; Strotmann et al., 2017; Thyberg and Tonjes, 2016).

Food waste prevention measures are very diverse in terms of both scale (national, regional and local) and domain (NGOs, private companies, international platforms, public institutions), from consumer awareness campaigns to new social enterprise models. However, little is known about the impact of actions on food waste volume reduction. To provide some guidance, a number of organisations have been working on transposing the waste hierarchy from the EU Directive

2008/98/CE into a food waste hierarchy (e.g. GIZ et al., 2016; Papargyropoulou et al., 2014). The hierarchy gives priority to prevention over recycling and final disposal. Prevention encompasses numerous actions aimed at avoiding the generation of food waste. If prevention is not possible, a set of alternatives are outlined to manage these "surpluses/waste-to-be/side-flows" and avoid them being disposed and losing all their value (nutritional, energetic, as a resource and so forth). Therefore, the second preferred option is to redistribute food for human consumption. If it is not possible to recirculate this "waste-to-be" for human consumption, the following options are: recycling into animal feed or composting, recovery of the embodied energy via anaerobic digestion or alternative treatments and, finally, disposal into landfills.

After a decade of public initiatives on food waste, there is no evidence showing to what extent they have contributed to reducing the magnitude of the problem (European Union, 2016). The complexity of the food waste phenomenon therefore requires further debate. New approaches are needed to analyse the appropriateness of all possible solutions. Cristóbal Garcia et al. (2016) suggested prioritizing measures with higher feasibility and a higher impact on the reduction of food waste. Although publications on this are still scarce, we found recent publications exposing and discussing different possibilities for preventing and reducing food waste and have suggested some ways to systematize and analyse multiple alternatives (Canali et al., 2017; Cristóbal et al., 2017; Göbel et al., 2015; Mourad, 2016; Priefer et al., 2016; Thyberg and Tonjes, 2016).

The emerging publications on classifying food waste prevention actions have proposed various different approaches. Thyberg and Tonjes (2016) produced a three-level classification of solutions based on whether they are related to values, skills or logistics. Cristóbal et al. (2017), following the food waste hierarchy, distinguished among the prevention actions (e.g. consumer campaigns, standardized food labelling), reuse actions (e.g. tax donation incentives, transportation) and recycling-recovery ones (e.g. compost, animal feed). Mourad (2016) also prioritized prevention over recovery (e.g. food donation) and recycling (e.g. animal feed, anaerobic digestion). However, she highlighted the relevance of differentiating between strong and weak prevention actions, drawing a parallel with the concepts of strong and weak sustainability (Neumayer, 2003). The main difference between the two is that the former seeks holistic changes in the food system to persist over time, while weak prevention only calls for process or behaviour improvement, thus neglecting the long-term risks and rebound effects. Figure 1. summarizes a possible classification and prioritization of food waste measures.

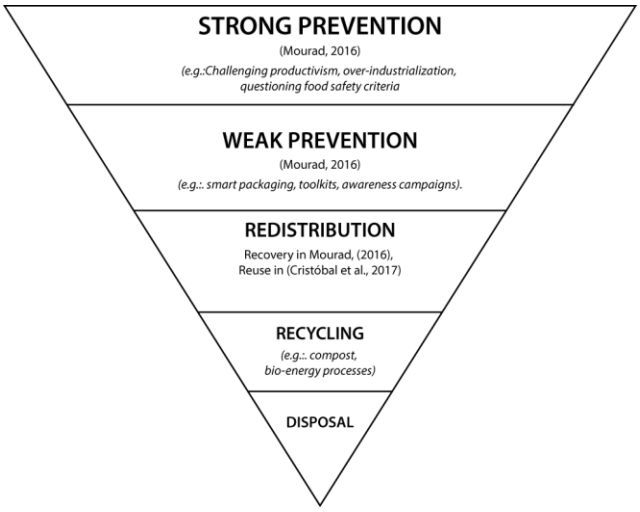

Figure 1 Food waste solutions priorities

More recently, some studies have pointed out the need to acknowledge the complexity of the food waste problem (Abiad and Meho, 2018; Campbell et al., 2017; GIZ et al., 2016; HLPE, 2014; Montagut and Gascón, 2014; Muriana, 2017; Papargyropoulou et al., 2016, 2014). The acknowledgement of its complexity necessitates the collaboration of different stakeholders to implement effective actions to prevent food waste stemming from the existence of different roles, responsibilities and levels of involvement in food system decision-making. Of all stakeholders, policymakers are key due to their important role designing public policies and plans. However, the interplay of stakeholders in the implementation of such policies and actions would suggests the need to include as wide a range of stakeholders as possible (Mourad, 2016). There is a significant body of literature from diverse domains stressing the importance of involving stakeholders in the study of complex environmental and social issues in order to approach them in a more effective way (Faysse et al., 2014; Li et al., 2017; Perveen et al., 2017; Reed, 2008). In this context, Cristóbal Garcia et al. (2016) and FAO (2015) classify stakeholders into five groups based on their role in a given food system in a region: 1) those catalysing the change (policymakers); 2) those understanding the food system (citizens and educational institutions); 3) those using policy instruments (farmers, processors, retailers, social enterprises); 4) those leveraging wider impact (NGOs, financial institutions): and 5) those learning and sharing knowledge (educational institutions, NGOs, social enterprises, researchers).

This paper seeks to address the prioritization of effective measures to prevent food waste and to examine the role of stakeholders in this. Thus, the following two questions are addressed in this paper: 1) what are the most effective measures to enhance the prevention of the food being wasted along the food supply chain; and 2) what is the role of stakeholders in food waste prevention? To address these

questions we carried out a holistic approach that comprised the participation of a diverse panel of stakeholders throughout the diverse stages of the food supply chain. The methodological framework was based on in-depth interviews and a Delphi survey. The study focused on a particular region – the Barcelona metropolitan region – which is one of the most populated areas in Europe.. The field work allowed us to answer the first research question and, an in-depth discussion of the results will serve to answer the second.

2. Materials and Methods

The methodological framework followed in this study (Figure 2) was based on a two-stage qualitative-quantitative approach. The first stage was exploratory; it comprised in-depth interviews of different stakeholders along the food supply chain followed by a content analysis.. The first stage was intended to identify possible measures to prevent and reduce food waste volumes in the region along different stages of the food supply chain. The second stage consisted of a Delphi survey to explore the degree of effectiveness of preventing food waste through each of the measures identified by the interviewees in the first stage and to assess the consensus among the stakeholders about the effectiveness of each measure.

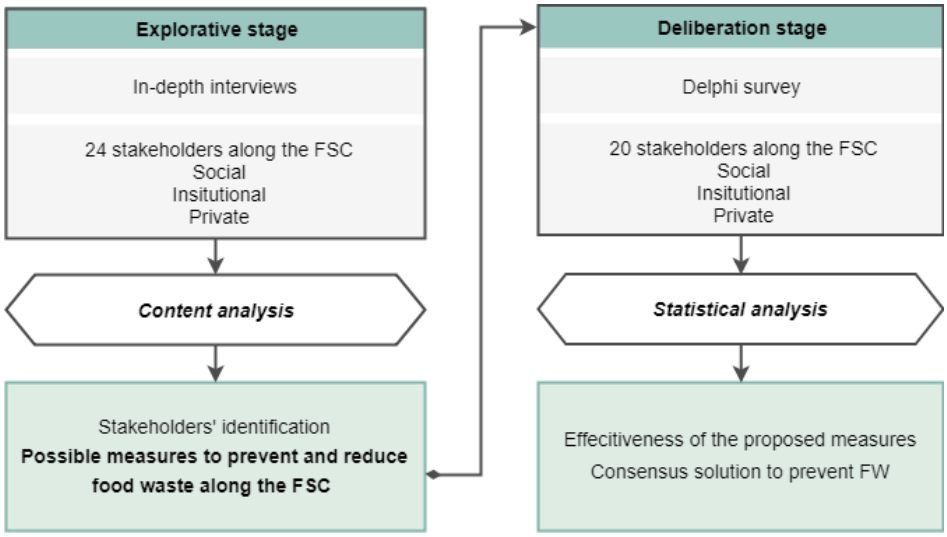

Figure 2 Methodological framework

2.1. Explorative and deliberation stage

Semi-structured interviews were conducted with 24 key stakeholders from October 2014 to January 2015 (see Table 1). The interview guide included different questions that ranged from general to specific. This was intended to explore different aspects of the food waste phenomenon (the causes, responsibilities, interest, knowledge and solutions). All the questions were open. The interviews

lasted from 45 to 100 minutes. All the interviews were recorded and transcribed verbatim. Here, we consider the last section of the interviews, which focused on exploring tentative measures to prevent and reduce food waste (the first part of the interview is addressed in Diaz-Ruiz et al., (2018)). By means of content analysis, it was possible to identify an extensive list of measures to prevent food waste that could be implemented along the food supply chain in the metropolitan region in the near future.

In the second stage, a two-round Delphi questionnaire was conducted. This stage was intended to analyse the effectiveness and the level of agreement among the panel of stakeholders on the set of measures to prevent food waste in the food chain identified in the first stage. The Delphi questionnaire was implemented from March to June of 2015 (the first round was from March to May, and the second from May to June). After the two rounds, we got answers for a final panel of 20 key stakeholders.

The Delphi method is a technique of collecting information that has been traditionally applied to reach consensus among experts on a complex issue as well as to forecast, explore new ideas and trends on a specific problem¡ (Kennedy, 2004). The process of obtaining results requires the participation of the panel over consecutive rounds of data collection through a more or less structured (depending on the phase of the study) questionnaire. The peculiarity of this method is that the Delphi questionnaire responses from each completed round feed into the next round, which will be applied to the same consulted panel. The three key elements to take into account in the Delphi survey are: 1) the communication between moderator and participants; 2) the continuous feedback of results; and 3) the anonymity of participants, as the opinions expressed are only presented in aggregate form (Callejo Gallego, 2009).

In our case, the participants evaluated all the identified solutions, during the interviews, to prevent food waste using a 100-point scale (from 0, not efficient, to 100, more efficient) in the first round. The measures were presented to the panel considering the different stages of the supply chain. After analysing the results from the first round, we sent the survey back to the panel. To facilitate stakeholders' comprehension and to allow them to compare their previous answers with the aggregated results of the panel, the second round survey provided the mean, the coefficient of variation and a boxplot figure. The panel again evaluated the set of measures and were able to change their previous score if they chose. We finished the Delphi survey after the second round (Gary and von der Gracht, 2015).

By analysing the final round of the Delphi questionnaire, it is possible to define the effectiveness of the measures and the level of agreement among the panel. The effectiveness of every statement

was evaluated on a 0-100 continuous scale. We adapted the importance scale from Clibbens et al. (2012) to classify measures in an effectiveness scale: very high: 90-100; high: 80-89; moderate: 65-79; low: 50-64; very low: below 50. To assess the consensus about the level of agreement on specific measures, the interquartile range (IQR) was used. Consensus is reached when IQR is no larger than 20 in a scale of 100 (adapted from Gary and von der Gracht, 2015; von der Gracht, 2012). In order to highlight the divergences among stakeholders, statements with an IQR equal to or higher than 40 were underlined as dissent statements.

2.2. Sampling and participants

The selection of the panel of stakeholders for the two-stage approach is key to the success of this methodological framework. Considering the complexity of the food waste phenomenon, the criterion followed to choose the participants involved enhancing heterogeneity of profiles as well as considering stakeholders along the entire food supply chain. Following Reed et al. (2009), we mapped the food system in the metropolitan region by identifying stakeholders from the private sector, public institutions and those specifically working on food waste in the social sphere. When referring to experts in Delphi studies, it considers individuals with knowledge in the research topic (Hasson et al., 2000). Thus, expert is understood in a broad sense, and it comprises either experts, scholars, those interested in or those directly affected by the subject matter (Pill, 1971). The specialized literature, recommend to create an heterogeneous panel (Kennedy, 2004; Rowe and Wright, 2011). On the selection of the members of the panel, previous authors suggest to consider the commitment to participate in the study, their willingness and ability to make valid contributions and their level of knowledge of the research topic (Hasson et al., 2000; Powell, 2003). Therefore, it requires a non-probabilistic sampling technique (Hasson et al., 2000). In our case, we carried out an intentional (or purposive) sampling, which is a non-probabilistic procedure where the selection of sample units attends to subjective criteria related to the aim of the study. The key informants strategy was chosen from various options (e.g. less common case, homogeneous subgroups) (Del-Val-Cid, 2009) to select stakeholders with the maximum information about the topic in the metropolitan region along the food supply chain, while considering the three categories: private sector, institutional representatives and the social aware ones. Based on our stakeholder map in the region, we start contacting those stakeholders who had previously showed an interest on food waste. At the time of the study food waste was not so widely covered in the metropolitan region.

To recruit the members, we first contacted them and invited to participate in the study for the first stage (in-depth interview), at the end of the interview they were asked to continue in the second stage. Table 1 shows the final panel of experts used for both stages of the study. We used the same panel

from the explorative stage to form the Delphi panel. In case we had a drop-out from a member of the first stage we tried to equilibrate the sample to keep the multi-actor approach and the heterogeneity required.

Table 1. Characteristics of the panel of stakeholders for the two stages of research

Participant profile	Stage		Type of stakeholder			Stage of the food supply chain							
	1: Explorative phase	2: Deliberation phase	Private	Institutional	Socially-aware	Food supply chain	Primary production	Processing	Wholesale	Retail	Redistribution	Catering	Consumers	Education
Social Enterprise "rescue" food	●	●			●	●								
Food security regional body	●	●		●		●								
Waste management regional body	●	●		●		●								
Environmental municipality	●	●		●		●								
Regional consumer body	●			●		●								
Primary production metropolitan body	●	●		●			●							
Agri-food regional body	●	●		●			●							
Farmers' organization	●			●			●							
Farmers organic cooperative	●		●				●							
Farmers' cooperative organization		●		●			●							
Industry association	●		●					●						
Industry	●		●					●						
Industry		●	●					●						
Distributor and industry		●	●					●						
Wholesaler organization	●	●	●						●					
Small wholesaler	●		●						●					
Retailer	●		●							●				
Retailer	●	●	●							●				
Retailer	●	●	●							●				
Local market body	●	●		●						●				
Wholesale retailer		●	●							●				
Charity food pantry	●	●			●						●			
Charity food bank	●	●			●						●			
Local popular dining "freegans"	●	●			●								●	
Consumer association	●	●			●								●	
Consumer association	●			●	●								●	
Expert academia	●	●			●									●
Environmental NGO	●	●			●									●

2. Results

The two-stage results are presented in this section. In the first stage in-depth interviews were analysed using content analysis. As a result, 48 measures to prevent and reduce food waste were identified (Table 2[1]). The stakeholders provided a highly diverse set of measures along the food supply chain, from those addressing particular and specific circumstances, such as the establishment of freezing protocols in supermarkets in order to increase fresh food donation to charities, to those

[1] Table A1 in the Appendix includes a full description of the solutions provided by the stakeholders.

addressing systemic aspects, such as promoting a strategic food access plan. The set of 48 measures extracted from the interviews were evaluated in the two-round Delphi panel. The results provided the stakeholders' perceived effectiveness as well as the degree of consensus/dissensus among them.

The perceived effectiveness of each measure in preventing and reducing the volume of food waste in the near future in the metropolitan region of Barcelona is shown in Table 2. This outlines the mean score for the effectiveness of each measure, the standard deviation, the medium and the IQR. In general, stakeholders assigned high values to all measures. There is no measure scoring under 50 points out of 100. The average score ranged from 57.2 to 89.4 points. The lowest valued solution was "applying a flexible mechanism to prices, offers typologies according to the production volume" (#6), while the highest valued was "education in values and valuing food and diet" (#34). Following Clibbens et al. (2012), we classified the proposed measures into three groups: 1) solutions with high effectiveness in preventing and reducing food waste (from 80 to 89 points), 2) those with moderate effectiveness (from 65 to 79 points); and 3) solutions with low effectiveness (from 50 to 64 points).

The high perceived effectiveness group comprises seven measures aimed at increasing society's food waste concern, and improving food redistribution and access to food. Three of these focused on increasing awareness of food waste in the society, with specific emphasis on households and schools (#34, #35 and #31). Two measures proposed increasing the awareness of food waste and promoting changes in consumer habits (#29 and #30). There was also a proposal to create a strategic food access plan (#48) and to build a network to redistribute and use farm surpluses instead of wasting them (#9).

The low perceived effectiveness group contains 11 measures. These mainly referred to the implementation of regulatory and policy changes, and improving business management. Measure number 8 suggested making the real situation of farmers more visible. Others referred to the introduction of changes in the way the food system and food redistribution is managed by incorporating price mechanisms (#6 and #43), or by planning and forecasting primary production (#1 and #3). The low effectiveness group also comprises measures in relation to regulations and policies aimed at increasing the price of waste generation (#32 and #15), and regulating and designing a network to improve the redistribution of food (#40, #18, #46 and #39).

The medium perceived effectiveness group is the biggest one, comprising the remaining 30 measures. Measures are diverse, focusing on both specific stages of the food supply chain and those along the entire supply chain.

Apart from the panel's perceived effectiveness of the set of measures, we were also interested in the degree of agreement among them. The last column of Table 2 shows the IQR of each measure;

consensus[2] was reached in 15 measures. These were mostly focused on increasing society's awareness of food waste, as well as promoting changes in business dynamics. Six solutions were related to encouraging a change in habits in the society and, more specifically, in the consumers (#30, #26 and #29) so as to better educate and increase awareness about the food waste problem (#35 and #31), and to educate people in values related to appreciating food and diet (#34). There was also a meaningful consensus on solutions encouraging improvements or changes in business logistics and management (#10, #2, #25, #28 and #27). Finally, three measures were linked to food redistribution (#9, #36 and #21) and one that, from a global perspective, promoted supporting social movements in order to make the problem more visible, which can encourage companies and institutions to react (#33).

Concerning dissensus,[3] stakeholders significantly disagreed about the perceived efficacy of eight measures. Six of them proposed a new regulation or policy (#40, #5, #43, #15, #41 and #46), of which three were related to monetary incentives, like guaranteeing a minimum price to farmers (#5), increasing the disposal of industrial waste management prices (#15), and implementing laws to regulate prices and donations (#43); the other three aimed at increasing food donations and distribution by law, not relying on companies donating food (#46), regulating redistribution to human consumption and feed for animals (#40), and facilitating the bureaucracy of food donations from supermarkets (#41). The other two measures with a clear dissensus were: increasing social pressure to increase food donations (#42) and influencing farmers' mentality to encourage them to take advantage of the whole crop (#4).

[2] Consensus among stakeholders if IQR≤20 following c(2015) and von der Gracht (2012). Statements in bold in Table 2.

[3] Dissensus among stakeholders when IQR≥40. Statements in italics in Table 2.

Table 2. Measures to prevent and reduce food waste, Delphi results

		Stage	$\bar{x}$	*s*	*Md*	*IQR*
High efficacy	**(#34) Education in values and valuing food and diet**	**Soc.**	**89.4**	**7.1**	**90.0**	**10.0**
	(#35) Awareness campaigns to increase consumer concern	**Hh**	**87.6**	**11.1**	**90.0**	**5.5**
	(#29) Change of habits to reduce food waste volumes	**Soc.**	**87.3**	**15.8**	**90.0**	**18.5**
	(#31) School teaching on food waste	**Soc.**	**85.5**	**17.8**	**90.0**	**20.0**
	(#30) Promoting food purchase planning	**Hh**	**84.4**	**13.7**	**86.5**	**17.5**
	(#48) Promoting a strategic food access plan	FSC	81.0	16.0	80.0	30.0
	(#9) Network to redistribute and use farm surpluses	**Agr.**	**80.3**	**16.1**	**80.0**	**17.5**
Moderate efficacy	**(#21) Donation protocols compulsory to all supermarkets**	**Ret.**	**78.9**	**22.1**	**80.0**	**20.0**
	(#33) Supporting social movements to make companies react	**Soc.**	**78.4**	**15.4**	**80.0**	**20.0**
	(#36) Freezing protocols to facilitate donation	**FSC**	**77.3**	**15**	**80.0**	**18.8**
	(#24) Business adaptability to clients	Ret.	76.0	22.5	80.0	27.5
	(#22) Supermarket pick up route promoted and funded by the local administration	Ret.	76.0	21.9	80.0	27.5
	(#44) Legislative changes to promote FW prevention and food redistribution	FSC	75.8	24.3	80.0	36.3
	(#38) Aggrupation of social charities at the local level	Ch.	75.8	23.1	80.0	27.5
	(#25) Companies joint work to minimize FW	**Ret.**	**75.7**	**15.7**	**80.0**	**10.0**
	(#20) Micro-donations program to minimize organic waste	Ret.	75.0	25.2	80.0	37.5
	(#13) Surpluses out of best before date to food banks	Ind.	74.7	25.2	80.0	30.0
	(#11) New category commercialization regulations	FSC	74.0	20.4	80.0	27.5
	(#47) FW prevention on waste management plans	FSC	74.0	23.5	80.0	37.5
	(#14) Voluntary actions to reduce avoidable FW	Ind.	74.0	18.2	80.0	27.5
	(#23) Guides on food security and false myths about food donation	Ret.	73.8	27.4	80.0	33.8
	(#41) Administrative facilitation of supermarket food donations	*Ret.*	*72.8*	*22.1*	*80.0*	*40.0*
	(#37) Better knowledge of charity functioning	Ret.	72.0	21.7	70.0	27.5
	(#10) FW reduction in the wholesale market management	**Who.**	**70.8**	**21.8**	**75.0**	**14.0**
	(#28) Retailer awareness of stock management	**Ret.**	**70.3**	**16.5**	**80.0**	**10.0**
	(#19) Training store staff about donation methods	Ret.	70.3	23.6	80.0	30.0
	(#17) Buying whole harvest for producers	Ag-I	70.2	18.6	70.0	25.0
	(#2) Forecasting farming linked to commercialization	**Agr.**	**67.9**	**21.2**	**70.0**	**20.0**
	(#12) Improving manufacturing processes to reintegrate product within the production line	Ind.	67.9	21.7	70.0	27.5
	(#26) Campaigns aimed at buyers	**Hh**	**67.9**	**18.3**	**70.0**	**20.0**
	(#42) Increasing social pressure to increase donations	*Soc.*	*66.8*	*25.8*	*70.0*	*40.0*
	(#27) Infrastructure improvements on food conservation	**FSC**	**66.6**	**16.2**	**70.0**	**17.5**
	(#7) Boosting local agricultural production model	FSC	66.4	26.9	70.0	37.5
	(#4) Farmers' mentality of taking advantage of the whole crop	*Agr.*	*65.9*	*24.5*	*63.0*	*40.0*
	(#45) Opening new horizons on food security	FSC	65.8	24.2	75.0	30.0
	(#16) Planning (distributors and producers) what is going to be consumed	Ag-Ret.	65.8	21.6	70.0	26.0
	(#5) Minimum profitable and promising price	*Agr.*	*65.6*	*30.2*	*71.0*	*40.0*
Low efficacy	(#1) Agriculture planning improvement to avoid surpluses	Agr.	63.6	25.0	70.0	30.0
	(#8) Making the reality of primary production known	FSC	63.2	18.6	70.0	25.0
	(#39) Network of potential donors of food	FSC	63.1	21.1	70.0	30.0
	(#46) Laws and regulations to avoid donation reliance on businessperson willingness	*FSC*	*63.0*	*31.8*	*65.0*	*65.0*
	(#3) Public bodies tracking farming forecast	Agr.	62.3	21.7	70.0	30.0
	(#18) Food redistribution with business' own transport	Ret.	62.0	30.2	70.0	30.0
	(#40) Regulation on compulsory prioritizing of redistribution over feed	*FSC*	*61.5*	*27.1*	*65.0*	*40.0*
	(#32) PAYT management system	Hh	61.2	20.4	60.0	30.0
	(#15) Increasing industrial waste disposal management prices	*Ind.*	*59.2*	*28.2*	*57.0*	*52.5*
	(#43) Laws regulating boundaries between price decreasing and donations	*FSC*	*58.2*	*27.8*	*60.0*	*47.5*
	(#6) Applying a flexible mechanism to prices	FSC	57.2	20.5	59.0	30.0

Note: (#) number of measure, see Appendix A to read the whole statement; FSC: food supply chain; Agr.: Agriculture; Ag-I: Agriculture and industry; Ind.: Industry; Ret.:retail; Hh:household; Soc.: Society; Ch.:charities, $\bar{x}$: mean; s: standard deviation; Md: median; IQR: interquartile range. In **bold**: consensus statements, in *italics*: dissensus statements

3. Discussion

Food waste is a burgeoning area of research and there are still big gaps in knowledge. However, there is an increasingly agreement on the necessity of reducing the current generation of food waste. Public, private and social institutions have multiplied their efforts in this direction, generating and, to some extent, implementing, alternative measures. In most cases, measures have been adopted individually by one specific stakeholder, without assessing the potential impact on other stages. There is therefore a need for multi-actor approaches to evaluate and prioritize actions that significantly reduce the current food waste volume. This study attempts to fill this gap by focusing on a specific territory: the metropolitan region of Barcelona. To answer the two research questions mentioned in the introduction – 1) what are the most effective measures to enhance the prevention of the food being wasted along the food supply chain; and 2) what is the role of stakeholders in food waste prevention– we classified all the measures included in Table 2 into three groups of solutions: strong prevention measures, weak prevention measures and redistribution measures. We also identified the stage of the food supply chain involved, the role of stakeholders in the implementation of the proposed measure and, finally, the geographical scope of the measure. Table 3 summarizes the main results, as well as identifying to what extent the suggested measures were mentioned in previous literature.

3.1. What are the best strategies and actions to address the current scenario and reduce the food waste generation along the food supply chain?

To answer the first research question we classified all 48 measures following Mourad's (2016) three-step food waste hierarchy (see Figure 2): strong prevention solutions, weak prevention solutions and redistribution. Within each group, and to better understand the type of solutions provided by stakeholders, the nature of the measures were classified into four groups by summing up the alternative classifications suggested in previous literature (Canali et al., 2017; Göbel et al., 2015; Priefer et al., 2016; Thyberg and Tonjes, 2016): 1) technologically oriented; 2) economic and business management related; 3) regulatory and policy related; and 4) appreciation and enhancement oriented.

Overall, stakeholders proposed more prevention (30) than redistribution measures (18). Regarding prevention measures, there was a preference for weak measures (19) over strong ones (11). There was no proposed solution that could be classified as recycling. With regard to their nature, a significant proportion of the measures were either business-related (17) or regulatory and policy-oriented (16); 13 measures were aimed at increasing knowledge and awareness, and only two were technology-oriented. Table 3 shows the classification.

Strong prevention measures are those aimed at avoiding the generation of wasted food by adopting a broader perspective, contributing to a change in paradigm or to a collective transformation of the system (Mourad, 2016). Notwithstanding the name given to these measures, previous studies have also suggested this type of action. Betz et al. (2015) and Göbel et al. (2015) claimed there is a need to develop a new appreciation for food. Stakeholders in the metropolitan region of Barcelona considered that this could be a highly effective measure to prevent and reduce food waste. Cristóbal et al. (2017) proposed changing produce specifications so as to accept and to integrate off-grade produce into the market. Similarly, Priefer et al. (2016) suggested replacing European marketing standards related to appearance with quality criteria, as well as reviewing food safety regulations. All three measures were also suggested by our panel. However, our panel assessed them as of moderate effectiveness in preventing and reducing food waste. Mourad (2016) and Priefer et al. (2016) discussed the potential impact on food waste prevention of bringing people closer to production and finding alternative marketing channels for producers. Barcelona's stakeholders also suggested promoting local production and increasing the citizen's knowledge about the work of local producers. However, such measures were not considered very effective ways to prevent and reduce food waste in the region. This could be explained by the fact that the Barcelona metropolitan region is a highly urbanized area where a limited number of peri-urban agricultural experiences have been developed. Finally, other studies have advocated the necessity of having a broader food policy approach to tackle food waste (Blay-Palmer et al., 2018; De Schutter, 2017; Mourad, 2016; Wunder et al., 2018), which in our case could have been partially covered by the highly effective measure of developing a new strategic food access plan.

Weak prevention solutions to food waste refer to avoiding the generation of wasted food by highlighting the implications for individuals, with a view to an optimization or an improvement of processes and/or behaviours (Mourad, 2016). Since this type of measure is not calling for a major change in current dynamics, they are easier to implement, and they have been more frequently proposed in both policy debates and previous literature than strong prevention measures. Very often, consumers are targeted in campaigns aimed at increasing their awareness of food waste, or by promoting a change in consumption patterns or food-related habits (Canali et al., 2017; Cristóbal Garcia et al., 2016; Cristóbal et al., 2017; Göbel et al., 2015; Mourad, 2016; Thyberg and Tonjes, 2016). Barcelona's stakeholders not only proposed similar solutions, but also agreed on their high effectiveness. Other economic and business management-related measures that are commonly suggested in the literature were also proposed, such as improving the manufacturing processes and the food conservation infrastructure (Cristóbal et al., 2017; Mourad, 2016; Thyberg and Tonjes, 2016). However, our panel only moderately valued these. Regarding technological solutions, previous

literature has suggested measures like improving the food operators' technological infrastructure and capacity (Canali et al., 2017), adjusting packaging (Cristóbal et al., 2017) and improving food labelling (Thyberg and Tonjes, 2016). However, our panel of experts did not pay significant attention to these measures.

In relation to new regulations and policies, we found different alternatives in the literature, such as stimulating investments (Canali et al., 2017), green taxation on food waste (Cristóbal Garcia et al., 2016), or changing the EU tax regulation to encourage food waste reduction (Priefer et al., 2016), among others. Our panel of stakeholders proposed two economic incentives to reduce food waste by increasing waste management prices for companies and consumers, which was also suggested by Canali et al. (2017) and Priefer et al. (2016). It is important to note that nuances matter when proposing such solutions. Although both measures #15 and #32 have low perceived effectiveness to prevent and reduce food waste, increasing industrial waste disposal management prices generated a clear dissensus among the panel, as it did not measure implementing a PAYT system to consumers.

Redistribution of food for human has been covered in previous studies from diverse perspectives (e.g**.** Midgley, 2014; Phillips et al., 2013; Reynolds et al., 2015; Vittuari et al., 2017). However, how to improve the current redistribution system is not equally covered. The main recommendations in this line, are related to improving the technology associated with food redistribution (transportation, storage, software) (Cristóbal et al., 2017), developing new innovative solutions (Göbel et al., 2015; Priefer et al., 2016), or promoting new regulations (Good Samaritan Law, gleaning, tax incentives) (Cristóbal Garcia et al., 2016; Cristóbal et al., 2017; Thyberg and Tonjes, 2016). These measures were not directly mentioned by the stakeholders in the metropolitan region of Barcelona, who were more in favor of regulatory measures to manage food redistribution. We observed here, again, that the framing of the measures matters when considering stakeholder perceptions. The panel agreed that establishing protocols to facilitate and make compulsory donations from supermarkets would be highly effective. However, they disagreed and considered incorporating new laws and regulations to avoid reliance on businessperson willingness to have a limited degree of effectiveness. This highlights the importance of nuance.

Regarding the potential relationship between strong prevention, weak prevention and redistribution measures and the consensus/dissensus among the panel of experts, it can be said that most of the consensus measures are in the group of weak prevention actions (see Table 3). They were highly or moderately valued by the panel as regards as their effectiveness to prevent food waste. They are measures are related to consumers 'and children awareness, voluntary plans and collaboration to reduce food waste within companies and improving food conservation infrastructures. Only two of

them were in the strong prevention measures: educating in values and making the primary production reality known. And the remaining three consensus measures were associated to redistribution improvements. On the other hand, most of the dissensus measures were related to the food redistribution. As it is previously mentioned, they were mostly aimed at implementing new regulation to make food donations compulsory. So, as in the same line of Mourad, (2016), who is advocating for the necessity of differentiating systemic changes (strong prevention) from efficiency related ones (weak prevention), we can observe that there is no such controversial in the weak prevention set of measures. However, those that are proposing more long-run changes or changes to the production system were not so agreed among the panel.

3.2. What is the role of stakeholders in food waste prevention?

Many public, private and social institutions can participate in actions to prevent and reduce food waste, as is currently happening. This participation can take different forms. Stakeholders can catalyse change, contribute to analysing and understanding the situation, use policy instruments, leverage the impact, or understand and spread knowledge (Cristóbal Garcia et al., 2016; FAO, 2015). All these profiles were considered in the stakeholder panel design. We also want to assess the role of stakeholders in the proposed measures in this case study by considering: 1) the effect of the stakeholder profile on dissensus; 2) the supply food chain stages involved in the implementation of the measures to prevent/reduce food waste; 3) the leadership required for the implementation of such measures; and 4) their geographical scope.

Concerning the role of stakeholder profile on consensus/dissensus, Figure 3 outlines the measures where dissensus was found. This differentiates the average score of the three types of stakeholders: institutional (public), private and socially aware. As can be observed in the boxplot, social institutions tended to provide higher average values on the effectiveness than the other two groups. Summing up, we identified dissensus due to: 1) a general disparity of opinions in all groups, such as in measure #46 about regulating food donation instead of voluntary arrangements; and 2) the contradictory opinions between the groups of stakeholders, such as in # 15 about increasing industrial waste disposal management prices. In the latter case, the implementation of such a measure would clearly affect the private sector, but should be regulated by public institutions. The overall average efficacy was 59.2 out of 100, and the IQR was 52.2. The private sector group were the ones bringing dissensus to the panel, since its perceived efficacy was valued by them at 37.1 points, while the public bodies and the social organizations valued it with 61.7 and 83.1 points respectively.

Secondly, as HLPE (2014) pointed out, it is important to differentiate where the food waste is generated and the actor responsible for this volume. Consequently, in order to implement a food waste

prevention measure, we should identify not only the main stage of the food supply chain at which the reduction will take place, but also all the necessary stages and stakeholders that should be considered to make such a measure effective. In this context, Table 3 identifies all the stages of the food supply chain and every single measure that might play a role in implementation (i.e. primary production, wholesalers, food industry, retailers, households or redistribution). As can be observed, proposed measures would need a considerable interaction among stages to succeed, which reinforces the holistic approach used in this study.

Thirdly, once the main stages of the food supply chain affected by any specific measure have been identified, the next step is to determine what type of stakeholder (public, private or both jointly) should lead the implementation of a specific measure. These results are also shown in Table 3. In general, regulatory and policy measures would need to be pushed by public bodies, while economic and business-oriented solutions would involve the leadership of the private sector.

Finally, identifying the geographical scope of food waste policies is highly relevant. This study focussed on a broad city context following the City Region Food Systems proposal (GIZ et al., 2016) and the leading role that cities are taking in achieving a more sustainable food system (e.g. Milan Urban Food Pact). However, there is no doubt that in a European context, policies and regulations are established at different levels. Therefore, in Table 3, we identify the minimum geographical scope at which each measure should be implemented to guarantee effectiveness. Three levels were considered: the region (metropolitan area, Catalonia), the state (Spain) and Europe. In the context of a global food system, not all measures will be applicable at the regional level. However, the stakeholders highlighted the need to implement some measures at the regional level in order to be effective. In any case, based on our results, it is highly necessary to encourage coordination between the regional, national and European policies in order to succeed.

Table 3. Food waste implementation hierarchy

	Strong prevention	**ty**	**P**	**W**	**I**	**R**	**H**	**C**	**wh**	**le**
H E	– Educating in values and valuing food and diet **(#34*)** (Betz et al., 2015; Göbel et al., 2015)	**A**					●		I	Re
	– Promoting a strategic food access plan (#48)	**R**	●	●	●	●	●		I	St/Re
Medium efficacy	– Supporting food waste social movements to make companies react **(#33*)**	**A**			●	●	●		I	Re
	– New categories and regulations to commercialize aesthetic and size rejected produce (#11) (Cristóbal et al., 2017; Priefer et al., 2016)	**R**	●	●	●	●			I	EU
	– Boosting a local agricultural production model (#7) (Mourad, 2016; Priefer et al., 2016)	**E**	●			●	●		I	Re
	– Planning (distributors and producers) what is going to be consumed (#16)	**E**	●			●	●		P	Re
	– Opening new horizons on food security (#45) (Priefer et al., 2016)	**R**	●	●	●	●	●		I	EU
	– Price guaranteeing to farmers **(#5!)**	**R**	●						I	EU
le	– Agriculture planning improvement to avoid surpluses (#1)	**E**	●						P	Re
	– Making the reality of primary production known **(#8*)**	**A**	●	●	●	●	●		P-I	Re
	– Public monitoring of farming (#3)	**R**	●						I	St/Re

	Weak prevention	**ty**	**P**	**W**	**I**	**R**	**H**	**C**	**wh**	**le**
	– Awareness campaigns to increase consumer concern and to promote a change of habits **(#35*, #29* and #30*)** (Canali et al., 2017; Cristóbal Garcia et al., 2016; Cristóbal et al., 2017; Göbel et al., 2015; Mourad, 2016; Thyberg and Tonjes, 2016)	**A**					●		I	Re
	– School teaching on food waste **(#31*)**	**A**					●		I	Re
	– Voluntary and collaborative work among companies (#14 and #**25***) (Canali et al., 2017; Göbel et al., 2015; Mourad, 2016)	**E**			●	●			P	St/Re
	– Including food waste prevention in waste management plans (#47)	**R**	●	●	●	●	●		I	Re
	– Production and stock management adaptation to suppliers and clients (#17, #24, **#28*** and **#2***) (Cristóbal et al., 2017; Göbel et al., 2015; Mourad, 2016; Thyberg and Tonjes, 2016)	**E**	●	●	●	●	●		P	St/Re
	– Food waste reduction plan in the wholesale market **(#10*)**	**E**		●					I-P	Re
	– Manufacturing process improvement (#12) (Cristóbal et al., 2017; Mourad, 2016)	**T**			●				P	Re
	– Campaigns aimed at buyers **(#26*)**	**A**				●	●		P	Re
	– Infrastructure improvement food conservation **(#27*)** (Cristóbal et al., 2017; Thyberg and Tonjes, 2016)	**T**				●			P	St/Re
	– Farmers' mentality of taking advantage of the whole crop **(#4!)**	**A**	●						P	Re
	– Payment for waste management (**#15!**, #32) (Canali et al., 2017; Priefer et al., 2016)	**R**		●	●	●	●		I	Re
	– Price mechanism – offers according to production (#6)	**E**	●	●	●	●	●		P	St

	Redistribution	**ty**	**P**	**W**	**I**	**R**	**H**	**C**	**who**	**level**
	– Network to redistribute and use farm surpluses **(#9*)**	**E**	●	●	●	●	●	●	I-P	Re
	– Donation protocols compulsory to all supermarkets **(#21*)**	**R**				●		●	I	St/Re
	– Aggrupation of social charities at the local level (#38)	**E**						●	I	Re
	– Legislative changes to promote FW prevention and food redistribution (#44)	**R**	●	●	●	●	●	●	I	St/Re
	– Institutional facilitation of donation (reducing bureaucracy, freezing protocols, pick up routes) (#22, **#36*** and **#41**!)	**R**	●	●	●	●	●	●	I	Re
	– Micro-donation programs in retail (#20)	**E**				●		●	P-I	Re
	– Surpluses out of best before date to food banks (#13)	**E**			●	●		●	I	St/Re
	– Guides on food security and false myths about donation (#23)	**A**	●	●	●	●		●	P-I	Re
	– Better knowledge spread of charity functioning (#37)	**A**		●	●	●		●	I	Re
	– Employee training on food donation (#19)	**A**				●			P	Re
	– Increasing social pressure to increase donations **(#42!)**	**A**					●		I	Re
	– Network of potential donors of food (#39)	**E**	●	●	●	●		●	P	Re
	– Laws and regulations to avoid donation reliance on businessperson willingness **(#46!)**	**R**	●	●	●	●			I	St/Re
	– Company transportation for food donation (#18)	**E**			●	●		●	P-I	Re
	– Regulation on compulsory prioritizing of redistribution over feed **(#40!**)	**R**	●	●	●	●			I	St/Re
	– Laws regulating boundaries between price decreasing and donations **(#43!**)	**R**	●	●	●	●			I	EU

Cat.: category; T: Technological; E: Economic and business management; R: Regulatory and policy; A: Appreciation and enhancement; P: primary production; W: wholesalers; I: food industry; R: retailers; H: households; C: redistribution charities; who: who leads it?; P: private bodies; I: Institution, public bodies; P-I: public-private collaboration; le: minimum level to be implemented (EU: Europe, St: state, Re: regional); * means consensus; ! means dissensus

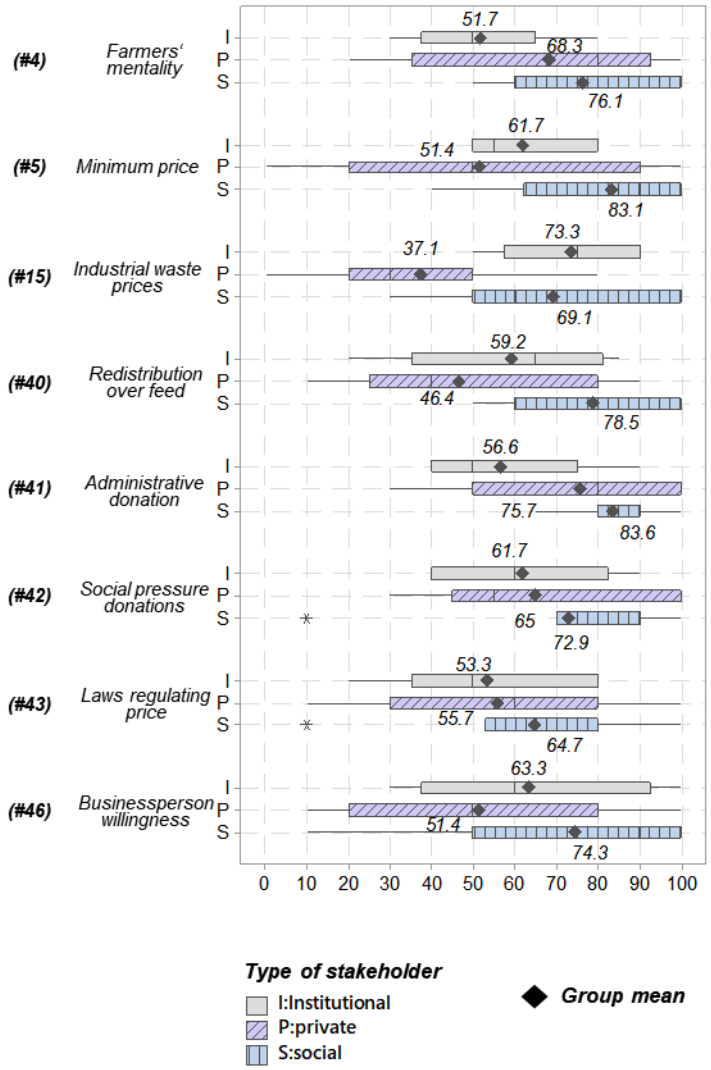

Figure 3. Effectiveness of measures to prevent food waste were dissensus among the panel was found by stakeholder profile

4. Conclusions

This paper has combined a whole chain approach and a participatory tool to identify and prioritize measures to prevent food waste along the food supply chain. The geographical context is an urban environment larger than a single area: a city region or metropolitan area with an important peri-urban agriculture. Priorities have been assessed by combining the stakeholders' perceived effectiveness of the different measures with the degree of consensus reached among stakeholders and the hierarchy of

447 food waste management. Policymakers should prioritize strong prevention measures where a higher
448 effectiveness and consensus can be reached, while less priority should be given to low effective
449 redistribution alternatives.

450 The results in this study suggest a number of points. First, there is a general consensus on the high
451 effectiveness of consumer-targeted measures to increase awareness and knowledge about food waste
452 and its generation. On the other hand, developing new regulations and policies was perceived as not
453 very effective, although no consensus was reached between the different types of stakeholders. More
454 research on the impact and perception of new regulation is needed. Second, the panel of experts in
455 this study suggested some measures to improve redistribution that had not appeared in previous
456 literature. In this regard, further research is needed to investigate the perceived effectiveness of
457 redistribution measures in other geographical contexts using a similar multi-actor approach. Third, it
458 is important to highlight that the stakeholders in this study did not mention any measure aimed at
459 gathering and generating more data on food waste volumes, which contradicts previous publications,
460 as well as the increasing international interest on this issue. We hypothesize that this result is related
461 to the panel composition. While in previous studies the panels were mainly composed of academics,
462 in this study a multi-actor approach was used. More research is needed on this issue and there is no
463 doubt about the necessity of data in the current situation.

464 Measures proposed by the panel were precise and extensive compared to common policy
465 recommendations from international bodies that tend to be concise and short. Moreover, results from
466 this study suggest that nuances and the framing of possible solutions matter since we found diverse
467 perceived effectiveness on similar measures. Future research and policy intervention should consider
468 this to gather future consensus and willingness to implement specific actions.

469 Although the results should be restricted to the metropolitan region of Barcelona, this study
470 suggests that more research is needed to analyse stakeholders' perceived effectiveness of potential
471 measures to prevent and reduce food waste. Similar studies should be undertaken in other
472 geographical contexts to check if some common measures can be identified worldwide or, at least, in
473 the European context. We found some similarities among the stakeholders' proposed measures and
474 previous literature, but more regional studies would help to clarify the similarities.

475 As explained in the methodological section, the Delphi study requires a non-probabilistic sampling
476 to gather as much heterogeneity of experts as possible. Therefore, we acknowledge that the results
477 found both from the interviews and the Delphi survey are linked to the composition of the panel and
478 the situation in the region at the time we did the research. However, all the process is explained, we

479 first mapped the supply chain in the region and second, we ensured the heterogeneity of
480 representatives.

481 Despite the recognized limitations, the methodological framework used in this study, based on the
482 combination of a participatory tool and a multi-actor approach, has proven to be effective in
483 generating valuable insights for policymakers to define their priorities and guidelines to address the
484 challenge of achieving the SDG's target 12.3 before 2030, as well as anticipating future conflicts
485 when implementing specific measures.

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490 ## Appendix

491 *Table A1 Complete statements of food waste prevention measures*

	#	
Primary production wholesalers	**1**	Agriculture planning improvement to avoid surpluses.
	2	Forecasting farming at the cooperative level linked to produce commercialization. Promoting farmers' cooperativism organization.
	3	Public bodies keeping track of farming forecast. Better knowledge of farmers' reality by means of audits with solution proposals.
	4	Farmers should have the mentality of taking advantage of everything from the crop, transforming parts of the harvest that have no other way out into preserves and looking for alternative sales channels.
	5	Guaranteeing a minimum profitable and promising price for the farmers.
	6	Applying a flexible mechanism to prices; offering typologies according to the production volume.
	7	Boosting a local agricultural production model.
	8	Making the reality of primary production known to other agents in the food chain so they will be increasingly flexible in size standards.
	9	Creating and promoting an interconnected system to redistribute and profit out of farm surpluses.
	10	Making a plan to include food waste reduction in the management of the wholesale market, direct and indirect.
	11	Including another category in the commercialization regulations to introduce products rejected due to aesthetic standards or sizes requirements into the market.
Industry	**12**	Making efforts to improve manufacturing processes to reintegrate products within the production line.
	13	Managing surpluses to send products that have surpassed the best before date to food banks.
	14	Applying voluntary actions, accompanied by the administration, to reduce avoidable food waste in the food industry.
	15	Increasing the price of industrial waste disposal management methods.
Distribution	**16**	Planning together (distributors and primary producers) what is going to be consumed each season.
	17	Industry and distributors buying whole harvest from producers and having to redistribute it to their different brand suppliers.
	18	Redistributing food suitable for consumption but not for sale to charity canteens or social entities (food pantries) with the business' own transportation.
	19	Training store staff about donation methods and protocols.
	20	Developing a micro-donations program to minimize bio-waste. Donating food suitable for consumption but not for sale, according to managers, to the closest charities to the store.
	21	Developing compulsory donation protocols for all supermarkets.

	22	Creating a pick up route through different supermarkets from a town/city to collect food for charities, promoted and funded by the local administration.
	23	Doing best practices guides and protocols together with the administration to guarantee food security and to minimize false myths about food donation and help store managers.
	24	Working inside the business planning sales and logistics by working with the historic sales data and improving the adaptation of stores to clients' typology.
	25	Different distributors and competing companies working together to find out the best ways to minimize food waste.
Small stores	**26**	Implementing campaigns aimed at buyers, together with local administrations and environmental departments to give them (buyers) anti-food waste recipes and menu planning to encourage rational purchases.
Small stores	**27**	Making infrastructural improvements to help with food conservation and food conservation logistics.
Small stores	**28**	Working on retailers' awareness to throw away as little food as possible through stock management and the use of a cold room system.
Consumers	**29**	Promoting a change of habits to reduce food waste volumes.
Consumers	**30**	Promoting food purchase planning.
Consumers	**31**	Developing school and school canteen teaching about food waste.
Consumers	**32**	Implementing a pay as you throw (PAYT) management system. Linking what we pay for waste management with the generation of waste.
Consumers	**33**	Supporting social movement organisations that are highlighting the problem of food waste because they are making companies and administrations react to the problem.
Consumers	**34**	Educating in values and valuing food and diet. Encouraging a safe and healthy diet because it creates responsibility and increases the valuation/appreciation of food.
Consumers	**35**	Implementing awareness campaigns to make the problem known and increase consumer concern.
Redistribution	**36**	Establishing freezing protocols for fresh produce, like meat, to facilitate donation to charities.
Redistribution	**37**	Encouraging a better knowledge of charity functioning to increase retailers and distribution companies' awareness. With trust, food redistributed increases.
Redistribution	**38**	Promoting the aggrupation of social entities (charities/food pantries) at the local level to join efforts and improve food redistribution.
Redistribution	**39**	Creating a network of potential producers and company donors of food.
Redistribution	**40**	Approve regulation to make the prioritisation of food redistribution over animal feed destination compulsory.
Redistribution	**41**	Administrative facilitation of supermarket food donation because sometimes this is bureaucratically complicated.
Redistribution	**42**	Increasing social pressure to increase donations.
Along the FSC	**43**	Having laws to regulate the boundaries between price decreasing and donations among different actors of the supply chain.
Along the FSC	**44**	Making legislative changes to promote food waste prevention and food redistribution.
Along the FSC	**45**	Opening up new horizons concerning food security in such a way as to have a certain tolerance level with some products.
Along the FSC	**46**	Incorporating laws and regulations in such a way as food donation is not depending on businessperson willingness.
Along the FSC	**47**	Incorporating food waste prevention into waste management plans as a relevant aspect.
Along the FSC	**48**	Promoting a strategic food access plan to ensure access to equitable food and a balanced diet for all citizens.

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