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How to identify and implement interventions for reducing Food Loss and Waste in Dhaka's food system?

M.G. (Melanie) Kok MSc, D.M. (Vera) Vernooij MSc and dr. R.B. (Bob) Castelein

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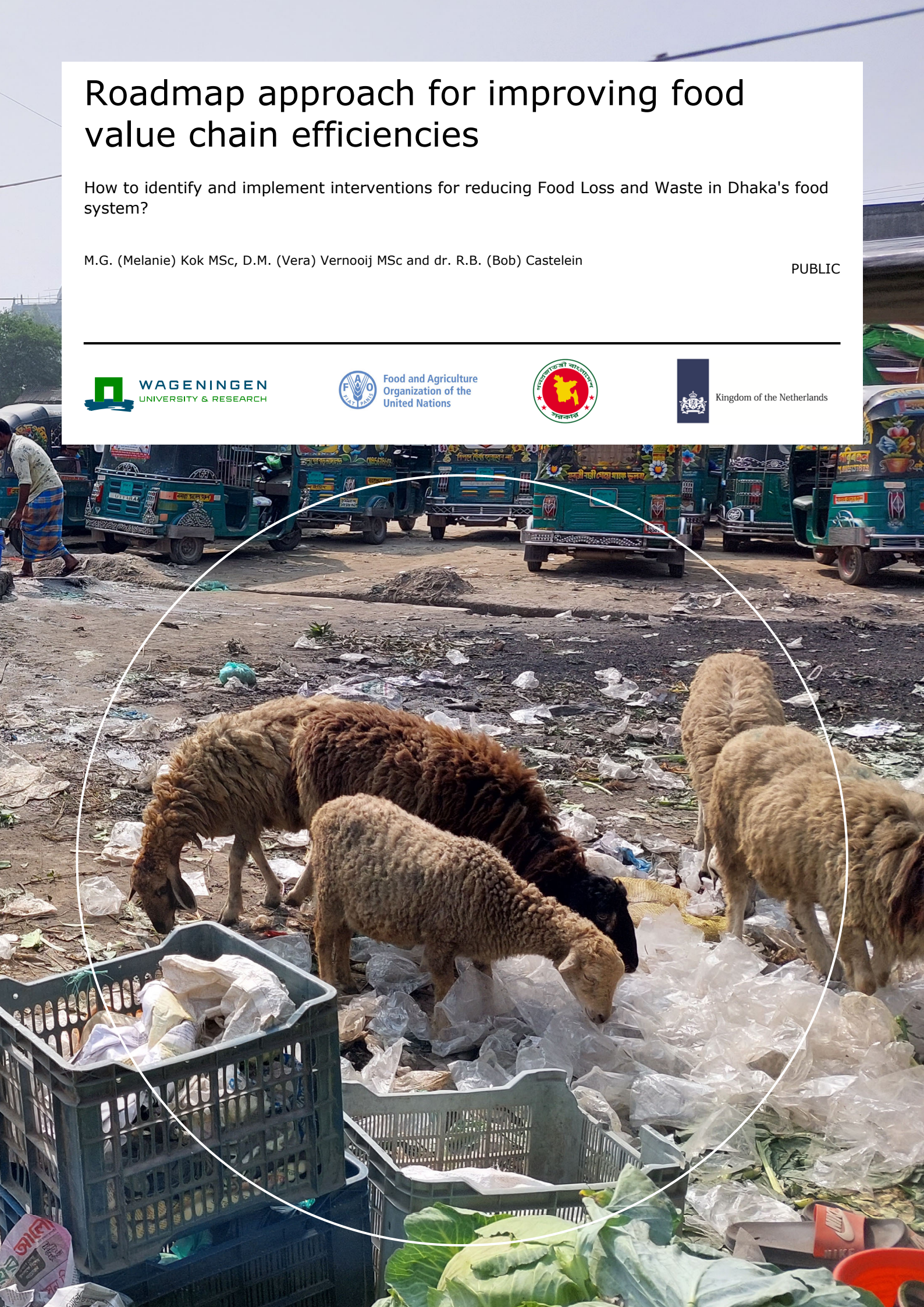

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Institute: Wageningen Food & Biobased Research

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This report contributes to the Dhaka Food Agenda 2041 (DFA 2041) that is developed in the DFS project. DFA 2041 is a stakeholder-created and evidence-informed long-term collective vision, a resource document to support policymaking and urban planning. The DFA 2041 is a synthesis of key challenges and aspirations for meeting Dhaka's food needs and forward-looking pathways to accompany transformation, which complements the existing policies and development goals of Bangladesh. This document aims to support that transformation. The DFA 2041 is guided by the vision on Dhaka's food system to: Meet Dhaka's future food demands in an equitable and inclusive manner, ensuring nutritious and safe food for all through a food system which is sustainable, resilient, and environment-friendly, and guided by collaborative stakeholder engagement and learning.

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Summary

Improving food value chain efficiencies can support greater availability of and access to safe and nutritious food for all, and help shape more resilient food systems, particularly in Low- and Middle Income Countries (LMICs). Acting effectively on value chain inefficiencies is a complex task and many variables and food system dynamics should be considered relevant for making intervention decisions. Lasting long-term change needs a combination of interlinking, inclusive interventions acting on different components of the food system (e.g. the food value chain itself, as well as the enabling environment), and attention to critical success factors (e.g., affordability and accessibility) to be able to provide the right conditions for success. This document serves to support intervention and implementation decisions towards the goal of reducing food value chain inefficiencies, focusing on the reduction of Food Loss & Waste (FLW) in Bangladesh, specifically in Dhaka Metropolitan Area (DMA).

As FLW represents a major food value chain inefficiency, this document specifically aims to answer the question 'How to identify and implement interventions for reducing Food Loss and Waste in Dhaka's food system?', to support greater availability of and access to safe and nutritious food for all. This approach can be used by value chain stakeholders (including policymakers, Non-Governmental Organizations (NGOs) and financiers) to develop their own strategies for improving food value chains at the local, regional, or national level, as well as by private sector actors who wish to strategically explore how and where to intervene to reduce FLW. It can also be used by researchers and other knowledge experts to build on and add to for purposes of enhancing knowledge and expertise on the topic of FLW reduction interventions for the specific food value chains that are elaborated, and new food value chains.

The framework includes the description of a value chain intervention roadmap. In this report, a roadmap focuses on addressing FLW, but the steps of the presented approach could be relevant for assessing other value chain inefficiencies as well, such as greenhouse gas emissions, food safety hazards, water use or food production issues. The roadmap approach consists of two main components: 1) Selection of FLW reducing interventions and 2) implementation strategy of FLW reducing interventions in the food system. For the first component we use the EFFICIENT protocol developed by Kok et al. (2021a), and for the second component we elaborate on intervention criteria as presented by Soethoudt et al. (2021). This document provides a structured, yet adaptable approach to sketch possible pathways and structure coherent action towards improved food value chains - a roadmap, not a blueprint.

The selected products for which FLW will be addressed in more detail are a selection of most frequently consumed items by households in Bangladesh, and continue work on earlier conducted value chain studies. The products are beef, chicken, fish, onion, potato and rice. The roadmaps focus on determining the FLW hotspots (from harvest up to retail - excluding consumer waste), unless stated otherwise. After having determined the FLW hotspots in the six food value chains, interventions are needed to address FLW at various levels (micro, meso, macro) and of several types (hardware, software, orgware), with support and commitment from diverse actors in the value chain and the wider food system. Data was collected via primary data collection by using survey data in Bangladesh for beef and onion. Other data collection activities for all products included primary data collection via a field visit (interviews and observations) conducted in March 2022, primary data from food value chain workshops, secondary data from a literature study, secondary data from using the EFFICIENT protocol and the authors' expertise.

For beef, the FLW hotspot – meaning the most relevant supply chain link or activity for FLW reduction interventions - was the wholesaler. The main FLW issue in the beef value chain was the spoilage of beef. The root causes included insufficient and ineffective slaughtering facilities, incomplete handling, untrained labour and inefficient work accuracy. Based on these observations the selected intervention was to create (financial) incentives and opportunities to invest in a better work environment, particularly for slaughtering.

For chicken, the hotspots of FLW were transportation and storage, due to the high mortality rate of broilers during transportation from farm until market, and during storage/waiting at the market before being slaughtered. The main root cause to solve related to the high mortality rate was high temperatures and

consequently heat stress of the animals. Therefore it was decided to select the intervention of consistent shading to reduce the heat stress during transportation and storage/waiting.

For fish, the FLW hotspot was found at the wholesaler, due to spoilage of fish. Spoilage of fish that reveals itself at the wholesaler arises from rot and damages that is initiated earlier in the supply chain. To solve the root causes related to handling, packaging and transportation, it was decided to select the intervention of improving transport, storage and packing.

For onion, the FLW hotspot is the wholesaler, as they face losses due to rots and damaged onions. The root causes include improper harvesting and curing, lack of proper storage, moisture content too high and improper handling during transport. The selected intervention to (partly) address the root causes is to invest in sufficient and effective storage capacity and use. The issues that are experienced by the wholesaler (and likely also the retailers, mobile vendors and hotels-restaurants) have root causes that occur earlier in the supply chain: this intervention is therefore not necessarily aimed at the wholesalers, but at suppliers to the wholesalers (intermediaries) and farmers (emphasising post-harvest practices to enhance onion quality and shelf life).

For potato, the FLW hotspots are at the agricultural producers, and during storage for both producers and wholesalers. The main root causes include rain, other conflicting food production interests, knowledge gaps regarding handling and uptake of new technology, cold storage demand mismatch, and production growth and demand fluctuations. To partly address these root causes, the selected intervention for the FLW roadmap is to increase cold storage facilities.

For rice, the FLW hotspot was the on-farm storage at farmer level. The main root causes to address were attacks of microorganisms, insects and rodents. Therefore it was decided to select the intervention of using hermetic storage facilities, such as containers, silo’s or hermetic bags.

The roadmap for the six different cases (beef, chicken, fish, onion, potato and rice) are not blueprints and remain very context dependent. The aim was to showcase and make links between observed food value chain issues, causes, and interventions, including supportive actions required for successful intervention implementation.

1. Introduction

Improving food value chain efficiencies can support greater availability of and access to safe and nutritious food for all, and help shape more resilient food systems, particularly in Low- and Middle Income Countries (LMICs). These inefficiencies can have a myriad of causes, and lead to undesirable outcomes such as Food Loss and Waste (FLW), deteriorating food quality, jeopardized food safety, high food prices, and reduced accessibility and affordability of food to (vulnerable) consumers. Acting effectively on value chain inefficiencies is a complex task and many variables and food system dynamics should be considered relevant for making intervention decisions. Namely, interventions should fit the context of the food system, should be economically viable on the long term, not increase the burden on the environment, improve access to food, and be socially and culturally acceptable (FAO, 2014; Van Berkum et al., 2018; Soethoudt et al., 2021).

This document presents intervention roadmaps for reducing FLW in six food value chains. It serves to support intervention and implementation decisions towards the goal of reducing food value chain inefficiencies, focusing on the reduction of FLW in Bangladesh, specifically in Dhaka Metropolitan Area (DMA). It specifically aims to answer the question 'How to identify and implement interventions for reducing Food Loss and Waste in Dhaka's food system?'. This approach can be used by value chain stakeholders (including policymakers, Non-Governmental Organizations (NGOs) and financiers) to develop their own strategies for improving food value chains at the local, regional, or national level, as well as by private sector actors who wish to strategically explore how and where to intervene to reduce FLW. It can also be used by researchers and other knowledge experts to build on and add to for purposes of enhancing knowledge and expertise on the topic of FLW reduction interventions for the specific food value chains that are elaborated, and new food value chains.

Despite good intentions, and the potential and urgency of interventions to improve value chain efficiencies, 39–64% of donor-funded development projects in LMICs do not meet initial expectations. Project management problems in international development project fall into three main categories: structural and contextual problems, institutional and sustainability problems, and management and organizational problems. These problems may fall into one or more of four main traps: The one-size-fits-all technical trap, the accountability-for-results trap, the lack-of-project-management-capacity trap or the cultural trap (Ika, 2012). This illustrates the danger of investing in so-called 'white elephants': large investments that seem promising on paper but cannot be put to useful work in the implementation context, and that often instead impoverish the recipient with the burden of maintenance and upkeep (Soethoudt et al., 2021). An example of such a 'white elephant' is the construction of a modern slaughterhouse at Mohakhali in Dhaka North City Corporation (DNCC). The slaughterhouse was inaugurated in December 2018, but closed soon after as DNCC, the authorities of the slaughterhouse, could not persuade traders to use it (Hasan, 2021). Instead, lasting long-term change needs a combination of interlinking, inclusive interventions acting on different components of the food system (e.g. the food value chain itself, as well as the enabling environment), and attention to critical success factors (e.g., affordability and accessibility) to be able to provide the right conditions for success (Klink, 2015; Plaisier et al., 2019; Soethoudt et al., 2021).

FLW represents a major food value chain inefficiency and FLW reduction represents a potential opportunity to enhance both food security and environmental sustainability (Shafiee-Jood et al., 2016). Reducing FLW is therefore targeted in the Sustainable Development Goals (SDG), specifically SDG 12.3 specifies to reduce per capita global food waste with 50% by 2030, and reducing food losses along production and value chains (United Nations, 2016). As Table 1 indicates, different types of FLW can be distinguished, namely physical FLW, quality FLW, economic FLW, and nutritional FLW; these are often related. Furthermore this report follows the (post-) harvest food loss definition as reported in Annex 1 of FAO (2018), also added as Annex 1 in this document.

Table 1 Different types of FLW (FAO 2018).

Type of FLW	Description
Food loss (FL)	Occurs in the production to distribution segments of the food supply chain
Food waste (FLW)	Occurs from retail to the final consumption/demand stages
Quantitative FLW	The decrease in mass of food
Qualitative FLW	Still eaten by people but has incurred reduction of nutritional value, economic value and/or food safety. The decrease of quality attributes of food without decrease in mass. Loss in quality and/or nutrients, typically resulting in economic loss (sold for lower price) or as downgraded product to industry

Reducing FLW can further result in higher food and nutrition security as more nutrition rich, but highly perishable food, becomes available at lower prices, benefiting consumers directly. DMA is growing fast, both demographically and economically. Its population increased by >40% in the last 10 years. The 21.7 million inhabitants of DMA require large amounts of nutritious food every day, most of which is brought into the city from other (rural) parts of Bangladesh or is imported from other countries (Worldbank, 2021). DMA is therefore an urban area that can benefit from increasing food value chain efficiencies and increasing the food system's resilience now and towards the future. Therefore, the Dhaka Food Agenda 2041 (DFA 2041) is developed. DFA 2041 is a synthesis of key challenges and aspirations for meeting Dhaka's food needs and forward-looking pathways to accompany transformation, which complements the existing policies and development goals of Bangladesh. The contents of this report will serve as supportive inputs for the DFA 2041 (FAO-WUR, *forthcoming*).

The food groups that are most wasted worldwide are roots, tubers, and oil-bearing crops; specifically in Central and Southern Asia there is a higher share of meat and animal products. Food loss from postharvest to distribution in Central and Southern Asia was estimated to be highest of the world, namely around 21% of total food produced in 2016 (FAO, 2019). In line with FLW trends particularly in LMIC, highest volumes are wasted at early stages of the supply chain and lower towards consumers. In South and South-East Asia, main products wasted at primary production are oil crops, rice, vegetables and fruits; at storage and handling rice is most wasted; at processing oil crops (although there is limited processing of other food categories); at food distribution vegetables, fruits and dairy stand out, and at the consumer FLW is mainly occurring for vegetables and fruits (Guo et al., 2020). In Bangladesh, an estimated 65kg of food is wasted per capita, but up to date and detailed food waste data is scarce (UNEP, 2021).

This document presents intervention roadmaps for reducing FLW in six food value chains consisting of two steps: a) selecting FLW reducing interventions, and b) implementation of a strategy of FLW reducing interventions in the food system. Intervention implementation can only be successful when it fits the context, and successful intervention implementation is defined as the positive economic -, social -, and environmental impact that can be sustained in the implementation context when external support is reduced (Soethoudt et al., 2021). Because a relevant intervention may need supportive actions[1] for it to have an effect in practice, it is necessary to have an approach to decide which supportive actions are needed, should be prioritised, and are feasible on the short-, medium- and long term. The products selected in this roadmap for which FLW will be addressed in more detail are beef, chicken, fish, onion, potato and rice. Beef and onion were selected to continue work on earlier conducted value chain studies of these products (Kok et al., 2021b; Kok et al. 2021c). The other four products were added as they are included in the food basket[2] of Bangladesh that is used to estimate the poverty line (Ahmed et al., 2019). The roadmaps focus on determining the FLW hotspots (from harvest up to retail (excluding consumer waste)), unless stated otherwise. After having determined the FLW hotspots in the six food value chains, interventions are needed to address FLW at

[1] Supportive actions: In this document supportive actions are a set of interventions that support the implementation of the selected intervention for FLW reduction.

[2] Food basket: products that represented some of the most frequently consumed items by households, but also because this food bundle provided the minimal nutritional requirements corresponding to 2,122 kcal per day per person.

various levels (micro, meso, macro[3]) and of several types (hardware, software, orgware[4]), with support and commitment from diverse actors in the value chain and the wider food system.

The next chapter presents the intervention roadmap approach in more detail, consisting of the first step where the EFFICIENT protocol (Kok et al., 2021a) is elaborated. Next, we elaborate about how an implementation strategy can be formulated. An intervention roadmap consists of the identification of FLW interventions, and a strategy including supportive actions to successfully implement the intervention. Thereafter, this document presents the six intervention roadmaps for the selected food value chains. These six cases should not be seen as fixed blueprints or explicit instructions for stakeholders working to upgrade Dhaka-oriented food value chains, but rather as an illustration of how taking a structured long-term perspective can inform decision-making on the development of these chains. The roadmap approach is explicitly not an exercise that can be completed, but rather a process-oriented approach that is to be used iteratively and collaboratively – readjusting as needed in line with (changing) circumstances, issues, stakeholder priorities and capacities.

[3] Micro, meso and macro level: Individual, group, and community/governmental level
[4] Hardware, software and orgware: Technology, competences & skills, and organisation

2. The roadmap approach

This section describes how a value chain intervention roadmap can be developed. In this case, a roadmap focuses on addressing FLW, but the steps of the presented approach could be relevant for assessing other value chain inefficiencies as well. As stated above, the roadmap approach consists of two main components (see Figure 1):

1. Selection of FLW reducing interventions
2. Implementation strategy of FLW reducing interventions in the food system

For the first component we use the EFFICIENT protocol (Kok et al., 2021a), and for the second component we elaborate on intervention criteria as presented by Soethoudt et al. (2021), which are elaborated in more detail below. The last sections ('Roadmap' and 'Data collection') elaborate on the visualisation of the roadmap and on data used.

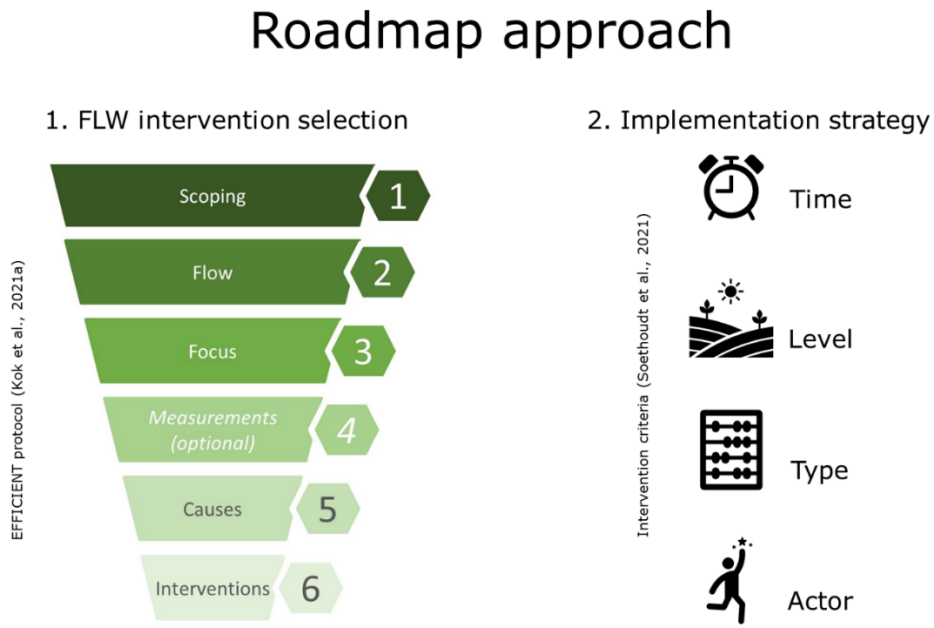

Figure 1 Visualisation of the two steps of the roadmap approach (authors' adaptation of Kok et al., 2021a; Soethoudt et al., 2021).

2.1. FLW reducing intervention selection

The goal of the first component of the roadmap approach is to select the most promising FLW reducing intervention in a selected value chain. Estimating FLW in value chains can be a time- and resource intensive exercise. In order to make this process less time- and resource intensive, Wageningen Food and Biobased Research (WFBR) developed the EFFICIENT protocol (Kok et al., 2021a). As Kok et al. (2021a) explain, instead of starting by conducting FLW measurements, FLW information per value chain link or actor is first collected based on estimates of expert panels, relying on the principles of the Delphi method (Turoff and Linstone, 2002, in Kok et al., 2021a, see also Linstone and Turoff, 2011). We use a tailored approach to the EFFICIENT protocol. The protocol consists of six phases as the figure above also portrays:

1. *Scoping* the food value chain and geography
2. Describing the *flow* of the value chain
3. Defining the *focus* in the chain at the FLW hotspot
4. Measurements (optional)
5. Investigating the *causes* of FLW
6. Defining FLW reducing *interventions*

For more guidance on these phases, consult Kok et al. (2021a).

The *scoping* phase defines the type of food value chain, aim and geographical location of the study, which should be determined by users based on their objectives and resources. The EFFICIENT protocol can be used to define these details, but it is not absolutely necessary to use, depending on whether the scope for the roadmap exercise is already clearly defined or not, which is required to move to the next phases of the EFFICIENT protocol.

The aims of the *flow* phase are to 1) get an understanding of the product flow and value chain and 2) to collect/register data per value chain actor. This is done by drawing a value chain flow diagram which shows the value chain actors and product flow, and by collecting data about FLW estimates per value chain actor and their activities, and the FLW destinations. This is already to prepare for the *focus* phase where FLW hotspots in the value chain are identified.

The *focus* phase defines the hotspots of FLW in the value chain. Based on the available data as collected in the (previous) *flow* phase, the hotspots of FLW can be identified based on several criteria for an informed decision making. The hotspot can be a value chain actor, an activity, or a combination of both. The hotspots of FLW can be determined based on evaluating at the value chain actor and/or activity, the total amount of FLW in tons/year, the FLW percentage, and/or the economic potential of reducing FLW. This should also be supported by soft criteria such as availability of potential leadership, funding options, confidence/believe, cultural factors and the political context (see EFFICIENT protocol).

The *cause* phase defines the root causes of FLW for the selected hotspot. We use the FLW cause & intervention tool[5] to help find the root causes based on the defined issues at the hotspot. This tool is an integrated but stand-alone part of the EFFICIENT protocol. We use the identified issues for the selected products as input for the tool. The tool automatically provides the related causes and root causes. For users with the relevant expertise, or for those who do not want to use the online tool, it is also possible to start with the described issues and use the '5 times why principle' to manually define the root causes of FLW, which 'simply' means to ask 'why?' in relation to a situation five times (Williams, 2001).

The *intervention* phase reveals the best interventions for FLW reduction, and can both be executed with the before mentioned online tool, or in the Excel-based version of the EFFICIENT protocol. The intervention phase produces a list of potential interventions that are appropriate for the issues identified in the chain in question, and an intervention selection table. This allows users to evaluate and select potential interventions that address the root causes of FLW hotspots in the selected value chain. In doing so, users can select multiple interesting interventions and finally help to decide upon one selected intervention. However, often long-term change needs a combination of interventions and supportive actions to be able to provide the right conditions for success. The development of a comprehensive intervention strategy based on this combination is described in paragraph 2.2. below.

2.2. Implementation strategy of FLW reducing interventions in the food system

The impact of a FLW reducing intervention greatly depends on the conditions in which the intervention is implemented. In other words, not any intervention will be a success or result in the expected impact automatically. It is therefore important to not only select an appropriate intervention, but also describe the necessary supportive actions and boundary conditions for successful implementation (interventions in their own right) to create a conducive environment. Box 1 provides an example of why supportive actions are needed to implement an intervention successfully.

[5] FLW cause & intervention tool: https://the-efficient-protocol.azurewebsites.net/

Box 1: Illustrative example: What supportive actions are needed to implement a cold storage facility successfully?

When the selected intervention is the need for cold storage facilities at the wholesale market, just building a cold storage facility (the hardware) will not automatically lead to a successful implementation and sustainable impact in terms of FLW reduction and better quality food being available. Successful optimization of fresh food supply systems requires an approach of several interventions to set the right conditions, often combinations of hardware, software, and orgware. In this example it means that the cooling facilities should be used properly. Other (hardware) conditions for cold storage to be implemented successfully include that we need an uninterrupted power supply, and materials to stack the produce. Additionally there is need to plan for capacity development (software) on how to handle the products that need to be stored, e.g. on what temperature, how to stack them, can products be combined with other products, how long can the products be stored, etcetera. Also, products need to have a sufficiently high quality before being stored, this might require closer coordination and communication between storage users with suppliers/producers of the product and is an example of required 'orgware'. Finally, changes in the enabling environment and business services, such as changes of regulations, institutional arrangements and organizing financial support are examples of orgware interventions too.

As part of the implementation of interventions in the food system, we label the selected intervention and supportive actions, and described conditions for successful implementation according to a number of criteria and categories in a priority matrix. This helps to implement the intervention and create the right conditions for success, in time.

The following criteria should be considered (based on Soethoudt et al., 2021):

- Expected implementation time (short/medium/long term)
- Intervention level (micro/meso/macro)
- Intervention type (hardware/orgware/software)
- Implementing actor (private sector (PS)/governmental organization (GO)/non-governmental organization (NGO))

Expected implementation time

The expected implementation time can be short, medium or long term (Table 2).

Table 2 Expected implementation time.

Criterion	Short term	Medium term	Long term
Implementation time	<1 year	1-5 year	>5 year

Intervention level

Interventions can be structured along three levels that on the one hand unravel the hierarchy of the causes for FLW and on the other hand clarify relations between the levels at which one can intervene in the food system. The structure consists of the micro, meso and macro level (Table 3).

Table 3 Intervention level.

Criterion	Micro level	Meso level	Macro level
Intervention level	Each particular stage of the food chain, from production to consumption, that acts in response (or not) to external factors. Micro-level interventions can be implemented in relative isolation for a specific chain link (e.g. improved equipment).	The level where internal actors (at the same or another stage) in the food value chain or external stakeholders, impact the FLW on micro level as a result of how different actors are organized together or related in one another, or of the state of infrastructure (e.g. storage) in the context of the relation. Meso level interventions impact on multiple chain actors at once (e.g. extension services, training programmes).	FLW is explained by more systematic issues, such as malfunctioning food systems, lack of institutional or policy conditions to facilitate the coordination of actors, to enable investments and adoption of good practices. Macro level interventions address these systemic issues (e.g. comprehensive market reform).

Intervention type

Interventions can be classified into three types; hardware, orgware and software (Table 4).

Table 4 Intervention type.

Criterion	Hardware	Orgware	Software
Intervention type	Technology. This includes low and high tech along the chain, measures to control product temperature and storage and packaging interventions.	Organizational, institutional, financial and procedural aspects. This includes understanding power balances in chain and enabling environment, organization of people and building trust.	Skills, knowledge and communication. This includes training, product knowledge and value chain knowledge and communication between actors.

Implementing actor

Three broad classes of actors can be identified (Table 5). The (types of) actors that should be involved in the selection and implementation of an intervention depends on the type and level of the intervention. For example, managing food products in the first period after harvesting can have a great impact on the shelf life of the product for the rest of the value chain. This in turn can affect the livelihoods of smallholders who can be disadvantaged by losses both on the farm and beyond the farm gate. However, it cannot be expected that smallholders alone will be able to design and implement FLW interventions. Interventions should also include promoting access to low-cost technologies, improving knowledge and skills in harvesting and storage, and finding small-scale appropriate financing to support usage of technologies. Each of these supportive actions require involvement of actors in addition to the individual smallholder farmer, including educators and programs for training, governments for tailored policies to support smallholders, technology providers and innovators, financial service providers, and intermediaries to provide low-cost technologies (Flanagan et al., 2019).

Table 5 Implementing actor.

Criterion	Private sector (PS)	Governmental Organization (GO)	Non-Governmental Organization (NGO)
Implementing actor	Input suppliers, agricultural producers, intermediaries, processors, wholesalers, retailers, vendors, etc.	Local governments, national governments, international governments, other governmental organizations, etc.	Facilitators, innovators, financiers, researcher institutes, education, donor organisations, civil society organisations, etc.

2.3. Visualisation of the roadmap

Classifying and structuring the intervention and the other defined supportive actions results in the roadmap for implementation. Successful implementation of the roadmap is highly dependent on commitment from all relevant food value - and wider food system actors. In Figure 2 the selected intervention and supportive actions are 'classified' on implementation time (horizontal axis), intervention level (vertical axis), intervention type (shading) and implementing actor (colour). For the last, also a combination of actors is possible and sometimes even necessary. This is also reflected in the colour coding. For example, the implementing actor for a single intervention can be a private sector (PS, colour coded red), other interventions should be implemented by a combination of SCA, GO and a NGO (colour coded purple), while other interventions should be implemented specifically by a GO (colour coded blue). Ideally, this roadmap is drafted collaboratively with the stakeholders that should be involved in the implementation context, and agreement is reached on the intervention strategy and the broad timeframe.

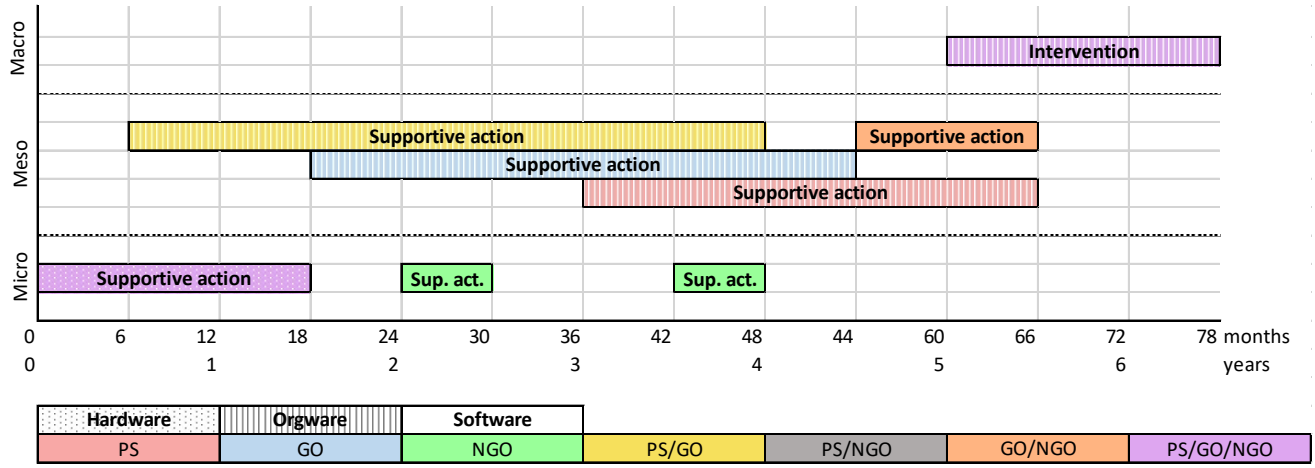

Figure 2 Example of a visualisation of the roadmap.

For this roadmap approach many aspects are relevant to take into account, but it is also worthwhile to make the actions to avoid explicit in order to enhance the success of interventions that reduce value chain inefficiencies. Box 2 elaborates these. Figure 3 visualises the roadmap approach metaphorically, showing that symptoms can be of problems located elsewhere, with (root) causes again elsewhere, and that interventions require careful consideration.

Box 2: Things to avoid for successful implementation (Soethoudt et al., 2021)

Short-term commitment: Ensure finance does not promptly stop or that there is only short term commitment from involved stakeholders;

Lack of ownership of the intervention/investment: Eventually the (implementing/policy) stakeholders have to decide which interventions they want to invest in. Sense of ownership is very important.

Lack of proof of relevance of the intervention in the context: To enhance successful implementation, start small with a pilot or experiment, learn the lessons, adjust, and then start thinking of scaling the intervention.

Lack of attention to 'care' for implemented hardware. Make sure newly built facilities, technologies or equipment can be maintained and/or repaired in the future by a local company that can also provide technical support.

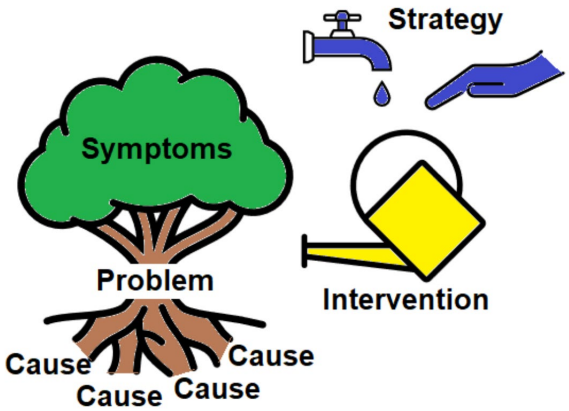

Figure 3 Metaphorical visualisation of the roadmap approach (from Kok et al., 2023).

2.4. Regular update roadmap

Be aware that the duration of activities, including the sequence of actions can be adapted based on country- and on-the-ground experience. During execution, new additional supportive actions can be needed. Therefore, every year the developed roadmap should be reviewed and adapted when needed. This document provides a structured, yet adaptable approach to sketch possible pathways and structure coherent action towards improved food value chains - a roadmap, not a blueprint.

2.5. Data collection

For the first steps of the roadmap, the flow and focus phases of the EFFICIENT protocol were informed by:

1. Primary data collection (survey data) in Bangladesh for beef and onion (Kok et al., 2021b; Kok et al., 2021c)
2. Primary data collection via a field visit (interviews and observations) conducted in March 2022
3. Secondary data in the form of a literature review for chicken, fish, potato and rice

Choices based in the causes and intervention phases of the EFFICIENT protocol were informed by a combination of:

1. Primary data collection (survey data) in Bangladesh for beef and onion (Kok et al., 2021b; Kok et al., 2021c)
2. Findings from the literature study for chicken, fish, potato and rice
3. Primary data collection via a field visit (interviews and observations) conducted in March 2022 for all cases
4. Finding from using the EFFICIENT protocol for all cases
5. Food value chain workshops for all cases
6. The authors' expertise for all cases

Figure 4 presents an overview of the data collection approach for the phases of the EFFICIENT protocol.

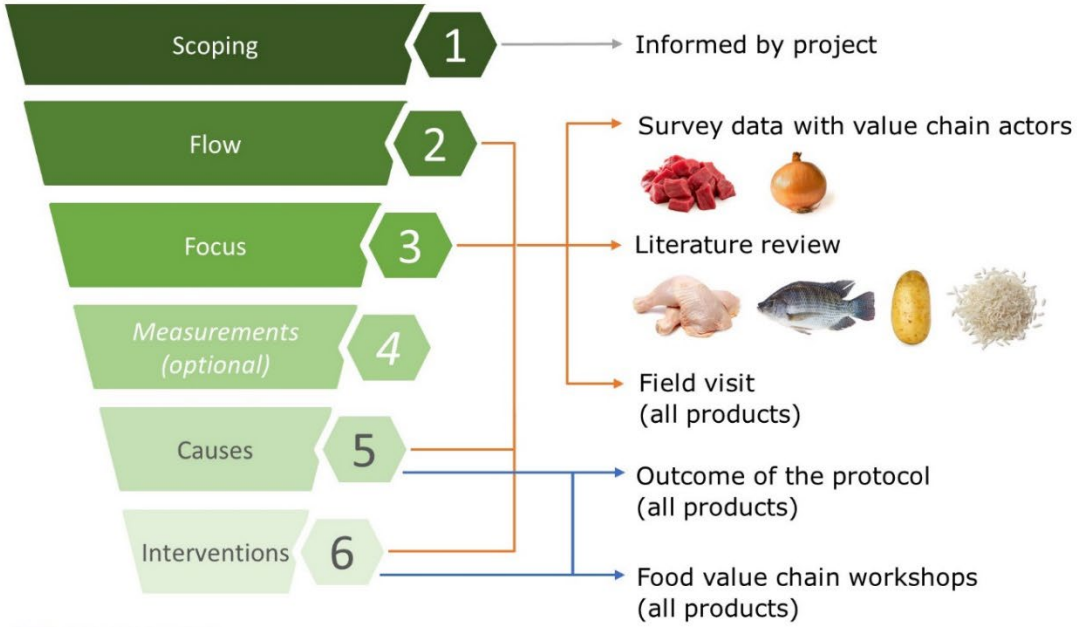

Figure 4 Overview of the data collection approach for the phases of the EFFICIENT protocol.

Two food value chain workshops were conducted in Dhaka, Bangladesh with experts of the product value chains in early 2023. The aims of the workshop were:

1. To support the experts with food value chain thinking
2. To practice with the general steps of the roadmap approach (intervention selection and implementation strategy)
3. To check and collect inputs for the product roadmaps

The findings of the workshop are described (Kok et al., 2023) and incorporated in the final product roadmaps in this document. This roadmap approach specifically focuses on FLW, but during the development of the roadmaps the authors also gained more extensive understanding of the broader value chain functioning, challenges and opportunities for each food value chain (via the literature review, survey data and workshops), what we call 'additional findings. Where deemed relevant, this information is added in separate text boxes in each of the product roadmap chapters.

3. Cases

The roadmap approach will be illustrated with examples for six different food value chains in the Dhaka food system; beef, chicken, fish, onion, potato and rice. These case studies are examples of what a roadmap can look like, but it is important to realise that the roadmap is likely to be adapted regularly in practice, as it should. The paths suggested for the cases below are meant as illustrative examples, not the only possible options. We advise to keep evaluating the roadmap together with local stakeholders, experts and partners.

3.1. Beef

3.1.1. Introduction

The livestock sub-sector is of importance to many livelihoods, and accounted for 1.5% of the total GDP in 2017-2018, at a growth rate of 3.4% that has steadily been growing. The share of livestock in agricultural GDP in 2017-2018 was 13.6%. The livestock subsector provides 20% of the 165 million people with direct jobs, and 45% with part-time jobs (DLS, 2019). Of all livestock products, particularly beef consumption is strongly linked to national, cultural and religious traditions, and it is a national development priority to further enhance the functioning of the sector (FAO-UNIDO, 2019). In 2019 there were 2,674,660 heads of cattle (FAOSTAT, 2019b), supporting an estimated 8,700,000 rural small-scale agricultural producers and 1,858,590 medium and large-scale agricultural producers (FAO-UNIDO, 2019). Nearly 1,200,000 small to large scale farms are associated with cattle production (DLS, 2019). Specifically the dairy and beef sub-sectors in Bangladesh are predominantly characterized by small-scale producers with less than three cattle per household and relatively low productivity (FAO-UNIDO, 2019). Smallholder cattle farmers supply fattened beef cattle to the cattle markets year-round (DLS, 2019; Rahman et al., 2012; Sarma et al., 2017; Expert consultation).

Beef is supplied in two main channels; a traditional channel and a modern channel. 93% of the beef supply flows through traditional channels in Bangladesh (FAO-UNIDO, 2019; DLS, 2019; Rahman et al., 2012; Sarma et al., 2017; Expert consultation). There is variety in the type of beef chains in Bangladesh, but a typical traditional beef marketing channel in Bangladesh consists of primary agricultural producers (smallholder farmers), cattle traders (*bepari*, local and larger scale), wholesale butchers, retail butchers, and consumers (Ahmed et al., 2010). The modern channel includes large meat processing companies like Bengal Meat and Pabna Meat Company, that source cattle from abroad or from producer groups, and market to the consumer through retail channels (WorldVision, 2018). Consumers with a higher income prefer meat that is offered in a supermarket in a hygienic and attractive way, with a broad variety of retail cuts on offer and are able and willing to pay much higher prices for that type of product (DLS, 2019; Rahman et al., 2012; Sarma et al., 2017; Expert consultation).

Value chain actors operating the beef supply channels experience challenges. Producers for example face mortality among their cattle, which is estimated to include 8% of their breeding cattle, 21% of their calves and 2% of their fattening cattle, translating to economic losses for the producers (Kok et al., 2021b). When rearing cattle, farmers additionally face challenges related to genetics, artificial insemination, veterinary service, nutrition, farm management and marketing. Cattle fatteners face challenges including lack of access to market information, technologies, capital and support service. Cattle in general have relatively low productivity (DLS Field Survey, 2014; Huque and Sarker, 2014; Sarma et al., 2017; Expert consultation).

Traders experience challenges regarding lack of market and transport information, access to finance, high transportation prices and lack of market infrastructures (DLS Field survey, 2014). Furthermore, there are challenges related to the periods of undersupply and oversupply of beef cattle. This is due to uncontrolled imports of cattle and beef, and the festival seasons (Kok et al., 2021b). Every year beef cattle experiences a surge in demand during important religious festivals, particularly Eid-ul-Azha. During these festivities, groups of individual consumers buy beef cattle to slaughter and to share the meat. The production of cattle usually

does not suffice the demand during this season, and therefore, cattle are also imported from India (FAO-UNIDO, 2019).
Butchers generally have no cooling facilities and therefore only stock meat that can be sold within the day. They experience challenges of a lack of hygienic processing equipment and a sustainable beef supply (DLS Field survey, 2014). Slaughtering is predominantly carried out without any supervision or inspection, there are not enough well-equipped and supervised slaughterhouses in Bangladesh, or the location is experienced as being unfavourable for connecting to other supply chain actors that supply cattle and buy beef (Kok et al., 2021b).

Distributors like retailers and wholesalers experience challenges regarding lack of hygienic selling points, lack of transportation options, fraud in beef supply (mixed with buffalo), and lack of quality pricing (DLS Field survey, 2014).

3.1.2. Intervention selection

Scope:
The scope of this case study includes live cattle, beef produced, and beef sold to domestic consumers in Bangladesh. This includes all imported life cattle, but not imported beef. It includes all actors in the beef value chain from breeding and fattening, and including retail, foodservice and mobile vendors.

Flow:
For the second phase we used the overview of the value chain from Kok et al. (2021b), slightly adjusted by making a distinction between the supply chains of life cattle and beef, visualized in Figure 5. The product in brackets, either beef or live cattle, describes the product once it arrives to the specific value chain actor. This representation mainly visualises the traditional channels. The modern channels are characterised by strong vertical integration where companies organise most value chain activities in-house, such as production and processing.

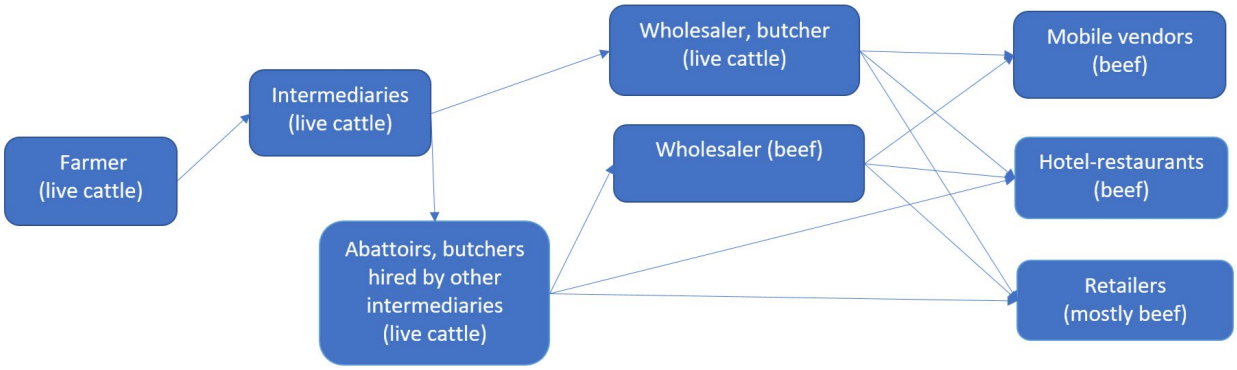

Figure 5 Beef value chain (Adjusted from Kok et al., 2021b).

Focus:
Table 6 presents the overview of the main hotspots of FLW (based on Kok et al., 2021b). The wholesaler was selected as focus due to the high volumes of FLW at this value chain link, namely 3407 kg's per year.

Table 6 Hotspot selection in the beef value chain[6].

Name actor	Activities	Destination	i	
			weight kg	weight %
Farmer (cattle)	Breeding and fattening cattle (calves, cows, bulls)	Unknown	Unknown	Unknown
Intermediaries (cattle)	Buying and selling fattening cattle	Unknown	Unknown	Unknown
Abattoir (cattle)	Slaughtering cattle and selling beef	- Own consumption - Sold on urban food market or to industy/restaurants - Landfill	243,7	5%
Wholesalers (cattle)	Buying and selling fattening cattle	Unknown	Unknown	Unknown
Wholesalers (beef)	Slaughtering cattle and selling beef	- Own consumption - Given to poor/employees - Sold on urban food markets or to industry/restaurants	3407,45	5%
Mobile vendors (beef)	Selling beef	- Own consumption - Given to poor/employees - Sold on the urban food market or to industry/restaurants - Animal feed - Landfill	338,8	5%
Institutional users (beef)	Selling beef	- Own consumption - Given to poor/employees - Sold to urban food markets - Landfill	4	0,01%
Retailers (beef)	Selling beef	- Own consumption - Given to poor/employees - Sold to urban food markets - Landfill	951,15	5%

Causes:
The main causes for FLW based on the collected primary data (Kok et al., 2021b) at the wholesaler (butcher) are bad work accuracy, bad quality meat, and lack of customers, and based on the food value chain workshops are spoilage of meat. The root causes revealed in the EFFICIENT protocol are untrained labour, incomplete handling, contamination with dirt and bacteria. A simplified overview of the relationship between the causes and root causes of FLW at the wholesalers is visualized in Figure 6.

[6] The 'Destination' column indicates the FLW destination

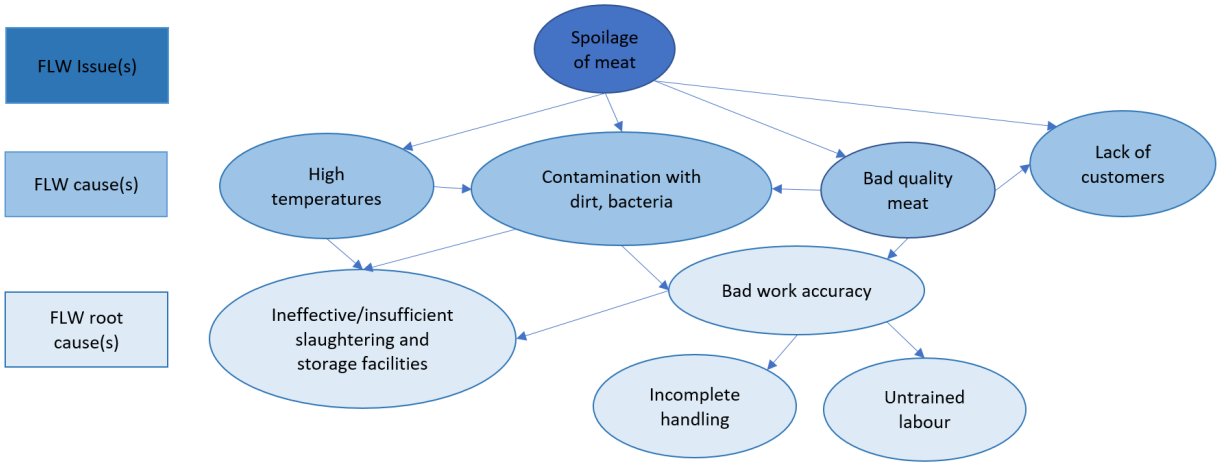

Figure 6 FLW causes and root causes in the beef value chain.

Spoilage of meat and bad quality meat can have several causes such as lack of customers and contamination with bacteria and dirt, especially in an environment with high temperatures. Causes for bad quality meat and hence lack of customers are related to bad work accuracy, which can again be caused both by incomplete handling and untrained labour, in combination with ineffective and insufficient slaughtering and meat storage facilities.

Interventions:
Based on the root causes, a long-list of interventions appeared which can be grouped in the following generic interventions (Figure 7).

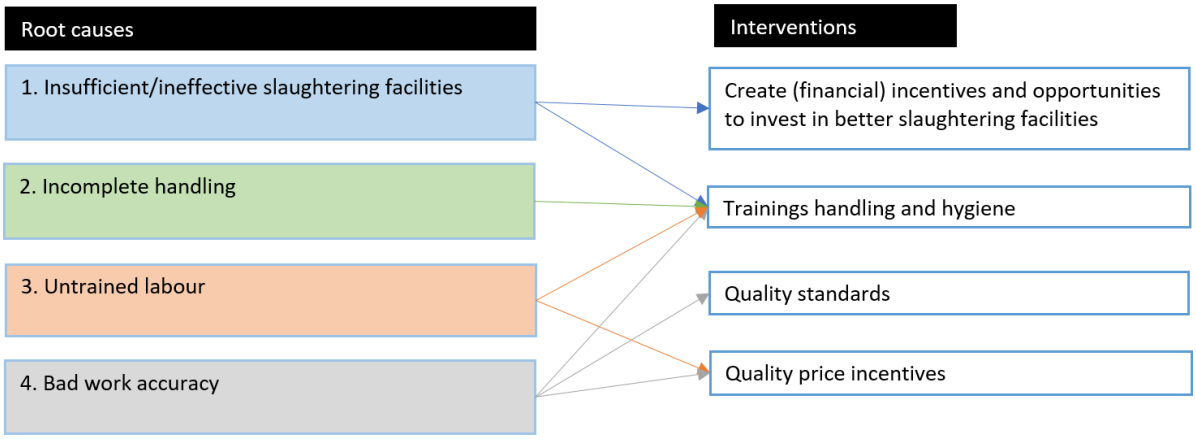

Figure 7 FLW reducing intervention in the beef value chain.

During the field visit in March 2022 additional practices of the wholesaler that are relevant to take into account for designing interventions were also described. Most common wholesaler practices for beef are:

- They sell meat the same day as much as possible;
- Price is driven by the supply, gender and breed of the cattle that is slaughtered;
- Consumers can choose the piece of meat they want and this is further processed on the spot, if necessary;
- In the early morning, (peak point) all the meat at the wholesale market is freshly slaughtered;
- Meat is not transported if the wholesalers slaughter it themselves, they slaughter and sell from the same place;
- Use of slaughterhouses is not very common but they exist. Some have cold storage rooms where customers come and pick up the carcasses. If wholesalers use slaughterhouses to slaughter, either the customers will have to come to the slaughterhouse, or the wholesaler will have to arrange transportation to get the meat to the customers.

Based on these observations and other findings from the literature we suggest to deal with the problem of spoilage of meat, and select the intervention to create (financial) incentives and opportunities to invest in better work environment.

Box 3: Additional findings in the beef supply chain

Investigating FLW and designing an intervention strategy has also revealed other issues in the beef supply chain. These are noted in this box, but because these do not directly speak to FLW they are excluded from the exercise. Most notably, these issues are mortality and relatedly, diseases. Because cattle dies prior to the cattle being ready for consumption, this is not considered FLW, but nevertheless a worrisome issue. Additionally, there are supply and demand issues negatively affecting prices of cattle and beef due to peak seasons around festive seasons leading to shortage of animals, and generally high supply other parts of the year due to unregulated imports of cattle from neighbouring India (for more info see Kok et al., 2021b).

Furthermore, in the food value chain workshops the following issues were discussed (Kok et al., 2023), primarily focusing on production, but also on others: Inadequate veterinary services, lack of grazing land, lack of capital to invest in beef rearing, low productivity of cattle, lack of market infrastructures to process meat, lack of import of cattle due to government ban, lack of adopting high-tech beef processing equipment by the butchers and lack of hygienic place in retail markets.

3.1.3. Implementation of interventions in the food system

The goal of addressing spoilage of meat is to have less FLW of beef. Improving the work (slaughtering) facilities for wholesalers (butchers) can contribute to minimising spoilage of meat. Multiple supportive actions are needed to realise this intervention. Below the intervention and examples of supportive actions are listed. This is not exhaustive, but to indicate that the success of one intervention falls or stands by the implementation of supportive actions to that intervention. The intervention:

[Slaughtering infrastructure]	Create (financial) incentives and opportunities to invest in better work environment

The supportive actions:

[Funding]	Acquire access to funds e.g. via loans, government subsidies, self-help-groups and/or donations for investments in better work environments, both upgrading available slaughter places and establishing new ones
[R&D]	Research and Development to optimal meat slaughtering facilities, locations and practices, including a pilot study
[Training]	Training on handling for wholesale butchers on hygienic work practices
[Policies]	Policy interventions on standards and protocols for supporting better meat processing, including effective regulation on these
[Market incentives]	Offering price incentives for good quality meat

The conditions for successful implementation are described below. The intervention and supportive actions are labelled and described according to a number of criteria and categories as described in the matrix. This helps to implement the intervention and create the right conditions for success in time.

The expected implementation time can be short, medium or long term.

Table 7 Expected implementation time beef.

Criterion	Short term	Medium term	Long term
Implementation time	<1 year	1-5 year	>5 year
	Training	Funding	Market incentives
		R&D	
		Policies	
		Slaughtering infrastructure	

The intervention can be implemented on micro level, meso level or macro level.

Table 8 Intervention level beef.

Criterion	Micro level	Meso level	Macro level
Intervention level	Each particular stage of the food chain, where FLW occurs, from production to consumption, that acts in response (or not) to external factor	The level where internal actors (at the same or another stage) in the food value chain or external stakeholders, impact the FLW on micro level as a result of how different actors are organized together or related in one another, or of the state of infrastructure (e.g. storage) in the context of the relation	FLW is explained by more systematic issues, such as malfunctioning food systems, lack of institutional or policy conditions to facilitate the coordination of actors, to enable investments and adoption of good practices.
	R&D	Funding	Policies
	Training	Market incentives	
	Slaughtering infrastructure		

Interventions can be classified into three types; hardware, orgware and software.

Table 9 Intervention type beef.

Criterion	Hardware	Orgware	Software
Intervention type	Technology. This includes low and high tech along the chain, measures to control product temperature and storage and packaging interventions.	Organizational, institutional, financial and procedural aspects. This includes understanding power balances in chain and enabling environment, organization of people and building trust.	Skills, knowledge and communication. This includes training, product knowledge and value chain knowledge and communication between actors
	Slaughtering infrastructure	Funding	Training
		Market incentives	R&D
		Policies	

The actors involved depend on who is responsible for the product or intervention. This can be one actor (group) or a collaboration between actor (groups) and can include the PS, GO or NGO.

Table 10 Implementing actor beef.

Criterion	Private Sector (PS)	Governmental Organisation (GO)	Non-Governmental Organisation (NGO)
Implementing actor	Input suppliers, agricultural producers, intermediaries, processors, wholesalers, retailers, vendors, etcetera.	Local governments, national governments, international governments, other governmental organizations, etcetera.	Facilitators, innovators, financiers, researcher institutes, education, donor organisations, civil society organisations, etc.
1. Funding	x	x	x
2. Market incentives	x	x	
3. R&D		x	x
4. Slaughtering infrastructure	x	x	x
5. Training	x	x	x
6. Policies		x	

3.1.4. Visualisation of the roadmap

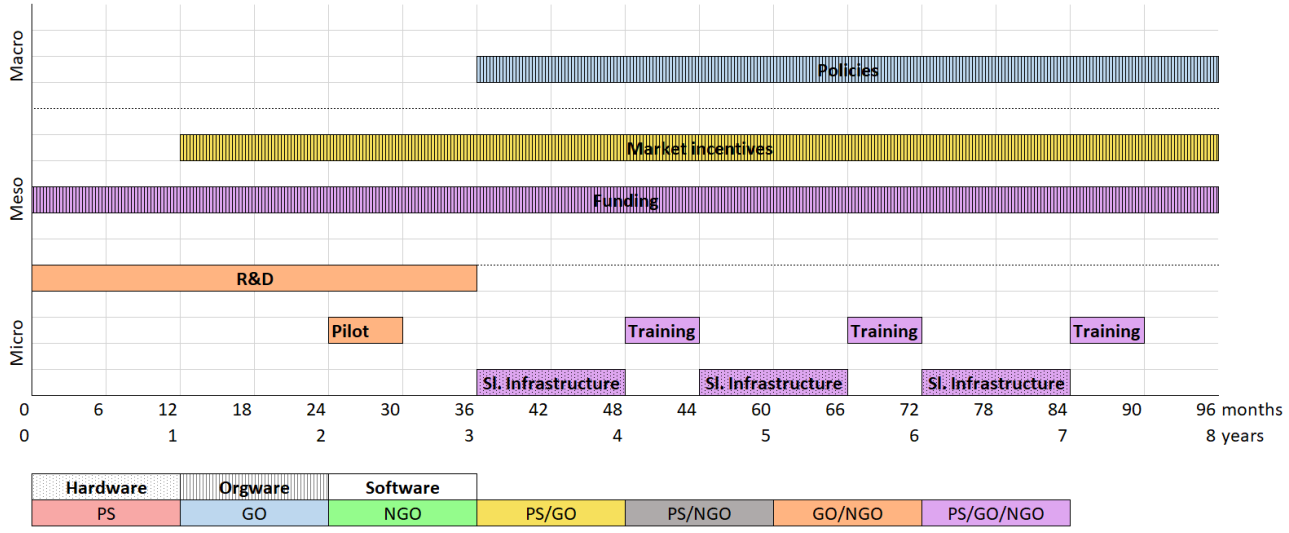

Figure 8 Visualisation of the roadmap for the improvement of the beef value chain.

The interventions and supportive actions are plotted in Figure 8 to create the roadmap. The sequence of the supportive actions is further explained per step below.

1. Since investments will have to be made to create better slaughtering facilities for the wholesalers, step one is to organize access to credit for the investments, for example via supporting/building loan structures and making public subsidies available. Ideally for greater sense of ownership the investment(s) (decisions) can be done by value chain actors, with help from GO and/or NGO.

2. In the end value chain actors will not be motivated to adjust their way of working without any price benefits, so successfully improving the beef value chain will have to be driven by price incentives for improved quality product. Price is now driven by the supply, gender and breed of the cattle that is slaughtered. Consumers can choose the piece of meat they want from the carcass and this is then further processed if required, all in the same spot. In the early morning, (peak point) all the meat at the wholesale market is freshly slaughtered. It is important to quickly start drafting pilots under the supportive action R&D with the wholesalers to experiment with creating price incentives for improved meat, as well as on where and how slaughtering facilities can best be upgraded and established.

3. Once the above is in place, wholesalers can be trained on handling practices. This is assumed to create for some the additional intrinsic motivation to want to invest in upgrading their activities. With improved access to credit those who want can then invest in improved work environments. Due to a lack of an hygienic work environment during slaughtering, presenting and further processing of meat there is contamination with dirt and bacteria. Clean slaughtering practices can greatly improve this. Investments in protective packaging and cooled transport can follow where this can reduce meat spoilage and where this is relevant. This is for the wholesalers to prioritize.

4. To successfully create price incentives for improved quality, government action is needed for the required institutional support in the form of standardization policies and the formulation of protocols for beef value chains. All 'orgware' interventions should be initiated and continued.

To conclude, after 8 years there should be less spoilage of beef due to improved slaughtering facilities and incentives for wholesalers (butchers) to practice slaughtering to minimise risks for spoilage of meat, such as contamination with dirt and bacteria and meat not being sold to consumers for reasons that have been understood and addressed. Work accuracy will be improved for optimal slaughtering of the meat on the carcasses in line with consumer preferences.

3.2. Chicken

3.2.1. Introduction

Per capita annual consumption levels for poultry meat is expected to increase with 26% in the coming five years (from 2020). Adding the estimated population growth (CARG 1.2%) to the expected consumption growth rates results in a total estimated poultry meat sector growth of 34%. Two main type of broiler breeds are consumed in Bangladesh. Sonali chicken is a local variety with a relatively high meat content and has been the fastest growing segment in recent years. The local Deshi chicken has the strongest consumer perception and hence is also the most expensive. The current broiler chicken population is estimated at 525 million birds. Out of the 525 million broilers annually consumed in Bangladesh, approximately 60% (300-325 million) are reared in commercial farms and the remaining 40% in semi-scavenging / traditional rural backyard conditions. Commercial poultry production requires a long backward linkage that starts from 'Pure Line' to commercialize Day old chick (DOC). In Bangladesh, poultry production starts from Grand Parent (GP) stock level followed by breeder farming for Parent Stock (PS) to commercial broiler or layer with the close integration with feed mills and hatcheries (RVO, 2020).

Although the poultry sector in Bangladesh is relatively underdeveloped in virtually all steps of the value chain, though what stands out is the absence of a professional downstream segment (slaughtering, further processing and cold chain logistics infrastructure). Modern slaughtering is limited to Dhaka and Chittagong, and currently only 2-3% of all broilers consumed in Bangladesh is slaughtered in modern slaughterhouses. The remaining birds are being slaughtered manually at wet markets (RVO, 2020).

Despite the poultry sector still being a relatively fragmented sector in Bangladesh (compared to other more developed economies), and involves a vast number of smallholders, there are also a number of larger (integrated) parties active in the business such as ACI-Godrej, Aftab, CP, New Hope, Nourish, Provita and Quality. These players are often active in multiple steps of the value chain, have a controlling position in the breeding business (supply of Day-old-Chick and Day-old-Layers), manufacture feed for third parties (independent farmers and contract farmers) and for their own (captive) demand (integrated farms), and to some extend have slaughtering capacity to cater urban consumers with processed poultry meat (RVO, 2020).

At producers level, however somewhat outdated, the mortality rate was estimated between 4-8% of the total flock (Islam et al., 2014; Ershad et al., 2004). Poultry carcasses may be disposed of through burial, disposed in concrete disposal pits, incineration, composting or dumping (Gupta et al., 2022; Sarker et al., 2009; rimi et al., 2017). Based on the field visit conducted in March 2022 it was observed that FLW in the informal channel at wet markets (wholesale butchers and retail butchers) was limited, as the butchers slaughter the

broilers based on the consumer demand. The unwanted inedible parts of the slaughtered broilers were brought to the nearby municipal waste disposal station, fed to the dogs living in the streets or sold as fish feed (field visit; Alam et al., 2019). Although unsold broilers are kept alive, the mortality rate of ready to slaughter broilers is estimated around 1% during transportation and overnight storage. However, sometimes these dead broilers are still slaughtered and sold to restaurants and food vendors (results food value chain workshops).

3.1.2. Intervention selection

Scope:
The scope of this case study includes broiler production and chicken meat produced in Bangladesh, and sold to domestic consumers. It includes all actors in the chicken broiler value chain, from moment of breeding day-old chicks at breeder farms till and including retail, foodservice and mobile vendors (both formal and informal).

Flow:
For the flow phase we used the overview of the value chain from Rahman et al. (2021) in combination with the insights from the field visit conducted in March 2022. The value chain is visualized in Figure 9. Distinction is made between the informal channel (butchers at wet markets) and the formal channel (modern slaughtering). In general, broilers produced at broiler farms are sold to intermediaries, who butcher the broilers based on consumer- and restaurant demand (informal channel) or who process the broilers via slaughterhouses for retail and (hotel-)restaurants (formal channel). In this study, data was collected per actor and used in the focus phase.

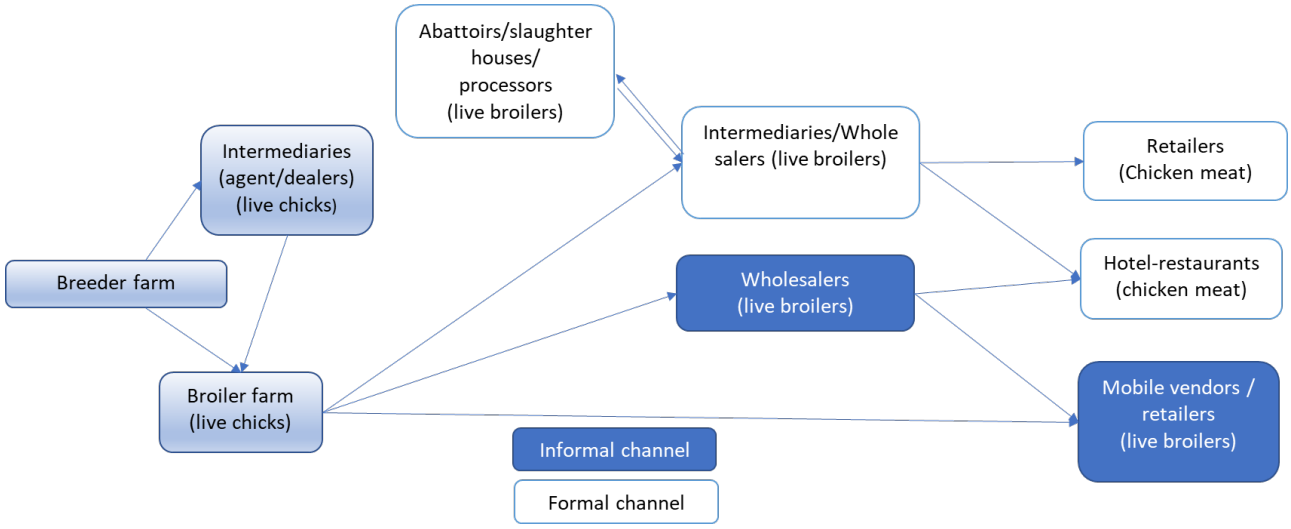

Figure 9 Broiler value chain (based on Rahman et al., 2021 and field visit).

Focus:
The result of the FLW analysis per actor is provided in Table 11. Due to the high percentage of broilers that are sold via the informal channel, and the occurring FLW due to mortality of ready-to-slaughter broilers during transport and overnight storage, it was decided to select the informal wholesale- and retail butchers for further analysis. Although the mortality rate is high at broiler producers, this is not FLW following the used FLW definition (FAO, 2018).

Table 11 Hotspot selection in the broiler value chain.

Name actor	Activities	Destination	i	
			weight kg	weight %
Producers breeders	Produce commercial broiler chicks/eggs	-Burning, -Buried in soil, -Dumping in open drain or nature, -Fed to dogs, -Disposed in a concrete disposal pit	Unknown	Unknown
Intermediaries (live chicks)	Transport chicks/eggs from breeder farm to broiler farm (and layer farms)	Unknown	Unknown	Unknown
	Sell inputs to farmers	Unknown	Unknown	Unknown
Producers broilers	Producing chickens to slaughter weight	-Burning, -Buried in soil, -Dumping in open drain or nature, -Fed to dogs, -Disposed in a concrete disposal pit	Unknown	7%
Formal channel: Wholesalers (meat)	Slaughtering (or 3rd party)	Unknown	Unknown	Unknown
	Trade	Unknown	Unknown	Unknown
Formal channel: Retailers (meat)	Selling	municipal waste disposal station	Unknown	Unknown
Informal channel: Wholesalers (live broilers)	Purchasing	-	0	0%
	Transport	Unknown	Unknown	1%
	Slaughtering/selling	-Fish feed, -Municipal waste disposal station, -Streetdogs	Unknown	5%
Informal channel: Mobile vendors/retailers (live broilers)	purchasing	-	0	0%
	Transport	Unknown	Unknown	1%
	Slaughtering/selling	-Fish feed, -Municipal waste disposal station, -Streetdogs	Unknown	5%
informal + formal channel: Hotel-restaurants (meat)	Transport	-	0	0%
	Preparing	Municipal waste disposal station	Unknown	Unknown
	Selling	Municipal waste disposal station	Unknown	Unknown

Causes:
The main causes of FLW during transport or overnight storage are related to mortality due to diseases or (heat) stress of broilers. A simplified overview of the relationship between causes and root causes are visualised in Figure 10.

Mortality can be caused by several factors, of which diseases and stress (heat) are the main causes. Diseases are caused by viruses or bacteria in combination with a low disease resistance. Heat stress occurs due to long transport distances in circumstances that are not ideal and warm temperatures at the markets. Broilers that are not being sold at the same day are kept in overnight storage cages to sell the next day.

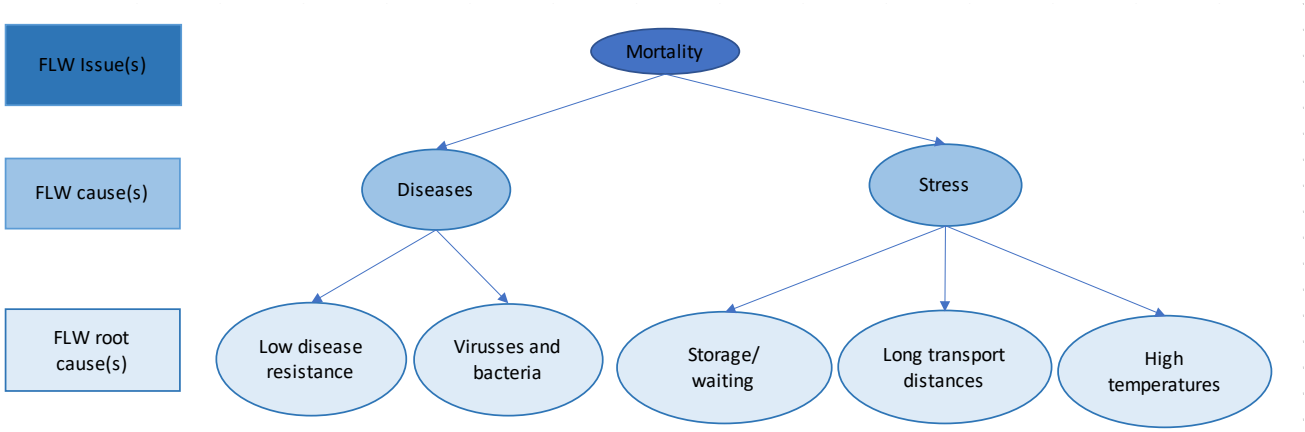

Figure 10 FLW causes and root causes in the broiler value chain.

Interventions:
Based on the root causes, a long-list of interventions appeared. These can be grouped and the following generic interventions (see Figure 11):

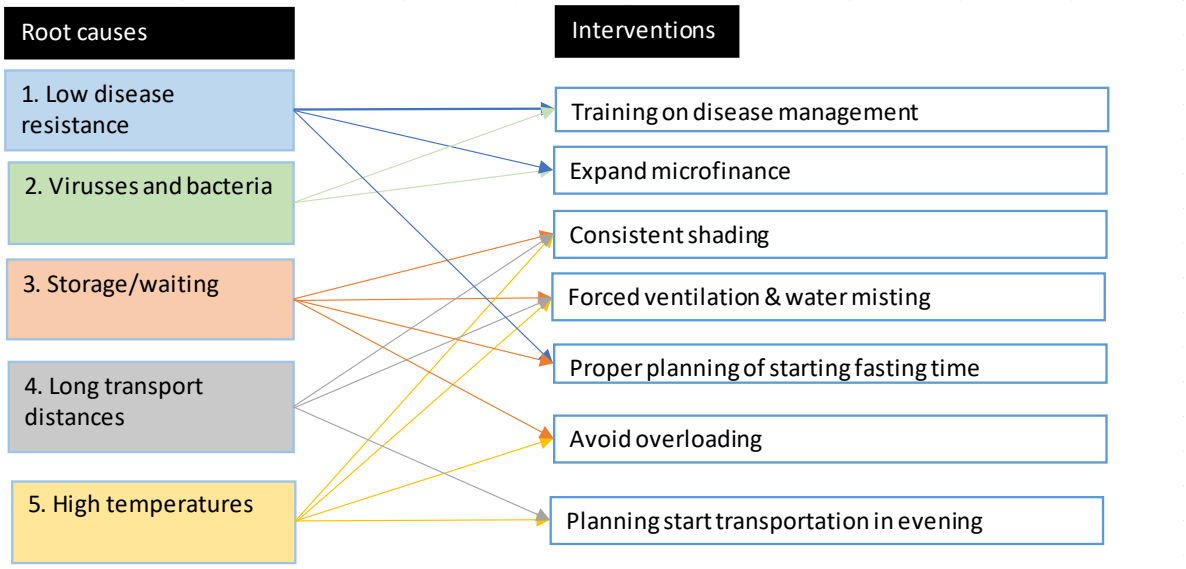

Figure 11 Interventions that address the root causes for mortality at broilers.

Based on observations during the field visit and literature review we suggest to deal with the problem the high temperatures during transportation and storage. Therefore the selected intervention will be 'consistent shading'. Reaching this intervention will keep the broilers as cool as possible from the moment of leaving the farm till being slaughtered for consumption. Adding other interventions can further decrease the heat stress of broilers, but is not taken into account in this case.

Box 4: Additional findings in the chicken broiler supply chain

Poultry farmers in Bangladesh have a lot to gain in terms production. The technical performance is low in terms of feed conversion, cycle length and mortality ratios (RVO, 2020). Small-scale farmers are dependent on local dealers for day-old-chicks (DOC), feeds, medicines, and other operational capital (Rahman et al., 2021). Often farmers face challenges with low quality DOCs, high feed prices, marketing problems, insufficient access to bank loans, lack of quality vaccines and high costs for vaccines, and diseases such as Avian Influenza (AI), Newcastle Disease (ND), Infectious Bronchitis (IB), Infectious Bursal Disease (IBD), Salmonella infections, Mycoplasmosis, Coccidiosis and Aflatoxicosis (Islam et al., 2014; Rahman et al., 2021).

Furthermore, in the workshops the following issues were described by the private sector (Kok et al., 2023):
- Feed crises → High prices of chicken feed
- High price fluctuation at retail level & high price gap between farmer gate price and retail price (live bird)
- Unhygienic slaughter practices and dead chicken are sold to restaurants
- Adverse business condition for small producers -> Small producers are out of business
- Lack of production mechanisms for small producers -> supply breakdown
- Lack of storage & processing facilities -> Dependence on live chicken
- Powerful intermediaries

3.2.3. Implementation of interventions in the food system

The goal of improving the broiler value chain is to have less mortality during transport and storage/waiting between moment of leaving the farm and being slaughtered for consumption. Multiple supportive actions are needed to implement the intervention of consistent shading successfully. Currently chickens are transported in open cages, baskets with nets, or by hand carrying and are exposed to the sun. Storage/waiting is done inside markets or outside on the streets, of which the latter also gives sun exposure to the broilers. In this time broilers have no access to food or water due to the fasting period before slaughtering.

[Shading] Create consistent shading for broilers from the moment they leave the farm till being slaughtered for consumption.

The proposed supportive actions to reach the goal of consistent shading include:

[Cages] Search for proper and affordable transportable cages with a good shading roof that are already available, or develop new, proper and affordable transportable cages with a good shading roof, and make them available in Bangladesh.

[Consumer] Inform consumers about animal welfare to promote the purchase of chickens that are transported and kept in good conditions.

[Monitor] Measure and monitor the current mortality rate. The current numbers on the mortality rate of broilers during transport and storage/waiting are outdated. Check if there can be business case when investing in new transport cages.

[Pilot] Start a pilot with a group of market- and street vendors by providing them improved transport cages and training, and monitor the mortality rate in a certain period.

[Subsidies] Acquire access to funds e.g. via loans, government subsidies, self-help-groups and/or donations for investments in proper cages.

[Training] Provide training to market- and street vendors on the influence of heat stress on broiler mortality, and suggestions to reduce heat stress of broilers during transport and storage/waiting (such as forced ventilation, proper planning of starting fasting time, avoid overloading, use of cloths and sunshades, and starting transportation during the evening).

[Upscaling] When the pilot is successful, increase the access to the training and promote the investment in proper cages with a good shading roof.

The conditions for successful implementation are described below. The intervention and supportive actions are labelled and described according to a number of criteria and categories as described in the matrix. This helps to implement the intervention and create the right conditions for success in time.

The expected implementation time can be short, medium or long term.

Table 12 Expected implementation time broiler.

Criterion	Short term	Medium term	Long term
Implementation time	<1 year	1-5 year	>5 year
	Monitor	Cages	
	Pilot	Consumer	
	Shading	Subsidies	
	Training	Upscaling	

The intervention can be implemented on micro level, meso level or macro level.

Table 13: Intervention level broiler.

Criterion	Micro level	Meso level	Macro level
Intervention level	Each particular stage of the food chain, where FLW occurs, from production to consumption, that acts in response (or not) to external factor	The level where internal actors (at the same or another stage) in the food value chain or external stakeholders, impact the FLW on micro level as a result of how different actors are organized together or related in one another, or of the state of infrastructure (e.g. storage) in the context of the relation	FLW is explained by more systematic issues, such as malfunctioning food systems, lack of institutional or policy conditions to facilitate the coordination of actors, to enable investments and adoption of good practices.
	Pilot	Cages	Shading
	Training	Consumer	Upscaling
		Monitor	
		subsidies	

Interventions can be classified into three types; hardware, orgware and software.

Table 14 Intervention type broiler.

Criterion	Hardware	Orgware	Software
Intervention type	Technology. This includes low and high tech along the chain, measures to control product temperature and storage and packaging interventions.	Organizational, institutional, financial and procedural aspects. This includes understanding power balances in chain and enabling environment, organization of people and building trust.	Skills, knowledge and communication. This includes training, product knowledge and value chain knowledge and communication between actors
	Cages	Consumer	Monitor
		Shading	Pilot
		Subsidies	Training
		Upscaling	

The actors involved depend on who is responsible for the product or intervention. This can be one actor (group) or a collaboration between actor (groups) and can include the PS, GO or NGO.

Table 15: Implementing actor broiler.

Criterion	Private Sector (PS)	Governmental Organization (GO)	Non-Governmental Organization (NGO)
Implementing actor	Input suppliers, agricultural producers, intermediaries, processors, wholesalers, retailers, vendors, etcetera.	Local governments, national governments, international governments, other governmental organizations, etcetera.	Facilitators, innovators, financiers, researcher institutes, education, donor organisations, civil society organisations, etc.
Cages	x	x	x
Consumer		x	x
Monitor		x	x
Pilot	x		x
Shading	x		
Subsidies		x	x
Training	x	x	x
Upscaling	x	x	x

3.2.4. Visualisation of the roadmap

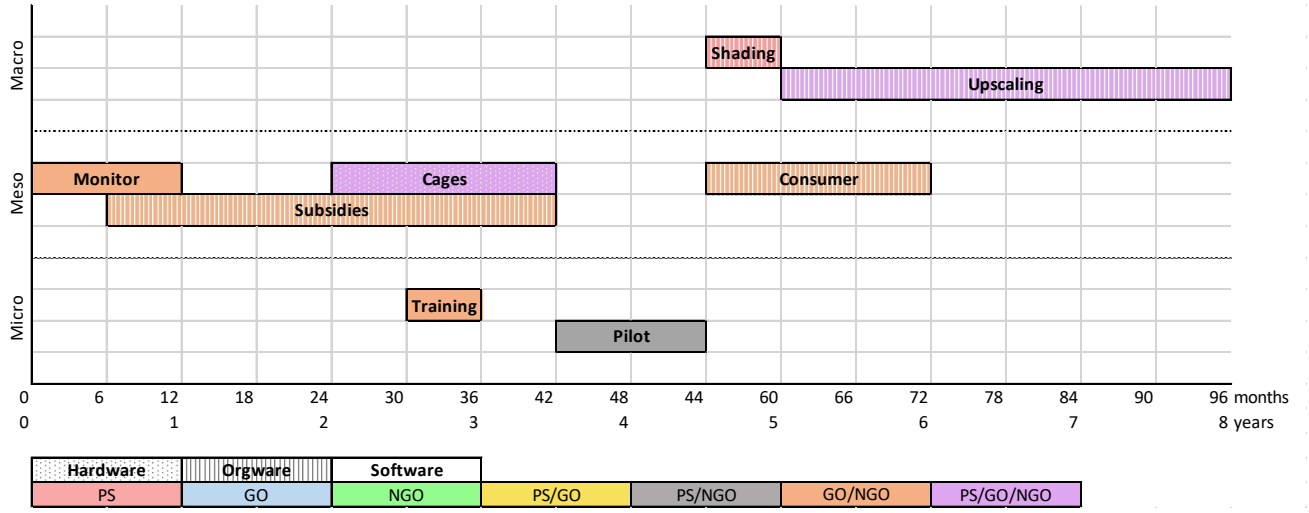

Figure 12 Visualisation roadmap improving the broiler value chain.

The intervention and supportive actions are plotted in Figure 12 to create a visualisation of the roadmap. The sequence of the intervention and supportive actions is further explained per step below.

1. The roadmap starts with monitoring the current mortality rate of broilers during transport and storage/waiting. As the current numbers on the mortality rate of broilers during transport and storage/waiting are outdated, it is unknown what type of investment space is available to invest in a profitable intervention. Besides, it is important to monitor if the provided intervention is enough to reduce the current mortality rate, or that other interventions need to be added to receive the preferred result.

2. At the end of the monitoring activity, acquire access to funds e.g. via loans, government subsidies, self-help-groups and/or donations can be started to be able to find additional ways to invest in the broiler value chain. This activity can take some time.

3. When the availability of subsidies in known, searching for proper transportable cages with a good shading roof can be started. Search for local available, affordable transportable cages. When not available, search for suitable transportable and affordable cages from other sides of the world. Research institutes or NGO's can help to provide possibilities and the private sector can provide input on their needs. If no good options are available, it is also possible to explore the possibility of designing new, affordable transportable cages with a local manufacturer that fit the Bangladeshi context. The implementation time is depending on the availability of these proper cages.

4. In the meantime training can be provided to a selected group of market- and street vendors on the influence of heat stress on broiler mortality, and suggestions to reduce heat stress of broilers during transport and storage/waiting (such as forced ventilation, proper planning of starting fasting time, avoid overloading, use of cloths and sunshades, and starting transportation during the evening). This training, combined with the access to transportable cages, should be finished before starting the pilot activity.

5. The pilot activity can start as soon as the training is finished and the access to transportable cages is arranged. The pilot should be conducted to see if market- and street vendors can properly use the new ways of transportation, to show the mortality rate reduction in a certain period in time and to solve issues that occur by using the new shading structures.

6. After the pilot is conducted, the vendors that were involved can now actively implement the intervention of creating consistent shading to the broilers. To further decrease the heat stress, this intervention can be combined with more active ways of reducing heat, such as forced ventilation, planning of fasting time, avoid overloading and transportation in the evening. A reduction in mortality rate will result in a higher sales for the vendors.

7. Although the sales will be higher when the mortality rate is reduced, informing consumers about animal welfare can further support the uptake of the intervention. Promoting the purchase of broilers that are transported and kept in good conditions with increase the consumer demand for these broilers, what will result in higher sales for the vendors that implement the intervention.

8. When the pilot is successful, increase the amount of participants and city regions to give more consumers the opportunity to purchase the broilers that are transported and kept in the shade and face less heat stress.

To conclude, after 8 years we have a broiler value chain that face less problems with animal mortality during transportation and storage/waiting at the market. It will increase the amount of broilers that can be sold, and reduce the amount of dead broilers that are still sold to local restaurants and canteens which create unsafe situations.

3.3. Fish

3.3.1. Introduction

Bangladesh is one of the major fish producing and consuming countries in the world. For all population groups in Bangladesh, fish is the primary source not only of animal protein but also of micronutrients. The rapid growth of aquaculture in Bangladesh has made possible higher per capita fish consumption despite an increasing population. Aquaculture, as a method of fish production, has become more intensified and diversified in response to market demand (Dey and Surathkal, 2020; Rahman and Islam, 2020).

Bangladesh has the third largest aquatic biodiversity in Asia behind China and India with about 800 species of fresh, brackish and marine water species and having world's largest flooded wetland and three main river systems Ganges, Brahmaputra and Meghna (Uddin et al., 2018).

Mymensingh (north of Dhaka) and Jashore (south west of Dkaha) districts of Bangladesh contribute respectively 12% and 6% to total aquaculture production and are therewith the largest producers; these areas also supply to Dhaka. Pangas production is about 23.2% of aquaculture production, and tilapia 16,64% (Acharjee et al., 2021). Less than 3% of total fish production in Bangladesh is exported (LEI, 2012). Most exported fish is unprocessed. In 2019 fisheries contributed 2.92% of GDP, and 23.04% of agricultural GDP (GLOBEFISH, 2022).

In recent years, pangas and tilapia have become the most popular commercial cultivable species due to high yield, higher response to external feeding, and availability of seeds to meet the farmers' demand. Pangas and tilapia production were 510,097 and 370,017 metric tonnes, which was 12.34% and 8.95% of total fish production, respectively, in 2017 (Uddin et al., 2018). From the field visit we learn that tilapia and pangasius are the cheapest fish and therefore most accessible to low income consumers. The price is based on weight and approximately 150-180 TK/kg. Fish is usually transported to the wholesalers alive in open bins with water and some in freezing boxes with ice. At markets the fish are presented alive in water, or on ice or a type of plate with a bit of water. At the selling locations fish is typically not in the water anymore and mostly sold to consumers dead, almost always as a whole fish (minimum processing has taken place). The price of fish is not dropped at the end of the day because the margins are already low. It lays in open air (not in packaging). Fish that is not sold is put in ice and sold the next day. Sometimes the fish rots and is disposed in the dustbin.

The reported losses by Acharjee et al. (2021) constitute physical, quality and market losses. When only considering physical losses, the following loss percentages apply:

Table 16 Physical loss percentages (based on Acharjee et al., 2021).

Stakeholder	Locations	Physical loss percentage (%)
Farmers	Average in Mymensingh and Jashore districts	2,14%
Intermediaries	Average in Mymensingh and Jashore districts	0,78%
Wholesalers	In Dhaka	1,07% [0,79% average combined with losses in districts]
Retailers	In Dhaka	0,73% [0,67% average combined with losses in districts]

3.3.2. Intervention selection

Scope:
The scope of this case study includes fresh (not frozen) fish production in Bangladesh, specifically of white fish tilapia and pangasius. It includes all actors in the value chain, from the hatcheries and nurseries to consumers.

Flow:
For the second phase we used the overview of the value chain from Uddin et al. (2018). The value chain is visualized below in Figure 13.

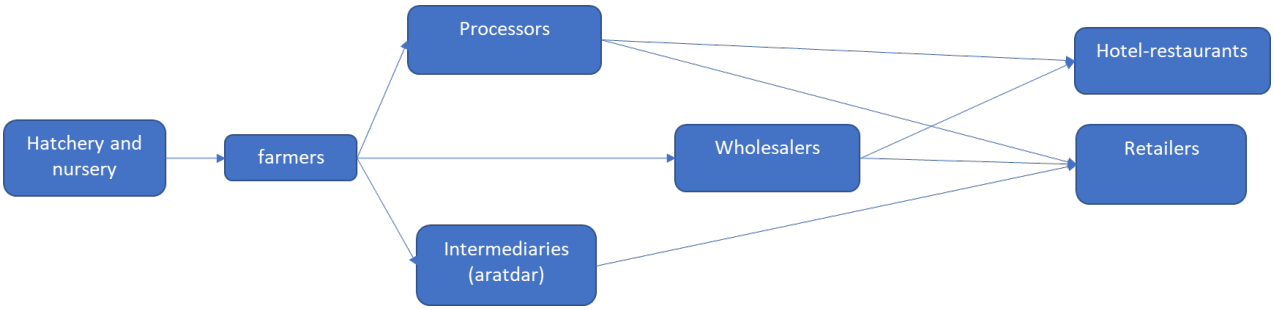

Figure 13 Bangladesh fish value chain overview (based on Uddin et al., 2018).

Focus:
Based on a study from Acharjee et al. (2021) it was decided to select the wholesalers as the main FLW hotspot, mainly due to the highest FLW percentage. In the production areas high percentages of fish died, however they were not ready to slaughter yet and therefore not seen as FLW (see definition FLW at FAO 2018). The field visit clarified that most fish is sold as whole fish to the consumers and that minimal processing is taking place; we therefore suspect minimal losses at processor level for the types of value chains that we focus on.

Table 17 Hotspot selection in the fish value chain (activities based on Kruijssen et al., 2020; weight % loss based on Acharjee et al., 2021).

Name actor	Activities	Destination	i	
			weight kg	weight %
Hatchery and nursery	-Breeding -Growing	Unknown	Unknown	Unknown
Farmers	-Growing -catch/harvest	Unknown	Unknown	8.1%
Processors	-Processing -Packing	Unknown	Unknown	Unknown
Intermediaries	-Handling -Storage -Transport -Selling	Unknown	Unknown	2.6%
Wholesalers	-Handling -Storage -Processing -Transport -Selling	Unknown	Unknown	2.7%
Hotel-restaurants	-Transport -Processing -Selling and packing	Unknown	Unknown	Unknown
Retailers	-Transport -Selling and packing	Unknown	Unknown	2.6%

Causes:
Spoilage is the main FLW issues that is caused due to damages or rotten products. Main reported reasons for physical fish losses at wholesaler (*paikar*) were inadequate packaging and storage facilities that also cause damage and spoilage of fish (Acharjee et al., 2021). Additionally, the literature mentions that most actors suffer from inadequate market information about supply and demand, typically resulting in selling at lower than envisaged prices, but likely also in physical losses when the fish cannot be sold soon enough. This is

therefore also included as a FLW cause. Figure 14 visualises FLW causes and root causes in the fish value chain.

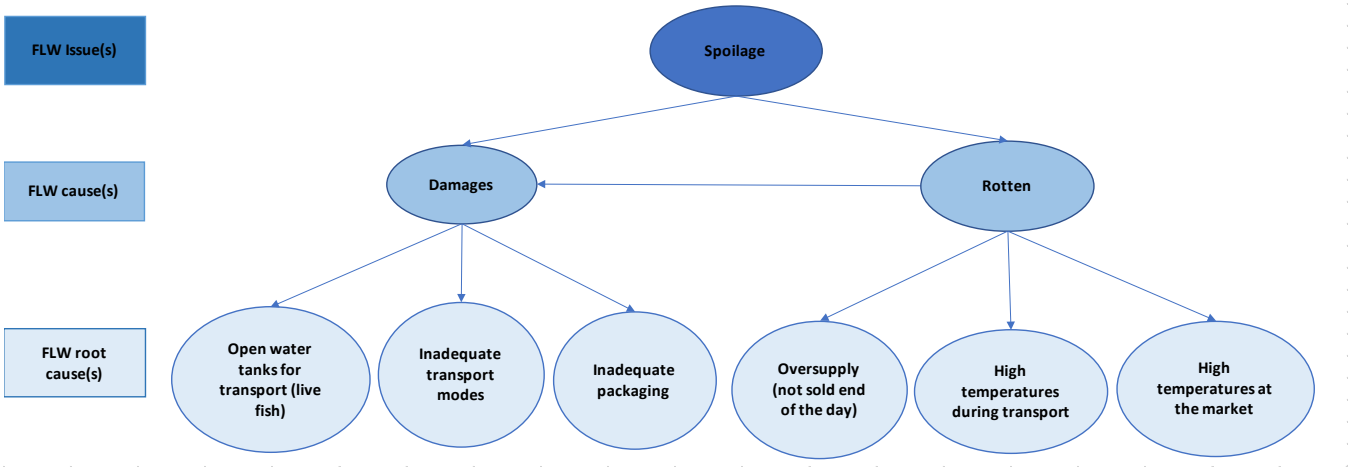

Figure 14 FLW causes and root causes in the fish value chain.

Interventions:
The main root causes and suggested interventions that directly or more indirectly speak to these are visualised in Figure 15 and elaborated below.

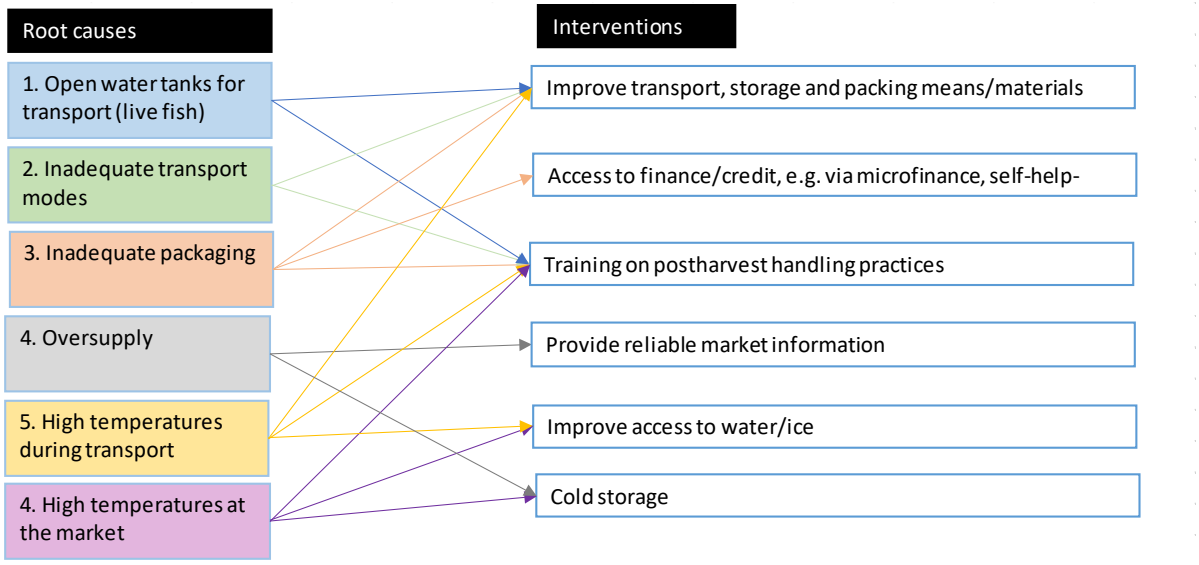

Figure 15 Interventions that address the root FLW causes for fish.

Based on observations during the field visit, the literature review and results of the FVC workshops showed that losses during handling and transportation are the main issue caused by among others deficient facilities and lack of know-how. The issue is crucial due to fish being a sensitive and highly perishable product. Therefore we select the intervention 'improving transport, storage and packing' as it can address inadequacies in product handling.

Box 5: Additional findings in the fish supply chain

Besides the issues focused on in this example, several other issues were highlighted in the workshop with value chain stakeholders.

- Availability, affordability and quality of inputs (feed, seed, utilities).
- Lack of value added (due to lack of technology and investment opportunities therefor), also being related to a perceived technology gap between farmers/processors and exporter, limiting the export potential of Bangladesh fish producers.
- Lack of food safety and hygiene. Although out of scope in this example (focusing on food losses), food safety and hygiene is related to product quality, quality loss, and can be improved upon by improving handling, transportation and storage to make this more sanitary.

3.3.3. Implementation of interventions in the food system

The goal of improving fish value chain is to have less spoiling of fish before it reaches their consumers.

Multiple supportive actions are needed to implement the intervention of consistent shading successfully. Currently fish are transported alive in open water tanks or dead in other packaging material. The amount of water is often limited in the water tanks during transport or when being sold in the market. Besides, for dead fish, ice is often lacking when transporting or selling live. To achieve this, there is a need for a combination on improvement of harvest and postharvest handling practices, of improved means of transporting the fish, storage, and packing which will allow also to improve the use of at least water (or ice) on the fish, and finally to improve market information for the value chain actors.

[Materials]	Proper harvest and postharvest management practices for the fish value chain require to possession of certain materials for storing and transporting that for example allow for adding water or ice.

This main intervention can be supported with training/education on handling practices (which could also help to address lack of knowledge as a general root cause of losses), improving accessibility of necessary materials (packaging, water, and ice) at loss hotspots, and financing and credit, enabling producers and wholesalers to invest. The need for financing and training was affirmed by workshop participants as well, who in addition introduced cold storage as a significant upgrade of current storage practices. The proposed supportive actions to reach the goal of consistent shading include:

[Credit]	Supporting the access to credit for example via microfinance of stimulating self-help-groups can help provide for the materials needed to properly implement best harvest and postharvest management practices.
[Ice/water]	Due to high temperatures and the perishable nature of fish, at least watering the fish can help to keep it cool. This requires also to have the right set-up such as infrastructure and materials to do so.
[Information]	There was an expressed concern by most value chain actors about limited access to reliable market information about supply and demand, often causing actors to sell at a lower than preferred price, resulting low margins and low means to reinvest in the chain. Providing reliable market information can support and attract investments in the chain by all actors.
[Training]	Particularly at farm level, losses can be prevented by investing in farmers harvest and postharvest management practices.

The expected implementation time can be short, medium or long term.

Table 18 Expected implementation time fish.

Criterion	Short term	Medium term	Long term
Implementation time	<1 year	1-5 year	>5 year
	Information	Credit	
	Training	Icing/watering	
		Materials	

The intervention can be implemented on micro level, meso level or macro level.

Table 19 Intervention level fish.

Criterion	Micro level	Meso level	Macro level
Intervention level	Each particular stage of the food chain, where FLW occurs, from production to consumption, that acts in response (or not) to external factor	The level where internal actors (at the same or another stage) in the food value chain or external stakeholders, impact the FLW on micro level as a result of how different actors are organized together or related in one another, or of the state of infrastructure (e.g. storage) in the context of the relation	FLW is explained by more systematic issues, such as malfunctioning food systems, lack of institutional or policy conditions to facilitate the coordination of actors, to enable investments and adoption of good practices.
	Materials	Icing/watering	Credit
	Training	Information	

Interventions can be classified into three types; hardware, orgware and software.

Table 20 Intervention type fish.

Criterion	Hardware	Orgware	Software
Intervention type	Technology. This includes low and high tech along the chain, measures to control product temperature and storage and packaging interventions.	Organizational, institutional, financial and procedural aspects. This includes understanding power balances in chain and enabling environment, organization of people and building trust.	Skills, knowledge and communication. This includes training, product knowledge and value chain knowledge and communication between actors
	Icing/watering	Credit	Information
	Materials		Training

The actors involved depend on who is responsible for the product or intervention. This can be one actor (group) or a collaboration between actor (groups) and can include the PS, GO or NGO. In the case of fish, the interventions will have to eventually be practically implemented by the individual or a collective of value chain actors, but for most interventions, governments as well as NGOs and donor organisations can assist.

Table 21 Implementing actor fish.

Criterion	Private Sector (PS)	Governmental Organization (GO)	Non-Governmental Organization (NGO)
Implementing actor	Input suppliers, agricultural producers, intermediaries, processors, wholesalers, retailers, vendors, etcetera.	Local governments, national governments, international governments, other governmental organizations, etcetera.	Facilitators, innovators, financiers, researcher institutes, education, donor organisations, civil society organisations, etc.
Credit	X	X	
Icing/watering	X	X	X
Information	X	X	X
Materials	X	X	X
Training	X	X	X

3.3.4. Visualisation of the roadmap

Figure 16 below visualises the required interventions, implementation time, type of intervention (hardware, orgware, software) and involved actors for reducing FLW in fish chains in Bangladesh. Below the advised steps are described.

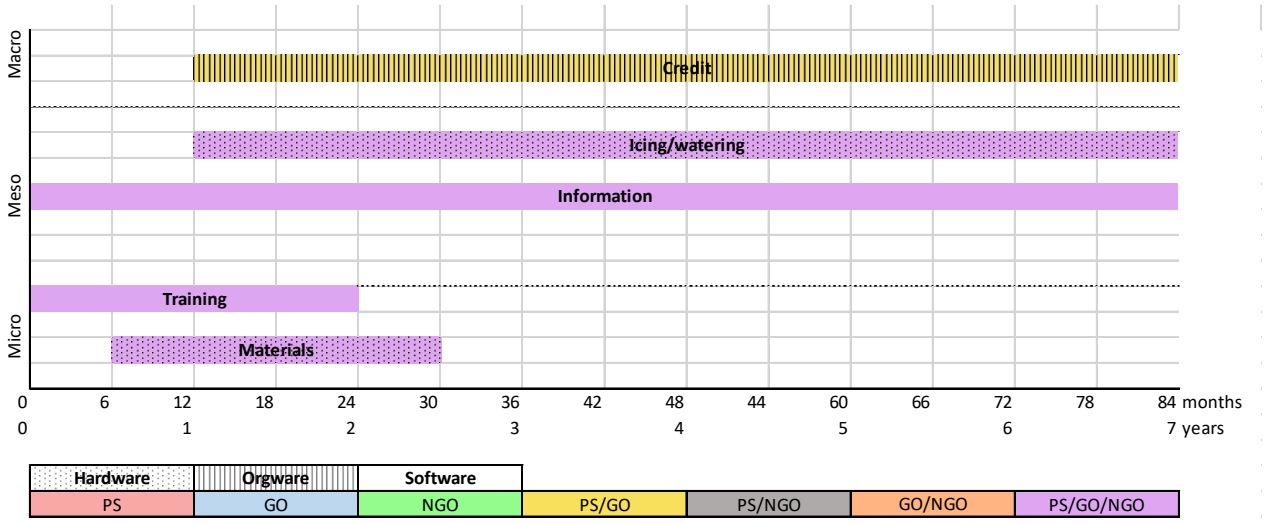

Figure 16 Visualisation roadmap for the fish value chain.

The aim of these interventions is to reduce FLW in the fish value chains, primarily focusing on the losses occurring at the farmer and at the wholesaler. The sequence of the supportive actions is further explained per step below.

1. Designing a harvest and postharvest handling training is needed. However, this training should not only focus on the wholesalers, but also on intermediaries who are responsible for transportation. This training should combine the knowledge about why it is so instrumental to practice the best practices, together with practical usability. Investing in improving postharvest handling so early in the chain can, in combination with other interventions, greatly extend the quality of the fish. This training requires the willingness of other actors to participate, and could be organised via government extension services and/or NGOs.

2. In order for actors to start making (more) investments in the chain value chain actors needs to be incentivised and get paid for good quality fish. In the study of Acharjee et al. (2021) market (economic) losses had the greatest share compared to physical and quality losses. Various value chain actors expressed concerns about unreliable market information, resulting in selling the fish at a lower than preferred market value. Therefore it is advised that strong efforts are put towards developing a reliable market information distribution system. Fish is a staple food so there is

sufficient demand, and a combination of improving postharvest handling practices and knowing where the markets are could result in greater returns for value chain actors.

3. In order to benefit from the training, it is likely that some additional requirements are needed in for example better tools, and storing, transportation and packing means.

4. Of utmost importance for lasting the quality of the fish is minimise the chance for the fish to heat/avoid spoilage, by keeping it cooled in (ice)water. Current practices are that higher valued fish (e.g. shrimp) tend to get more of the scarcely available and costly ice. Even is ice is costly and not widely available, water should. For those that wish to deliver higher quality white fish, more ice and cold water should be available and transportation and storage means should be able to accommodate this.

5. In addition to perhaps being able to get higher returns on investments than now with the previous interventions, it is likely that additional funding is needed in order to really benefit from this in the form of taking the business to a next desired step. It is therefore advised to governments, and NGOs to continuously support and establish efforts for small entrepreneurs to access credit.

To conclude, these interventions are designed to specifically reduce FLW for the fish value chain at producer and wholesaler level in seven years due to improper product handling. The combination of the intervention and sequences supportive actions is expected to address the root causes and therefore result in less FLW at these value chain links.

3.4. Onion

3.4.1. Introduction

In 2020, Bangladesh produced 1.95 million tons of onion. The production volume of onions is relatively small compared to the main staple crops like rice and potatoes in Bangladesh (FAOSTAT, 2021). The top five production districts are Pabna, Faridpur, Rajbari, Kushtia and Rajshahi, in the Midwest regions of the country (BBS, 2018). Production of onions keeps increasing. According to the Department of Agricultural Extension, above 1.2 million agricultural producers have cultivated onions on a record 0.24 million hectares of land in 2020 (Sami, 2020).

Besides domestic production, Bangladesh also imported around 664 thousand tons of onions, primarily from India, but also from China, Pakistan, Egypt, Myanmar and Turkey (BBS, 2018; FAOSTAT, 2021). Onion imports are needed, since Bangladeshi onions are a seasonal product. Onions produced in Bangladesh are harvested between January and April and most actors in the value chain store the onions less than one week or between 1-4 weeks maximum (Kok et al., 2021c).

Onions are a popular product in Bangladesh, mostly used as spices to give aroma, taste and flavor to food. Onions are used in all types of curries and salads being prepared on a daily basis in home kitchens and restaurants (BBS, 2018). The consumption of onions in Bangladesh increased substantially since 1995, namely more than doubling from 12 gram/capita/day to 31 gram/capita/day in 2016. Urban consumers consume slightly more than rural consumers: in 2016 urban consumers consumed 35 gram/capita/day whereas rural consumers consumed 30 gram/capita/day (BBS, 2016a). The average onion consumption varies between regions and the main outlets are in the urban areas of Sylhet, Chattogram and Dhaka (Ahmed and Hoque, 2014).

A typical agricultural value chain consists of agricultural producers (farmers), different types of traders and consumers. Traders involved in the onion value chain in Bangladesh are, from smaller scale to larger scale, faria, bepari, arathdar, wholesalers (local, divisional and regional) and retailers (local and urban) (Sabur et al., 2006).

FLW studies for onion in Bangladesh are scarce but indicate that the loss percentage in the value chain increases with the length of the value chain, varying from 2 – 9% depending on chain length, from the shortest (one intermediary between agricultural producer and consumer) to the longest (four intermediaries between agricultural producer and consumer) value chain (Adnan et al., 2014).

At the production stage a low productivity and low quality is reached, due to poor planting materials, low fertilizer use, weed infestation, low quality seed and no plant protection (Hussain, 2019). Furthermore there is limited extension services available and poor control of moisture content (curing, moisture meters) leading to not meeting humidity requirements (Kok et al., 2021c; Setiya & Muthuselvan, 2018).

In the value chain, problems are related to infrastructure, marketing, storage facilities and capital (Islam et al., 2019). Inadequate transport facilities, poor infrastructure and high logistics costs result in poor linkages (Kok et al., 2021c; Islam et al., 2019; Setiya & Mutuselvan, 2018). Inadequate marketing information and distorted price signals between actors results in limited collaboration and fluctuating prices (Kok et al., 2021c; Islam et al., 2019). Suitable cold storage capacity is often lacking and operating capital is lacking too (Islam et al., 2019; Sabur et al., 2006).

3.4.2. Intervention selection

Scope:
The scope of this case study includes onions produced in Bangladesh that are produced for the domestic market. It includes all actors in the onion value chain, from moment of harvest till and including retail, foodservice and mobile vendors. Data collected from the study conducted by Kok et al. (2021c), in combination with other literature collected in a literature search and a field visit conducted in March 2022 to validate the results.
Flow:
For the second phase we used the overview of the value chain from Kok et al. (2021c). The value chain is visualized in Figure 17.

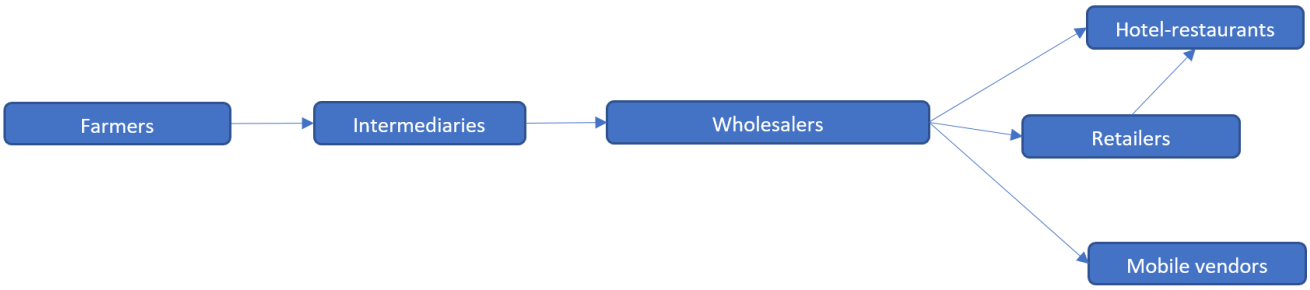

Figure 17 Onion value chain (Source: Kok et al., 2021c).

Focus:
The data collected per actor in Kok et al. (2021c) was used to determine the overview of the hotspots of the value chain (see Table 22). The wholesaler was selected because FLW volumes by far exceed the other actors' FLW volumes, although the wholesaler has a relatively low FLW percentage of 2%, compared to for example the retailers (4%) and mobile vendors (5%).

Table 22 Hotspot selection in the onion value chain.

Name actor	Activities	Destination	i	
			weight kg	weight %
Producers	Harvest and sorting	Domestic consumption, landfill and composting	213	2,4%
Intermediaries	Collection and transport	Landfill, sold at lower price	6.108	0%
Wholesalers	Selling	Landfill, domestic consumption	32.565	2%
Retailers	Sorting and selling	Landfill, domestic consumption	2.088	4%
Mobile vendors	Preparing food	Landfill, domestic consumption	1.473	5%
Hotel-restaurants	Preparing food	Landfill, domestic consumption	62	1%

Causes:
The main problems in the onion value chain at the level of the wholesaler included rot, decrease in quality and physical damage (Kok et al., 2021c; field visits March 2022). Based on the problems and causes in the value chain we visualise the root causes in Figure 18 in a simplified way.

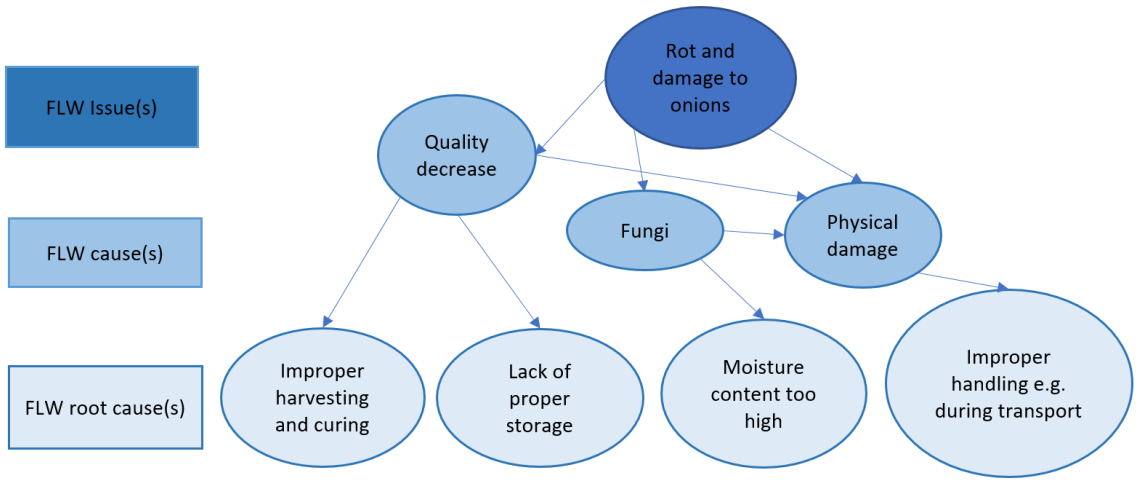

Figure 18 FLW causes and root causes in the onion value chain.

Rots are caused by several factors, including fungus and high moisture contents. Decrease in quality is caused by for example rots and lack of proper storage practices, but also by physical damaged due to bulk transport.

Interventions:
Based on the root causes, a long-list of interventions appeared. These can be grouped and the following generic interventions (see Figure 19):

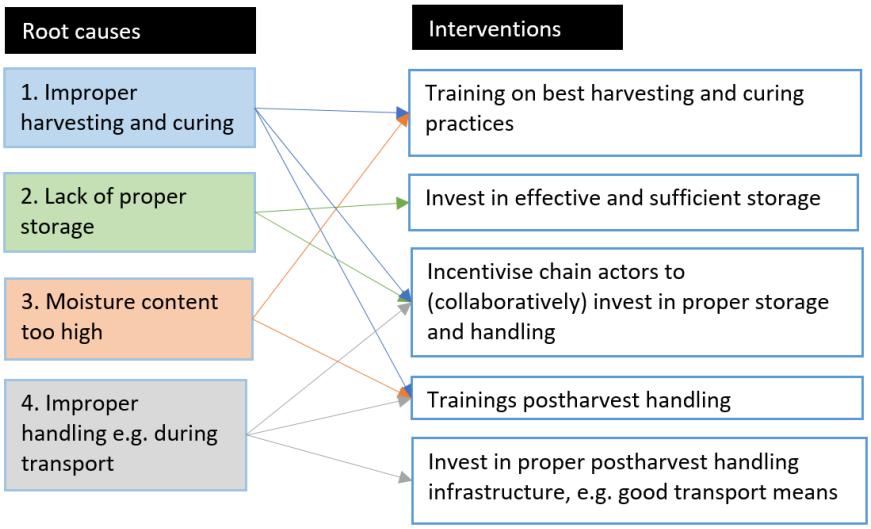

Figure 19 Grouped interventions that address the root causes.

Based on observations during the field visit and interviews conducted by Kok et al. (2021c) and the workshop results (Kok et al., 2023) we suggest to deal with the problem of lack of proper storage. The issues that are experienced by the wholesaler (and likely also the retailers, mobile vendors and hotels-restaurants) have root causes that occur earlier in the supply chain, this intervention is therefore not necessarily aimed at the wholesalers, but at suppliers to the wholesalers (intermediaries) and farmers.

Box 6: Additional findings in the onion supply chain

- Increase of production of onion will not result in meeting the year-round demand
- With current technology for storage not possible to store onion for more than 8 months
- Low production of summer onions (produced in August to September with harvest in October)
- Lean period may be filled up by this summer production
- Summer variety is available BARI onion 3, 4 and 5, but need to disseminate in the field level
- Need to develop modern technology for summer onion production technology

3.4.3. Implementation of interventions in the food system

The intervention 'storage' will not automatically result in the desired outcomes of less FLW due to rot and damages. Therefore it is important to not only select the intervention, but also describe the boundary conditions for successful implementation and the necessary supportive actions to create this conducive environment. The intervention in the tables and figure below is summarized and described as:

[Storage]	Effective and sufficient storage

The supportive actions are:

[Funding]	Acquire access to funds e.g. via loans, government subsidies, self-help-groups and/or donations for investments in better storage facilities, both upgrading available storage capacity and establishing new capacity
[Training]	Training on good handling for storage (e.g. check moisture, temperature and other practices such as curing)
[R&D]	A lack of modern technology for storage can be addressed by investing in Research & Development (R&D) to establish the which storage innovations can most effectively address the experienced storage challenges
[Chain coordination]	Because issues of rot and others occur later in the chain but have root causes earlier in the chain, chain coordination between private sector actors is very relevant. Every

party should be incentivised to ensure a better quality onion reaches the consumer and less is wasted along the supply chain

Secondly the conditions for successful implementation are described. The intervention and supportive actors are labelled and described according to a number of criteria and categories as described in the matrix. This helps to implement the intervention and create the right conditions for success in time.

The expected implementation time can be short, medium or long term.

Table 23 Expected implementation time onion.

Criterion	Short term	Medium term	Long term
Implementation time	<1 year	1-5 year	>5 year
	Training	Funding	Chain coordination
		Storage	
		R&D	

The intervention can be implemented on micro level, meso level or macro level.

Table 24 Intervention level onion.

Criterion	Micro level	Meso level	Macro level
Intervention level	Each particular stage of the food chain, where FLW occurs, from production to consumption, that acts in response (or not) to external factor	The level where internal actors (at the same or another stage) in the food value chain or external stakeholders, impact the FLW on micro level as a result of how different actors are organized together or related in one another, or of the state of infrastructure (e.g. storage) in the context of the relation	FLW is explained by more systematic issues, such as malfunctioning food systems, lack of institutional or policy conditions to facilitate the coordination of actors, to enable investments and adoption of good practices.
	Training	Storage	Chain coordination
		Funding	
		R&D	

Interventions can be classified into three types; hardware, orgware and software.

Table 25 Intervention type onion.

Criterion	Hardware	Orgware	Software
Intervention type	Technology. This includes low and high tech along the chain, measures to control product temperature and storage and packaging interventions.	Organizational, institutional, financial and procedural aspects. This includes understanding power balances in chain and enabling environment, organization of people and building trust.	Skills, knowledge and communication. This includes training, product knowledge and value chain knowledge and communication between actors
	Storage	Funding	Training
			R&D
			Chain coordination

The actors involved depend on who is responsible for the product or intervention. This can be one actor (group) or a collaboration between actor (groups) and can include the PS, GO or NGO.

Table 26 Implementing actor onion.

Criterion	Private Sector (PS)	Governmental Organization (GO)	Non-Governmental Organization (NGO)
Implementing actor	Input suppliers, agricultural producers, intermediaries, processors, wholesalers, retailers, vendors, etcetera.	Local governments, national governments, international governments, other governmental organizations, etcetera.	Facilitators, innovators, financiers, researcher institutes, education, donor organisations, civil society organisations, etc.
Storage	x	x	x
Funding	x	x	x
Training	x	x	x
R&D		x	x
Chain coordination	x	x	

3.4.4. Visualisation of the roadmap

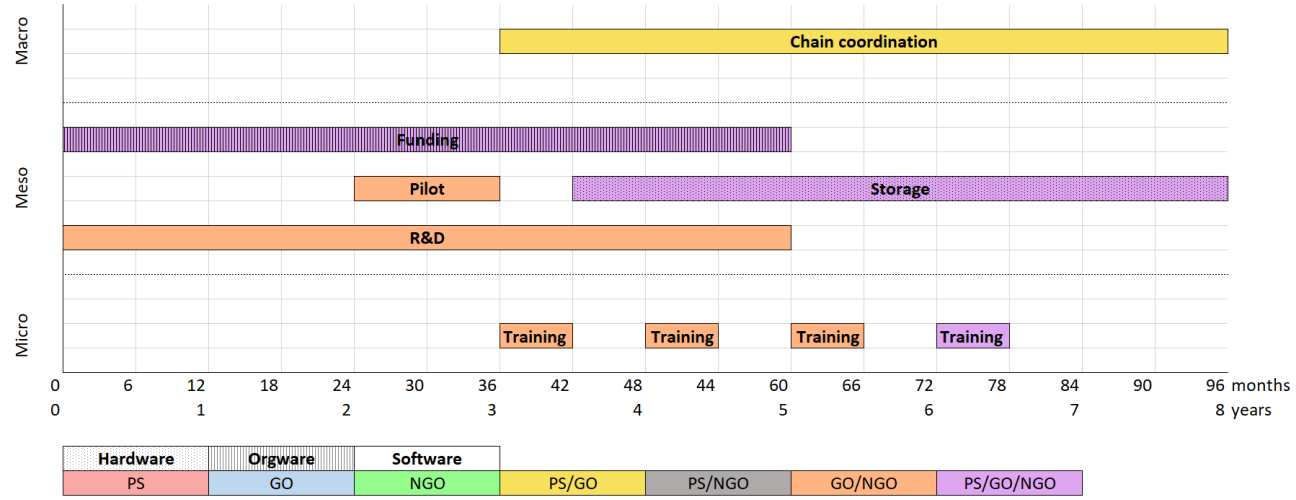

Figure 20 Visualisation roadmap for the improvement of the onion value chain.

The 'scored' intervention and supportive actions are plotted in Figure 20 to create the roadmap. The sequence of the supportive actions is further explained per step below.

1. The roadmap starts with creating available funding for agricultural producers and traders, since it is often a long lasting process. For example subsidies/loans are desirable for actors to be able to invest in available or new storage facilities. In parallel, the storage capacity, location(s) and best technology options should be defined by R&D. For example, storage facilities should be near production hubs to limit the transportation costs and be affordable for the private sector users.

2. After subsidies/loans are almost in place and the storage capacity and location(s) are defined, the storage facilities can be designed and finally be constructed. Storage facilities should be upgraded and established using the funding, include all relevant equipment to make the storage facilities completely operational. For example, the storage facilities should be equipped with moisture meters and registration forms

3. The actors who will use the storage facilities need to receive training on proper handling, curing and using the storage facility. There should be multiple training sessions per storage facility. Trainings can be designed and first executed by government extension services and NGO's, and later after successful knowledge transfer and implementation by private actors themselves.

4. After the storage facility is constructed and the first training is provided, the first onions can and should be stored. In parallel, training sessions should continue to be able to have rounds of feedback and questions and to further guide the user in using the storage facilities in an optimal way. It is

advised to start with a pilot for the first year, so this year can be used to further optimize the storage conditions, to solve problems and fix errors.

5. Because the FLW issues experienced closer to the consumer are caused by issues earlier in the supply chain closer to the producer it is important to invest in chain coordination among private sector actors all along these supportive actions. R&D could for example play a role in identifying best practices for enhancing chain coordination and via which communication means.

To conclude, in 9 years the quality of onion should have increased within the supply chain and less products should be wasted due to rot and other damages. There is sufficient and effective storage, and actors are incentivized to make use of storage.

3.5. Potato

3.5.1. Introduction

Bangladesh is the seventh largest tuber producing country in the world. In 2020 Bangladesh produced around 11 million tons of potatoes (Rahim et al., 2023). Potato is the second largest crop in Bangladesh in terms of production value, second to paddy rice. Bangladesh is the third largest potato producer in Asia (Hengsdijk et al., 2020). Import and export are minimal at 8 kton imports in 2020 and 38kton exports in the same year (FAOTSTAT 2020), making it more or less negligible compared to total production volumes. Potatoes are grown from October till March in Bangladesh. There are typically two types of production varieties: local varieties and high yielding varieties. High yielding cultivar production strongly dependents on imported seed potatoes (Banglapedia, 2021) and these volumes used are growing steeper relative to local seed use (BBS, 2016b; Sabur et al., 2021). Potatoes can be home-stored (not cooled) or in cooled storage facilities; it is estimated that about 1/3 of potatoes move via cold-storage (Hajong et al., 2014). This results in different types of intermediaries (cold store owners, big/small traders, commission agents, wholesalers), but with overlapping functions. Cold storage owners are also involved in inputs provision, particularly of seed, financing, and assist in matching clients and buyers. Potato production partly happens close to Dhaka particularly in Munshigonj, and primarily in the Northern parts of the country (Momotaz et al., 2019; Rahim et al., 2023).

Various authors have described potato value chains in different regions in Bangladesh (K. Akter et al., 2022; T. Akter et al., 2016; Hossain, 2016; Reardon et al., 2012). Hossain (2016) describes six most common supply channels based on a study in Bogra and Munshigongj districts in Bangladesh, the latter close to Dhaka. The described supply channels are 1) assembly traders procuring from producers and selling to wholesalers, then to retailers, 2) assembly traders/wholesalers procure potatoes to put in cold storage and sell to retailers, 3) producers keep potato in cold storage and sells to traders/wholesalers and then it is sold to retailers, 4) exporters procure from producers and export to foreign markets through ocean vessels, 5) processors procure potatoes for processing and then export. K. Akter et al. (2022) confirm the diversity in lengths of the value chains for potato. T. Akter et al. (2016) show that most value is added at producer level (26.35%) followed by wholesalers (17.86%).

It is relevant to distinguish between cold-stored and home stored potatoes. The average home-storage time is 3-4 months, the average cold storage time is 9 months. Cold storage facilities also function as input hubs for seed, financing, and linking to markets (Reardon et al., 2012).

There is relatively limited processing of potatoes in Bangladesh because the quality of the potato is often not sufficient for processing. Due to short growth duration the dry matter content of potatoes is low, reducing processing quality (Hengsdijk et al., 2020).

The potato value chains in Bangladesh face issues, including expensive transportation and storage, inadequate transport, poor market facilities and potato diseases – all of which contribute to FLW along the chain (Hossain, 2016; Masum et al., 2011). Generally the quality of potatoes is poor due to too early harvesting. This is because the potato season potentially interferes with the rice crops that are grown before

and after potato in the typical crop rotation, and because farmers prefer quick cash so they quickly harvest (Hengsdijk et al., 2020). This also results in mismatches between supply and demand, and price hikes. High prices occur in December during the growing season and lowest prices in March during harvesting season (Sabur et al., 2021). In terms of inputs used, potato seed supply is maintained by both formal and informal systems in which the quality of particularly the latter is limited (Rahim et al., 2023). Also, while production volumes grow, potato consumption has remained relatively stable in the last years at around 7 million tons. Therefore, surplus potatoes are wasted or end up as animal feed. Additionally, there are poor market linkages (price signals distorted, producers have little knowledge of markets), with numerous layers of intermediaries between producers and city consumer (Reardon et al., 2012).

Various studies have been conducted to estimate FLW in Bangladesh potato value chains (e.g. K. Akter et al., 2022; Hossain, 2016; Hossain & Miah, 2011; Masum et al., 2011, the latter specifically for postharvest losses due to potato diseases), summarized/aggregated in the table below. K. Akter et al. (2022) have most recently published on postharvest losses along the value chain of potato in Bangladesh. Data were collected through a face-to-face interview schedule from a sample of total 60 farmers, 6 wholesalers, 5 aratdars, 5 retailers, and 14 consumers in Sirajdikhan and Sadar Upazila of Munshiganj district. They uncovered that 6.6% of postharvest losses is occurring at the producers, 5.3% at wholesalers, 1.1% for aratdars and 2.1% for retailers in the study areas.

Hossain & Miah (2011) collected data on postharvest losses of potatoes in six major growing districts, namely Comilla, Jessore, Munshiganj, Bogra, Rajshahi and Thakurgaon, where they collected data from 960 respondents (farmers, cold storage managers, traders and consumers). Average on-farm loss was found to be 5.65%. Home storage loss for a three months storage period was 7.35%, while the average loss in cold storage during nine months was lower at 3.82%. The average losses at trader's level for home- and cold-stored potatoes were 11.95% and 9.61%. Households and out-of-home (restaurant) eateries lost 3.24% of home stored and 4.25% of cold-stored potatoes. The aggregated value chain losses for potatoes that were home-stored were 31.48%, and 25.59% for cold-stored potatoes; both relatively high losses percentages.

Hossain (2016) analysed the potato value chain in selected areas of Bogra and Munshigonj districts. He estimates total on-farm losses at 5.75%, very close to the percentage in Hossain & Miah (2011). Total loss percentage estimates at traders are 12.45% for home-stored and 8.65% for cold-stored potatoes. Loss at households and restaurants is estimated at 5.15% overall losses. Total postharvest losses are estimated at 26.65% for home-stored and 22.45% for cold stored potatoes.

3.5.2. Intervention selection

Scope:
The scope of this roadmap includes potatoes consumed in Bangladesh. It includes all actors in the potato value chain, from moment of harvest till and including retail, foodservice and mobile vendors.

Flow:
Figure 21 provides the food flow diagram of potatoes from the farmer to retailers and out-of-home consumption. Value chain structures in the literature do not distinguish between cold or non-cooled chains, but the activities at each actor can vary, some engage in cool storing the potatoes and some do not.

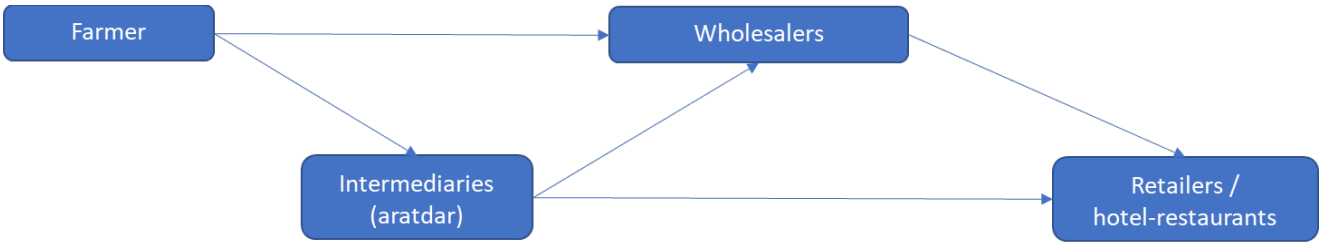

Figure 21 Basic structure of potato value chain in Bangladesh **(based on K. Akter et al., 2022; T. Akter et al., 2016; Hossain, 2016).**

Focus:
Based on the secondary literature it was decided to select the producers as the hotspot of FLW, since the loss percentage is significantly highest at this actor. Regarding activities, storage is also seen as a FLW hotspot, since significant volumes of potatoes are lost during storage (Hossain & Miah, 2011). However, this activity cuts across various value chain actors, but mainly done by producers and wholesalers. The causes of storage losses and losses at producer are therefore elaborated below.

Table 27 Hotspot selection in the potato value chain* (based on average values from *K. Akter et al., 2022; Hossain, 2016; Hossain & Miah, 2011).

Name actor	Activities	Destination	i	
			weight tonnes	weight %
Farmers	-Harvesting -(Storage) -Selling	-Left on the field -Fed to cattle -Unknown	Unknown	6.0%
Aratdar	-Buying -Handling -Transport -Selling (bags remain closed)	Unknown	Unknown	1.3%
Wholesalers	-Buying -Handling -Storage -Transport -Selling	Unknown	Unknown	2.7%
Retailers	-Buying -Selling	Unknown	Unknown	2.8%

Causes:
The causes of FLW at the producer and during storage are explored via the EFFICIENT protocol based on the inputs from literature. FLW in the potato value chain occurred due to spoilage. Causes of FLW include improper harvesting time, rough harvest- and post-harvest handling and oversupply. Root causes of improper harvesting time and rough handling included rain, other conflicting interests, such as need for quick money and interfering with rice production season, and a knowledge gap regarding handling and uptake of new technology. Oversupply was causes due to a mismatch between cold storage facility availability and demand in certain regions, and since the production grown the last couple of years, while the demand stabilized. Figure 22 below visualises main causes and root causes for producer and storage losses of potatoes.

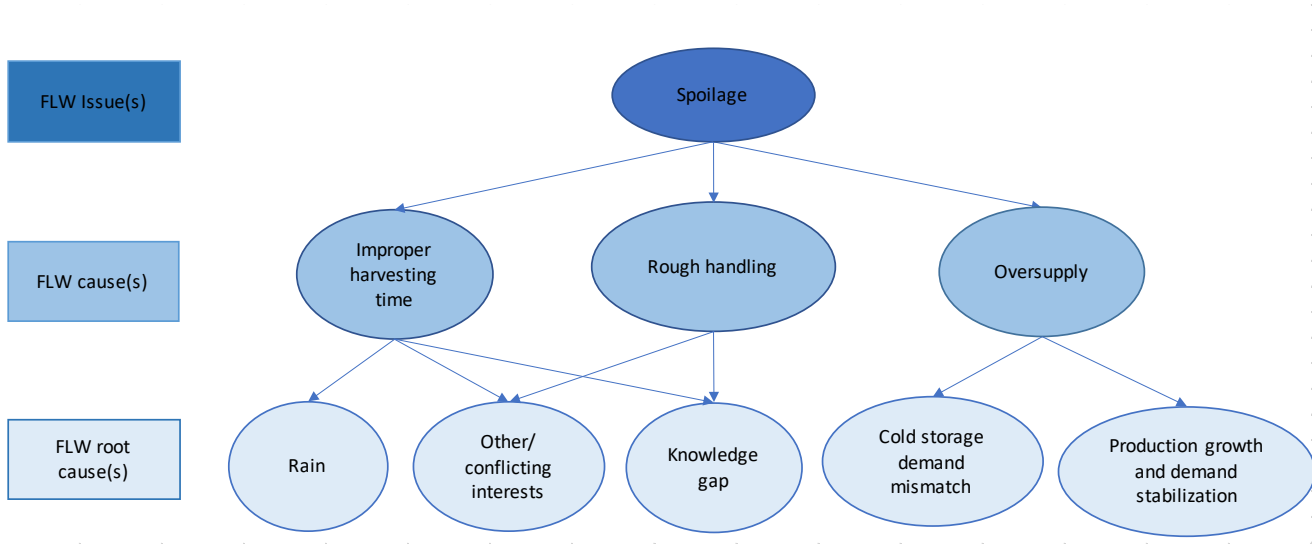

Figure 22 FLW causes and root causes for potato producers and during storage in Bangladesh.

Interventions:

Based on the root causes, a long-list of interventions appeared. These can be grouped and the following generic interventions (see Figure 23).

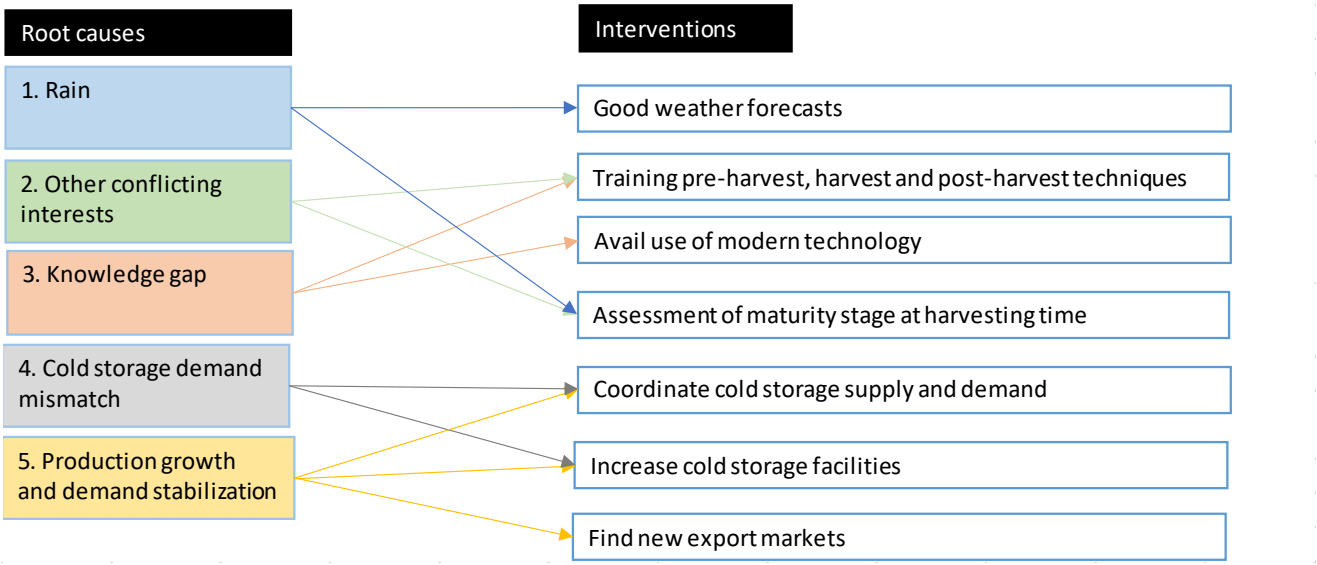

Figure 23 Grouped interventions to address FLW causes in the potato value chain in Bangladesh.

Ideally, we select an intervention that would reduce losses and improve the availability of potatoes at the market, as well as improving marketing opportunities for producers. Of all FLW root causes identified above, improving cold storage facilities and practices would mitigate losses in several chain stages. Therefore, in this example we focus on the intervention 'increase cold storage facilities' (notwithstanding that other causes, in particular in the production stage, are worthwhile to address as well, see box 6).

Box 7: Additional findings in the potato supply chain

Besides the issues focused on in this example, several other issues were highlighted in the workshop with value chain stakeholders.

- Availability, accessibility and quality of seed material
- Production – lack of mechanized equipment (availability and accessibility), inputs (e.g. pesticides, fungicides) modern farming practices in potato farming

3.5.3. Implementation of interventions in the food system

The intervention 'increase cold storage facilities' will not automatically result in the desired result of less FLW during potato storage. Therefore it is important to not only select the intervention, but also describe the boundary conditions for successful implementation and the necessary supportive actions to create this conducive environment. The vision is to reduce FLW while availing more potato on the market at increased quality. This offers additional potential for processing and export.

[Increase cold storage] In addition to better coordinating supply and demand of cold storage which will address part of the need for more cold storage, cold storage capacity can be built to benefit not only potato but potentially also other product value chains;

The supportive actions needed for successful implementation include:

[Cold storage demand] Coordinate cold storage supply and demand across the production and distribution areas to make better use of available cold store facilities and improve the potato quality;

[Modern technologies] Support use of modern technologies that limit damage to the product, such as modern harvesting techniques. Can also be supported by R&D to low-cost modernisation options;

[Processing and export] With an increased quality potato processing and export potential can be (further) explored and anticipated.

[Stabilise input prices] Stabilise fertiliser and pesticide prices e.g. via subsidies or other forms of governing prices so that using the products can become available to producers and limit diseases and growth malfunctions, which will overall avail more potatoes on the market and increase the quality;

[Training] Training on pre-harvest, harvest and postharvest techniques of potato growing and storing, including but not limited to assist with establishing the maturity of potatoes and packing and storing techniques;

The expected implementation time can be short, medium or long term.

Table 28 Expected implementation time potato.

Criterion	Short term	Medium term	Long term
Implementation time	<1 year	1-5 year	>5 year
	Training	Modern technologies	Processing and export
	Stabilise input prices	Cold storage demand	
		Increase cold storage	

The intervention can be implemented on micro level, meso level or macro level.

Table 29 Intervention level potato.

Criterion	Micro level	Meso level	Macro level
Intervention level	Each particular stage of the food chain, where FLW occurs, from production to consumption, that acts in response (or not) to external factor	The level where internal actors (at the same or another stage) in the food value chain or external stakeholders, impact the FLW on micro level as a result of how different actors are organized together or related in one another, or of the state of infrastructure (e.g. storage) in the context of the relation	FLW is explained by more systematic issues, such as malfunctioning food systems, lack of institutional or policy conditions to facilitate the coordination of actors, to enable investments and adoption of good practices.
	Training	Cold storage demand	Stabilise input prices
		Increase cold storage	Modern technologies
			Processing and export

Interventions can be classified into three types; hardware, orgware and software.

Table 30 Intervention type potato.

Criterion	Hardware	Orgware	Software
Intervention type	Technology. This includes low and high tech along the chain, measures to control product temperature and storage and packaging interventions.	Organizational, institutional, financial and procedural aspects. This includes understanding power balances in chain and enabling environment, organization of people and building trust.	Skills, knowledge and communication. This includes training, product knowledge and value chain knowledge and communication between actors
	Increase cold storage	Cold storage demand	Training
	Modern technologies (also orgware)	Stabilise input prices	Processing and export
		Modern technologies (also hardware)	

The actors involved depend on who is responsible for the product or intervention. This can be one actor (group) or a collaboration between actor (groups) and can include the PS, GO or NGO.

Table 31 Implementing actor potato.

Criterion	Private Sector (PS)	Governmental Organization (GO)	Non-Governmental Organization (NGO)
Implementing actor	Input suppliers, agricultural producers, intermediaries, processors, wholesalers, retailers, vendors, etcetera.	Local governments, national governments, international governments, other governmental organizations, etcetera.	Facilitators, innovators, financiers, researcher institutes, education, donor organisations, civil society organisations, etc.
Cold storage demand	x		x
Increase cold storage	x	x	x
Modern technologies	x	x	x
Processing and export	x		x
Stabilise input prices	x	x	
Training	x	x	x

3.5.4. Visualisation of the roadmap

Figure 24 visualises the roadmap to reduce FLW at producer level and during storage for the potato value chain in Bangladesh. Below the steps are described.

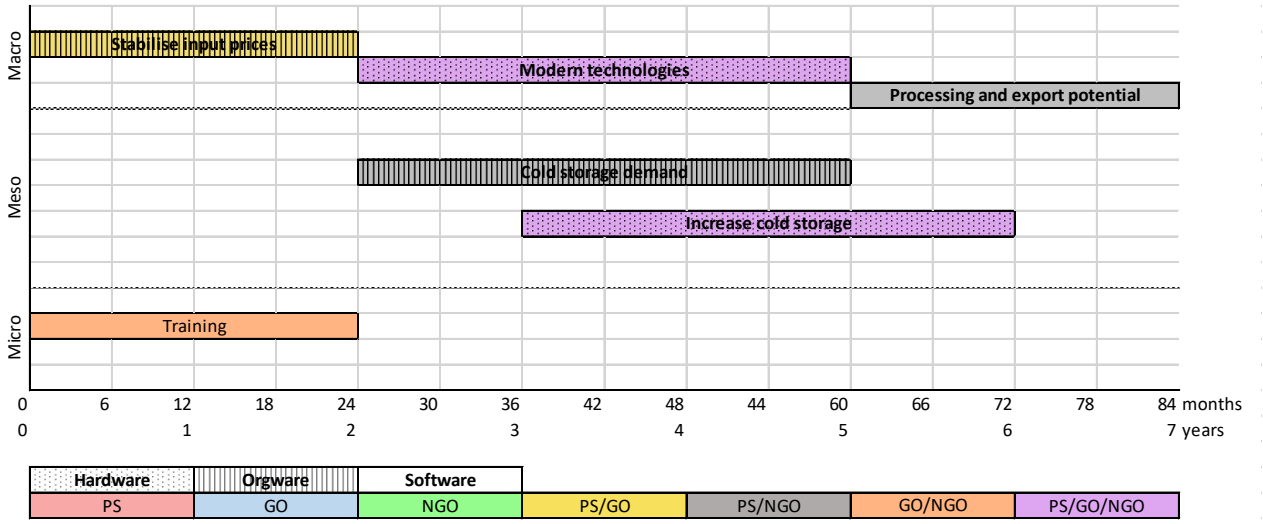

Figure 24 Visualisation roadmap to reduce FLW at producer level and during storage for potatoes in Bangladesh.

The sequence of the supportive actions is further explained per step below.

1. Governments and donor organisations should actively avail training on proper pre-harvest, harvest and postharvest technologies for potatoes to farmers. This training should at least include knowledge sharing on establishing the maturity of potatoes, and handling advice on how to minimise damaging, but also information on potato diseases, how to recognise and minimize them with proper prevention techniques. Particular emphasis should be paid to understanding producer's priorities and objectives during potato season, which is typically in between two rice growing seasons. How can production and potato quality be optimised given this farmer preference?

2. Producers have expressed issues with fluctuating input prices, resulting in irregular use and therefore incomplete/contra productive input use. Both growth of the potatoes and disease control can be enhanced, and stabilising the input prices is an important prerequisite for this. First, reasons for peak pricing should be understood. Prices can be stabilised by mechanisms such as subsidies, or government regulated input supply.

3. Modern technologies, particularly harvesting techniques, can greatly reduce potato damage, resulting in rot and diseases, and improve quality. These techniques are not readily available. Modern harvesting and later other techniques can be accommodated by the government and NGO's, e.g. at subsidised prices.

4. There is cold storage used in potato value chains, but often supply and demand for cold storage are not well organised resulting in some areas have under – and some oversupply of cold storage. There is great potential to make more optimal use of the available cold storage infrastructure by first of all stimulating coordination between various cold store owners and users. NGO's could offer capacity to further establish the areas with supply and demand during which periods of the year and could initiate alignment between the relevant actors.

5. There is currently cold storage lack that can most likely not be fully resolved by better organising available supply and demand. Anticipating also improved quality potatoes and greater availability of potatoes that reach the market, as well as home-stored potato owners that might want to move to cold-storing, there is potential to invest in cold store capacity. First explorations of where there is greatest need can guide the development of pilot studies for how the cold storage should be organised and set up; then it can be scaled to other relevant areas.

To conclude, currently there is limited export of potatoes and processing because of the quality of the potatoes. With the previous interventions the potato quality can be improved and interesting business cases

for exporting or processing of potato can arise. It is worthwhile investigating and stimulating this since this can incentivise further investments in the potato value chain.

3.6. Rice

3.6.1. Introduction

Rice is the staple food for the people in Bangladesh. It delivers almost 2/3 of the total calories and represents half of the total protein intake of each person (BBS, 2015). In 2020 54.9 million tonnes of rice was produced in Bangladesh, which was an increase of rice production of almost 6% since 2016. The increase in rice production was due to a small increase in yield, since the total harvested area was equal in the period 2015-2020 and was estimated at 11.4 million hectare. Based on these numbers it is estimated that the rice yield increased from 4.6 ton/ha in 2015 to 4.8 ton/ha in 2020 (, 2020). Bangladesh is basically self-sufficient in rice production, since only 125 thousand tonnes was imported in 2019, which is only 2% of the total rice consumption in Bangladesh (Reardon et al., 2012; FAOSTAT, 2019a). Aus, Aman and Boro are the main varieties cultivated (BBS, 2015).

The supply chain of rice includes agricultural producers, intermediaries, processors, wholesalers and retailers. Agricultural producers are responsible for harvesting, threshing, winnowing, drying and on-farm storage of paddy. Their harvest- and post-harvest losses, from harvesting till and including storage, are estimated around 10%, of which mechanical threshing, traditional sun drying and on-farm storage are estimated as the FLW hotspots on farm level (Naht et al., 2016; Kumar and Kalita, 2017; Bala et al., 2010). During harvesting, food losses occur due to shattering (due to wind or delayed harvesting), insects, rodents and birds, or unharvested products. During drying, losses occur due to heavy winds, grains consumed by chicken, birds and ducks, contamination, or overheating (Naht et al., 2016; Kumar and Kalita, 2017). For threshing and cleaning losses occur due to improper separation of grains, broken grains by threshing, scattering of grains and improper cleaned grains (Kumar and Kalita, 2017). For storage of rice, the losses were estimated between 1% (for use of hermetic bags) till 6% (for using open storage) by Kumar and Kalita (2017). Overall storage structures are mostly traditional and poor in design (Bala et al., 2010). The grains stored in these structures are susceptible to damage by natural calamities like heavy rainfall, flood, cyclone and attack of microorganisms, insects and rodents, which cause a considerable damage and loss every year (Awal et al., 2018).

Processing the paddy into rice is conducted by millers. They remove the husk and bran layers of paddy to provide cleaned and whole white rice kernels (Kumar and Kalita, 2017). In this process a small percentage of FLW occurs in terms of side streams and broken kernels. There are traditional milling facilities in rural areas and a small number of large, high-tech processing facilities who have a large share in the total market. These millers are well-organized and operate in an association, as do wholesaler who often coordinate with them. However, these millers also purchase directly from agricultural producers via own contracted agents (Kumar and Kalita, 2017; Reardon et al., 2012; Rahman et al., 2020).

Intermediaries can act between agricultural producers and processors, but also between processor and retailer (Raha et al., 2013). Based on the field visit conducted in March 2022, it was observed that FLW is limited after milling, since properly dried and packed rice can be stored for a long time. Only some losses occur due to broken bags or because they get out a small portion per bag to show the quality to their customers. The destination of the lost and wasted rice in Dhaka is unknow, but is probably left on the ground or put in the nearby wastebin.

3.6.2. Intervention selection

Scope:
The scope of this case study includes paddy production in Bangladesh and rice sold to domestic consumers in Bangladesh. It includes all actors in the ricer value chain, from moment of harvest till and including retail, foodservice and mobile vendors (excluding consumers).

Flow:
For the flow phase we made a simplified overview of the rice value chain based on information from Rahman et al. (2020). The value chain is visualized in Figure 25. From farmer till arrival of at the rice mill, the food flow includes paddy. Private intermediaries or miller's agents arrange the bulking and transport to the rice processor. At the rice mill the paddy is processed into rice, whereafter it is distributed to intermediaries or directly to retailers.

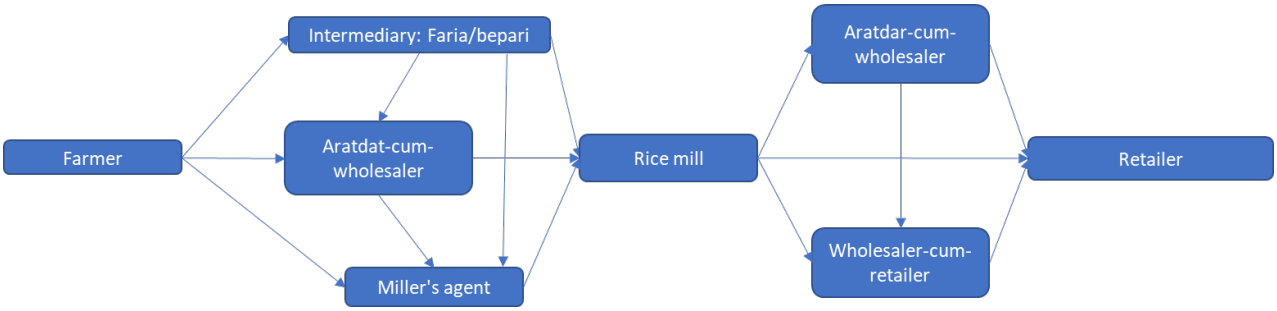

Figure 25 Food flow rice value chain (based on Rahman et al., 2020 and field visit).

Focus:
The FLW analysis is shown in Table 32. Based on high amount of losses at the agricultural producer, it was decided to select the agricultural producers as hotspot of FLW. Due to the large variety of activities an agricultural producer conducts, it was decides to further focus on one specific activity. The highest on-farm losses occur during on-farm storage and this activity is therefore selected as hotspot of food loss.

Table 32 Hotspot selection in the rice value chain.

Name actor	Activities	Destination	i	
			weight tonnes	weight %
Farmer	Harvesting	-At field (scattering), -Animals	Unknown	1.9%
	Carrying	Unknown	Unknown	0.8%
	Threshing	At plant material	Unknown	3.2%
	Cleaning/winnowing	-At field, -Animals	Unknown	0.4%
	Drying	-At field (scattering), -Animals	Unknown	3.1%
	Storage	-Insects and rodents, -Molds	Unknown	6.0%
Intermediaries	Trading	Unknown	Unknown	Unknown
Aratdar-cum-wholesaler	Trading	Unknown	Unknown	Unknown
Miller's agent	Buying	Unknown	Unknown	Unknown
Rice mill	Milling	Unknown	Unknown	1.2%
Aratdar-cum-wholesaler	Storage	Unknown	Unknown	0.2%
wholesaler-cum-retailer	Storage	Unknown	Unknown	0.2%
Retailer	Storage	Unknown	Unknown	0.2%

Causes:
Focussing on on-farm storage losses, two main causes of damaged- or lost rice during storage were found; Attack of micro-organisms, insects and rodents, and natural calamities such as heavy rainfall, floods or cyclones. Attacks occur due to bulk storage (unpacked), open storage structures or because the bags are easily accessible. Natural calamities, such as heavy rainfall or floods occur due to climate change. A simplified overview of the relationship between FLW issues and root causes are visualised in Figure 26.

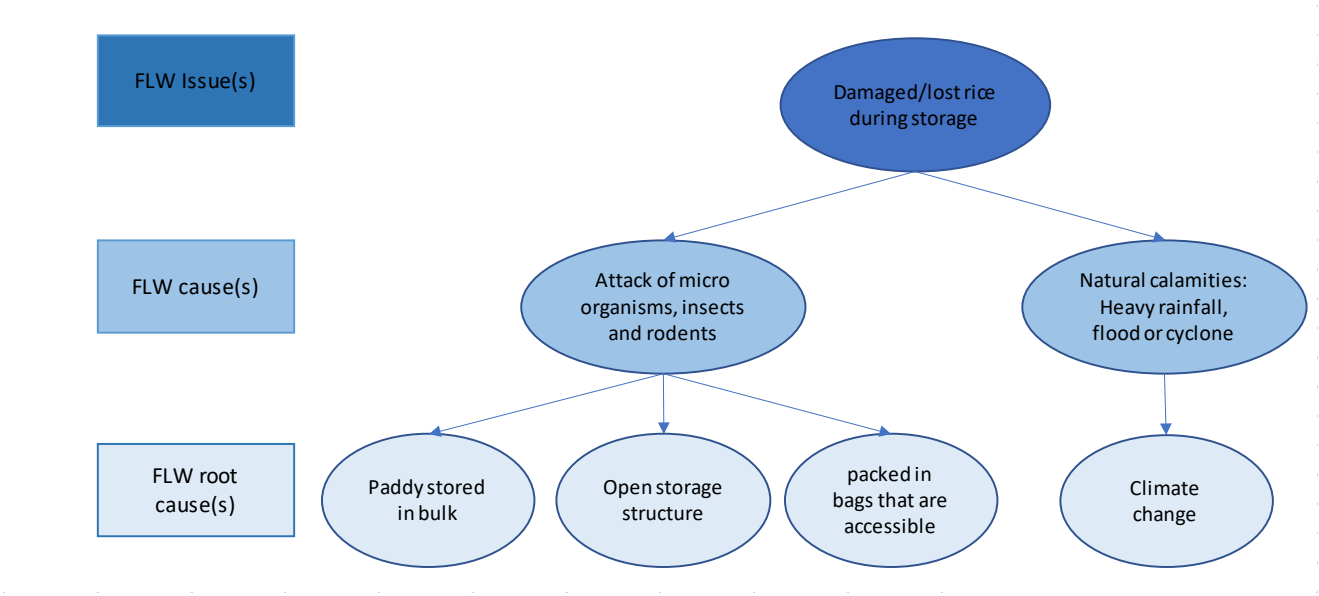

Figure 26 Root causes in the rice value chain during on-farm storage.

Interventions:
Based on the root causes, a long-list of interventions appeared (see Figure 27). Based on the literature review we suggest to select the intervention of 'use of hermetic storage containers, silo's or bags'. Use of hermetic storage containers, silo's or bags will tackle the problem of attack of microorganisms, insects and rodents, which is one of the major causes of FLW.

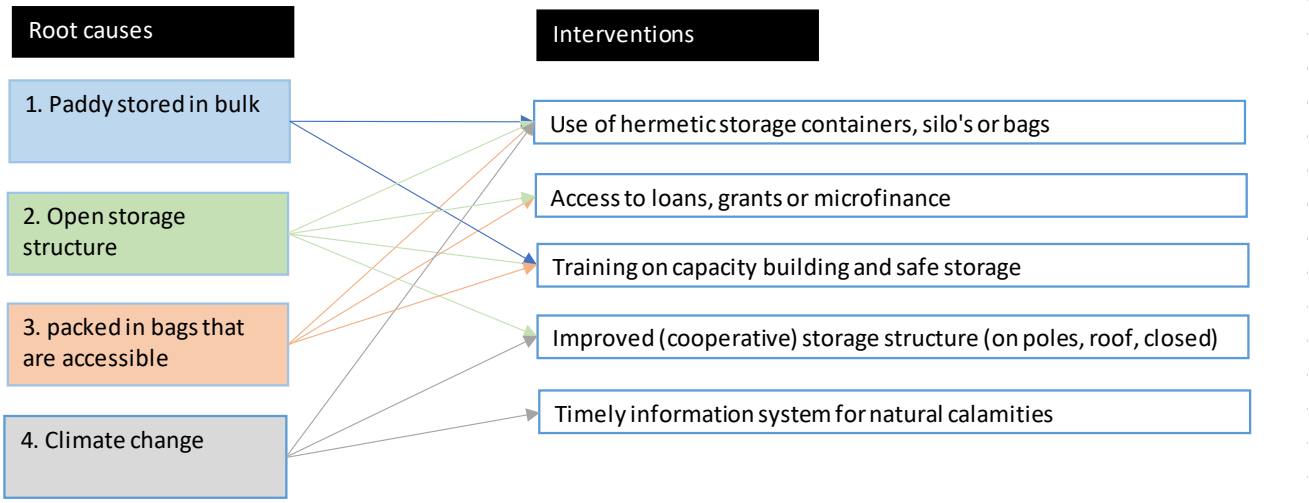

Figure 27 Potential interventions in the on-farm storage activity in the rice value chain.

Box 8: Additional findings in the rice value chain

At farm level, farmers in Bangladesh have a lot to gain in terms of production. The current technical efficiency is low. Issues that arise include small farm size, low level of education, lack of microcredit, lack of training and extension service (Majumder et al., 2016). Furthermore climate change result in production issues. Heavy rains, droughts and strong winds result in pre-harvest problems and reduce the productivity (Naht et al., 2016; Kumar and Kalita, 2017).

It is estimated that there are about 16,000 rice mills across Bangladesh, of which most only are operational a few months during the year (Rahman et al., 2020; Reardon et al., 2012). Milling of paddy containing foreign materials results in a high amount of cracked and broken kernels and can also damage the milling machines (Kumar and Kalita, 2017). In recent years, the potential market power of millers and private traders has also raised concerns (Rahman et al., 2020).

Furthermore, in the workshops the following issues were described by the private sector (Kok et al., 2023):
- Shortage of good quality seed for production.
- Soil structure of rice production areas differ from region to region → tailor made practices/seeds needed - Rice production is hampered due to water scarcity in northern and southern parts of Bangladesh during the summer season.
- Labor shortage and high wages → more people are getting education and other alternative opportunities which attract them more in other jobs than agriculture.
- Modern scientific technology is not introduced and, in some extent, unavailable for the local farmers.

3.6.3. Implementation of interventions in the food system

The goal of improving the rice value chain is to reduce FLW during on-farm storage. Multiple supportive actions are needed to implement the intervention of use of hermetic storage containers, silo's or bags successfully. Currently paddy is mainly stored in open storage structures, in bulk or easy accessible bags.

[Facilities] Use of hermetic storage facilities; containers, silo's or bags.

The proposed supportive actions to reach the goal of the use of hermetic storage facilities include:

[Finance] Acquire access to loans, grants, subsidies or microfinance for investments.
[Pilot] facilities Start a pilot with a group of farmers to show the benefit of investing in hermetic storage for on-farm storage.
[Purchase] Purchase (and distribute) the hermetic storage facilities.
[Training] Training on capacity building, safe storage practices and use of hermetic storage facilities.
[Upscaling] Increase the amount of participants and city regions.

Secondly the intervention and supportive actions are labelled and described according to a number of criteria and categories as described in the matrix. This helps to implement the intervention and create the right conditions for success in time.

The expected implementation time can be short, medium or long term.

Table 33 Expected implementation time rice.

Criterion	Short term	Medium term	Long term
Implementation time	<1 year	1-5 year	>5 year
	Facilities	Finance	
	Pilot	Upscaling	
	Purchase		
	Training		

The intervention can be implemented on micro level, meso level or macro level.

Table 34 Intervention level rice.

Criterion	Micro level	Meso level	Macro level
Intervention level	Each particular stage of the food chain, where FLW occurs, from production to consumption, that acts in response (or not) to external factor	The level where internal actors (at the same or another stage) in the food value chain or external stakeholders, impact the FLW on micro level as a result of how different actors are organized together or related in one another, or of the state of infrastructure (e.g. storage) in the context of the relation	FLW is explained by more systematic issues, such as malfunctioning food systems, lack of institutional or policy conditions to facilitate the coordination of actors, to enable investments and adoption of good practices.
	Facilities	Finance	Upscaling
	Pilot		
	Purchase		
	Training		

Interventions can be classified into three types; hardware, orgware and software.

Table 35 Intervention type rice.

Criterion	Hardware	Orgware	Software
Intervention type	Technology. This includes low and high tech along the chain, measures to control product temperature and storage and packaging interventions.	Organizational, institutional, financial and procedural aspects. This includes understanding power balances in chain and enabling environment, organization of people and building trust.	Skills, knowledge and communication. This includes training, product knowledge and value chain knowledge and communication between actors
	Facilities	Finance	Pilot
		Purchase	Training
		Upscaling	

The actors involved depend on who is responsible for the product or intervention. This can be one actor (group) or a collaboration between actor (groups) and can include the PS, GO or NGO.

Table 36 Implementing actor rice.

Criterion	Private Sector (PS)	Governmental Organization (GO)	Non-Governmental Organization (NGO)
Implementing actor	Input suppliers, agricultural producers, intermediaries, processors, wholesalers, retailers, vendors, etcetera.	Local governments, national governments, international governments, other governmental organizations, etcetera.	Facilitators, innovators, financiers, researcher institutes, education, donor organisations, civil society organisations, etc.
Facilities	x		
Finance		x	x
Pilot	x		x
Purchase	x		x
Training		x	x
Upscaling		x	x

3.6.4. Visualisation of the roadmap

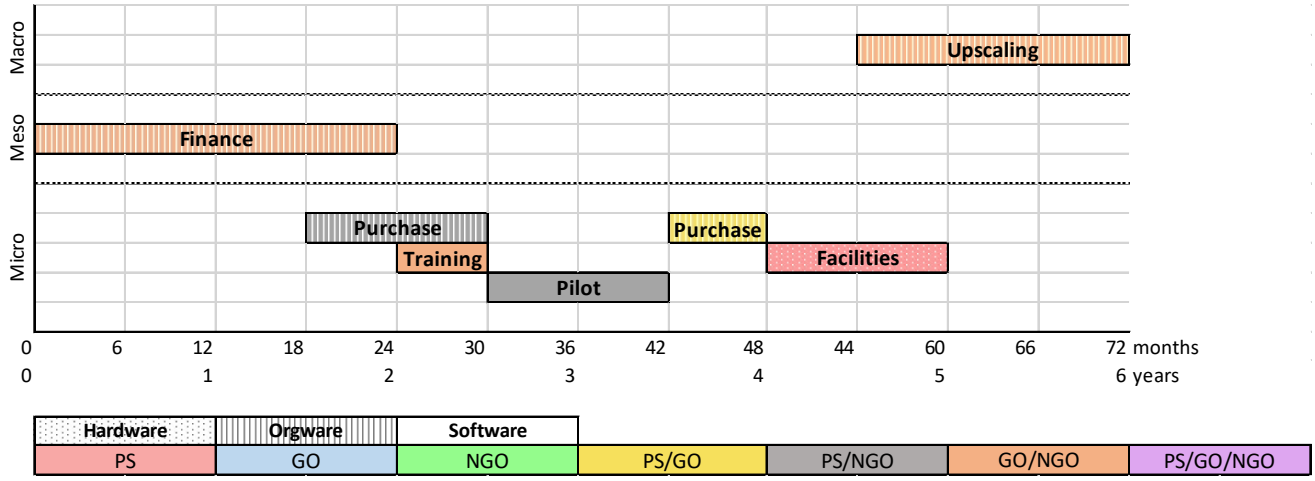

Figure 28 Visualisation roadmap improving the rice value chain.

The intervention and supportive actions are plotted in Figure 28 to create a visualisation of the roadmap. The sequence of the supportive actions is further explained per step below.

1. The roadmap starts with acquiring access to loans, grants, subsidies or microfinance for investments. Many agricultural producers, active in paddy production, do struggle to invest in improved, durable hermetic storage facilities. Therefore it is important that the government provides access to loans or grants, or donor organizations get interest in financing (a part of) the facilities. Also microfinancing can be a possibility. It is suggested to properly investigate the best possible method. Also money is needed to start a pilot with the use of the hermetic storage facilities.

2. When the finance for a pilot is found, the purchase of suitable hermetic storage facilities can take place. These are needed to be able to start a pilot and showcase the use of the hermetic storage facilities. These hermetic storage facilities can be containers, silos or bags, depending what is most practical, and works best in terms of food loss reduction in their situation, or a combination of all to test which type works best in the local context.

3. Training on capacity building, safe storage practices and use of hermetic storage facilities should take place to learn farmers to properly use the new facilities, but also to learn safe storage practices, such as storage management and type of storage rooms. They can also be included in the design of the pilot.

4. The next step is to start with the pilot. A baseline measurement should be conducted to measure the current paddy losses during on-farm storage at the participants' farms. This is needed to monitor the impact when the new hermetic storage facilities are used, compared to the current on-farm storage practices.

5. After the pilot and the 'prove' of food loss reduction during on-farm storage, the farmers should be able to buy the hermetic storage facilities themselves, with help of a loan or subsidy. Own investment of farmers increase the uptake of an intervention, as the changes increase to use the newly purchased facilities compared to when you receive something for free. In case a donor organization was found to distribute the hermetic storage facilities, larger quantities can be purchased and distributed to the farmers.

6. After the purchase, farmers can start to use the hermetic storage facilities, such as containers, silo's or bags. The farmers who participated in the pilot now received the training and invested in the facilities themselves. This increases the uptake of the hermetic containers, silo's or bags.

7. When farmers indeed using the newly purchased intervention, it is time to increase the number of participants and regions to start reducing the on-farm paddy losses during on-farm storage at all actors in Bangladesh.

To conclude, after 6 years we have reduced the on-farm paddy losses in Bangladesh and this will finally result in increased availability of paddy for the consumers in Bangladesh and an increased income for the farmers.

4. Discussion and conclusion

This document presents a roadmap approach for how to create impact in food value chains to effectively reduce FLW. We thereby answer the question; 'How to identify and implement interventions for reducing Food Loss and Waste in Dhaka's food system?' As the case chapters describe, this lies in effective FLW hotspot identification, understanding the perceived issues, its causes and root causes, and identifying a suitable intervention. To enhance the success of FLW reducing interventions, these should be accompanied by supportive actions ranging from addressing hardware, orgware, and software, including various types of actors such as the private sector and government, and include short – and longer term actions and visions.

In this report we focus on FLW reduction in Bangladesh and we use the EFFICIENT protocol (Kok et al., 2021a) for intervention selection in six different food value chains: beef, chicken, fish, onion, potato and rice. For implementation of interventions in the food system, we elaborate on intervention criteria as presented by Soethoudt et al. (2021). Together, we describe this approach as the roadmap approach. Reducing FLW can increase food quality and quantity for consumers, increase food value chain actor's incomes, and enhance efficient resource use of for example land and water, thereby addressing the environmental impact of FLW.

The roadmap for the six different cases are not blueprints and remain very context dependent. In each case one intervention is selected, but selecting another relevant intervention would have resulted in a different roadmap. This document provides the framework that is needed to design your own FLW reducing roadmap. The cases give informed examples of what a roadmap can look like, but various other options are possible. We advise to use this document as a grounded and informed inspiration source to implement FLW reducing intervention successfully.

This approach can be used by value chain stakeholders (including policymakers, NGO's and (other) financiers) to develop their own strategies for improving food value chains at the local, regional, or national level, as well as by private sector actors who wish to strategically explore how and where to intervene to reduce FLW. It can also be used by researchers and other knowledge experts to build on and add to for purposes of enhancing knowledge and expertise on the topic of FLW reduction interventions for the specific food value chains that are elaborated, and new food value chains. Successful implementation of the roadmap is highly dependent on commitment from all relevant food value - and wider food system actors.

The aim is to showcase making links between issues, causes and interventions for reducing FLW, including supportive actions required for successful intervention implementation. Although interventions are sometimes focused on a specific actor or locations, such as farms or wholesale markets, these cases show that there is no common thread in the different food value chains when selecting FLW reducing interventions. With regards to selecting the hotspot for FLW, some cases (e.g. onion) show that it can be a choice between selecting the actor with the highest FLW volumes (often wholesalers), or the actor with the highest FLW percentages. There is no right or wrong and both options lead to identification of FLW hotspots.

While this roadmap approach is specifically tailored to investigate FLW reduction options, the broader line of thinking from identifying food value chain issues, causes, and interventions could potentially also be relevant for addressing other food value chain inefficiencies besides FLW. The chapters present text boxes with addition findings of the food value chain studies that were identified in the roadmap process; these additional findings could be starting points for exploring other value chain inefficiencies besides FLW. The EFFICIENT protocol is specifically tailored to identify FLW hotspots, causes, and interventions, so an alternative approach should be applied to assist with this part of the roadmap approach when applied to other types of value chain inefficiencies. The relevance of the roadmap approach to explore these other issues, such as for example greenhouse gas emissions, food safety hazards, water use or production issues, have however not yet been explored, but are worthwhile to investigate.

The roadmap approach as is presented in this document also has limitations. Most notably, the case chapters have not considered the calculation of the investment space before selecting an intervention. Within the EFFICIENT protocol, determining the investment space is one of the most important activities to execute

before selecting an intervention. In practice, understanding the investment space will greatly influence the type of intervention options that become relevant, and economic feasibility is a very important intervention selection criteria. Calculating the investment space before selecting an invention becomes essential in more defined FLW cases with greater detail about availability of funds, and was therefore not addressed in this roadmap approach which aims to emphasize more the structured approach on how to identify and implement FLW reducing interventions. It is highly recommended to take the economic feasibility into account before starting to implement an intervention.

Additionally, it can be worthwhile to investigate further which combination(s) of interventions and supportive actions could best be identified, or how the selected intervention and supportive actions are expected to address other root causes, for a better understanding of optimal synergies between interventions.

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Annex 1: Food loss and waste definitions

Table 37 Food loss and waste definitions, adapted from FAO 2018.

	Grains	Fruits & Vegetables	Milk & Meat	Fish
Pre-harvest loss	Losses that occur before the beginning of the harvesting process and that may be due to attacks by insects, mites, rodents, birds, weeds, or diseases afflicting and damaging crops.	Damage due to disease, insect, pest and biological or climatic reasons in any of the crop and commodity which is not fit for human consumption at the time of harvest is considered as preharvest loss.		The post-harvest refers to the period of time when a fish is separated from its growth medium. This includes the time a fish enters a net, is caught on a hook or in a trap.
Harvest loss	These occur during the harvesting process and may be due to shattering, mechanical damage and shedding of the grain from the ears to the ground	Quantity of produce lost during harvesting operations.		Harvest loss occurs mainly due to discard in good condition juveniles and low value fish. Harvest loss is the loss at the time of catch occurring at ponds/landing centres/ boats/fishing crafts/trawlers etc.
Post-harvest loss	Any losses occurring after the separation of the product from the site of immediate growth (harvest) to the moment it reaches the consumer	Postharvest loss can be defined as reduction in available quantity of produce which becomes unfit for human consumption i.e. the degradation in quantity of a food production from harvest to consumption		Post harvest losses occur immediately after the catch from ponds/landing centres/ boats/fishing crafts/trawlers etc. to various marketing channels till reaches to the consumer level due to improper handling, insufficient icing, insufficient containers used for transportation of fish, delay in transportation, physical damage and chemical changes leading spoilage making it unavailable and unacceptable for human consumption.
Transportation loss	For transportation, stock movement and other losses caused by spilling, losses are normally estimated as the difference in weight between the quantity loaded and the quantity unloaded. For long transport operations, grain samples can be taken at the loading stage and at the unloading stage, and then examined for changes in moisture content and qualitative damage during transit	Pilferage, spillage and damage during transportation of produce from one place to another are to be considered as transportation loss.	Pilferage, spillage and damage during transportation of produce from one place to another are to be considered as transportation loss.	Pilferage, spillage and damage during transportation of produce from one place to another are to be considered as transportation loss.
Storage loss	For losses arising during storage – due to insects and molds – at farm level, the weight loss must always be related to the quantity in store at the time of the assessment	The amount of produce which becomes unfit for human consumption due to rotting, infestation of insect and pest etc. during storage is to be considered as storage loss.	Quantity spoiled during storage.	Rotten or damaged due to any of the reasons during storage is to be considered as storage loss.
Packaging, handling and distribution	Improper packaging of produce may facilitate pest infestation or the appearance of moulds and fungi leading to grain damage, weight loss, or rejection because of			

	spoilage, especially if the produce is stored or transported for long periods. Improper handling may lead to grain damage and spillage, resulting in weight as well as quality losses. These losses may arise at different phases, for example during transport from farm to storage and from storage to market, at different points of marketing channels, and at the wholesale and retail levels.			
Processing	Food grains are subjected to different types of processing before reaching the market and being finally consumed. For instance, paddy rice is generally de-husked or dehulled to obtain brown rice, manually by hand pounding or, more commonly, by machines such as rice hullers. When processing paddy, additional operations such as precleaning, de-stoning, parboiling (pre-milling treatment), polishing and glazing may also be required. During these operations, losses are essentially due to damage to the grain, certain grain kernels resulting broken, and to spillage. A key efficiency parameter for rice milling is the recovery in terms of whole grain and the percentage of			

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