Primary data collection using the EFFICIENT protocol

Case studies for optimizing food value chains

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Institute: Wageningen Food & Biobased Research

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Abbreviations

CA-storage	Controlled Atmosphere storage
EFFICIENT	EFFectIve food Chain IntervENTions
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FLW	Food Loss and Waste
GDP	Gross Domestic Product
GHG	GreenHouse Gas
NGO	Non-Governmental Organisation
SAU	Sher-e-Bangla Agricultural University
SDB	Sustainable Development Goals
SPA	Strategic Partnership Arrangement
UN	United Nations
USA	United States of America
USD	United States Dollar
VND	Vietnamese Dong
WFBR	Wageningen Food & Biobased Research
WUR	Wageningen University & Research

Contents

1 Introduction

Worldwide one-third of the food is lost or wasted, and food loss and waste (FLW) is a threat to food security and a significant contributor to greenhouse gas (GHG) emissions (FAO, 2011; FAO, 2013). Therefore, the UN SDG Target 12.3 sets the aim to reduce food losses in production and supply chains and to halve food waste per capita by 2030 against the reference year 2015 (UN, 2015). The formulation of this goal has accelerated the development of numerous quantification methodologies to quantify FLW and monitor progress towards SDG Target 12.3. Moreover, several of these quantification methodologies allow users – government, NGO, and private sector alike – to identify loss hotspots, and – ideally – take action to address these (GIZ, 2015; Tostivint et al., 2016; WRI, 2016; Delgado et al., 2017; Fabi & English, 2019; UNEP, 2021). This proliferation of FLW quantification methodologies is a reflection of increased awareness of the issue. However, as each of the existing methodologies are developed for a specific aim and audience, it still may be hard for food chain actors to find a quantification methodology that fully meets their needs.

In order to stimulate action with respect to FLW, Wageningen Food & Biobased Research (WFBR) developed as part of the project "*Consortium for Innovation in Post-Harvest Loss and Food Waste Reduction – Innovation Platform to Gain Sustainable Efficiencies in the Global Food System*" (US Foundation for Food and Agriculture Research award number Grant ID: DFs-18-0000000008 and the Rockefeller Foundation award number 2018 FOD 004) the EFFICIENT (EFFectIve food Chain IntervENTions) protocol. This newly developed EFFICIENT protocol is based on design principles regarding

- usability: a lean protocol that can be implemented with minimal effort for a useful result,
- insightfulness: the protocol should help users better understand (their part of) the food system,
- pragmatism: drawing on existing information when available, and
- orientation on action: quick identification of hotspots and appropriate interventions.

More so than other quantification methodologies, the EFFICIENT protocol emphasizes a sequence of interconnected steps that are strongly aligned towards the end result of a FLW-reducing intervention. Progressing through these steps allows a user to further elucidate and define their position in the food system and the actual problem(s) they are facing, and to identify FLW hotspots based on available (or new) information through a structured process. Depending on the scope defined, the protocol provides a common denominator in monitoring progress on FLW reduction and provides food chain actors an accessible and solution-oriented tool to monitor their performance over time, identify (remaining) bottlenecks, and evaluate the efficacy of various interventions (Kok et al., 2021a).

The protocol workflow is sequential and all steps converge towards recommendations for targeted interventions. However, users can start from any phase in the workflow and work towards the intervention recommendations, or iterate back to earlier steps to refine the results of the cause analysis and intervention recommendations, depending on the user's needs, prior knowledge and available data. In Figure 1 we show the six phases of the EFFICIENT protocol.

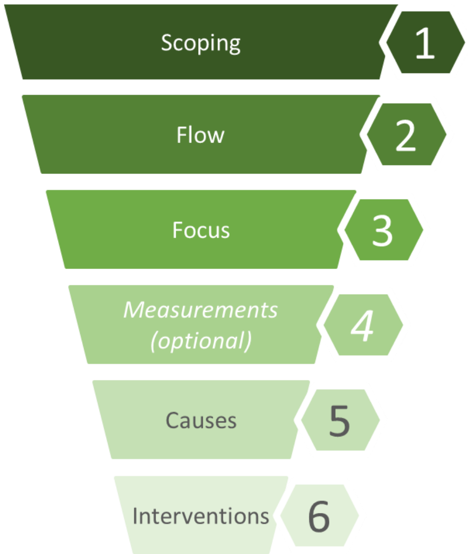

Figure 1 ***The EFFICIENT protocol (source: Kok et al., 2021a)***

Phase 1 (Scoping) sets the boundaries of the study. In Phase 2 (Flow) and Phase 4 (Measurements) data is collected and interpreted on activities, input- and sales volumes, FLW volumes and -percentages, and destinations of food flows. Phase 3 (Focus) identifies the hotspot(s) for FLW in the scoped supply chain. Based on the hotspots, insights in causes of FLW, and the structured process towards intervention selection and implementation considerations are included in Phase 5 (Causes) and Phase 6 (interventions). The EFFICIENT protocol is an intervention-oriented methodology with careful and logical alignment between data collection, targeting FLW hotspots and taking action to reduce FLW, is easy to implement for the purpose of a variety of stakeholders, and is time and resource efficient to support action.

1.1 Reporting the collected new primary data

The EFFICIENT protocol is a step-by-step approach to guide the user through minimum effort necessary to get to action reducing FLW and therefore suits users best that are requiring a pragmatic, flexible, intervention-oriented approach to quantifying and mitigating FLW in a targeted and systematic approach. The world is fare behind meeting the SDG target 12.3 and urgent actions are needed to meet this target. The EFFICIENT protocol wants to support the users to efficiently collect, structure, and interpret relevant, reliable, and actionable information that supports action in the form of implementation of FLW reducing interventions and delivering to SDG 12.3 and many other related SDG’s. The protocol is action oriented and wants to avoid that unnecessary time and therefore money is spend on gathering the most accurate data possible.

In this report we describe seven case studies where (parts of) the EFFICIENT protocol is being used as part of the research. In the description of these case studies the focus is on the collected primary data because the premise of the project “*Consortium for Innovation in Post-Harvest Loss and Food Waste Reduction – Innovation Platform to Gain Sustainable Efficiencies in the Global Food System*” was to collect new primary data across supply chains. The EFFICIENT protocol tackles this challenge and leads to new primary data as shown in this report.

2 Case studies

This chapter describes seven case studies to show how new primary data was obtained using the EFFICIENT protocol (Table 1). It is presented how the EFFICIENT protocol can be used to collect new primary data across a variety of supply chains. It validates the use of the protocol for a different variety of stakeholders, as all studies have a different aim and scope, use a different data collection methodology or use a different definition of FLW. For every case study, the background of the project and the scope of the study (Phase 1 of the EFFICIENT protocol) are explained. Thereafter the food flow, data collection methodology and the new primary data is provided. This information is collected in Phase 2 (Flow) of the EFFICIENT protocol, sometimes in combinations with additional measurements (Phase 4).

Table 1 ***Case studies***

Country	Value Chain
Bangladesh	Onion
Bangladesh	Beef
Bangladesh	Mango
Nigeria	Rice
Vietnam	Dragon Fruit
Honduras	Lettuce
Mozambique	Cassava

2.1 Bangladesh; the onion value chain

Within the project 'Support for Modelling, Planning and Improving Dhaka's Food System[1]' institutes of Wageningen University & Research (WUR) have integrated their expertise on diverse aspects of the food system in Dhaka that include food system governance, consumer behavior, food economy, agricultural production, logistics, spatial planning, and impact assessments of interventions. In a joint effort with the Food and Agricultural Organization of the UN (FAO) as lead implementor, and local stakeholders, WUR contributes to finding integrated solutions to address Dhaka's present and future food needs.
As part of the project three value chain analyses were performed with the aim to develop a strategic action agenda for the four city corporations in Dhaka. The goal is to decrease FLW and increase food availability. The selected products included onion, beef and mango.

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. Generally for vegetable supply chains in Bangladesh, post-harvest losses and shrinkage are considered main weaknesses and losses are estimated to be higher than 5%. Food Loss and Waste (FLW) studies for onion in Bangladesh are scarce but indicate that the loss percentage increases with the amount of actors in the supply chain. An opportunity for the onion supply chain in Bangladesh
is to work towards reducing food losses at various links of the chain.
As part of the work, and due to the scarcity of data, Wageningen Food & Biobased Research (WFBR) focused on collecting new primary data and performing a value chain analysis. For collecting the data, and identifying the leverage points for reducing food losses for onions in order to improve the performance of the onion value chain, the EFFICIENT Protocol light version was used.
Below findings are further elaborated by Kok et al. (2021b).

[1] https://www.wur.nl/en/Research-Results/Research-Institutes/centre-for-development-innovation/show-cdi/Improving-Dhakas-food-system.htm

2.1.1 Scope (phase 1)

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 supply chain, from moment of harvest till and including retail, foodservice and mobile vendors. The geographical regions in scope included the main production areas (Kushtia, Pabna, Faridpur, Rajshahi and Rajbari districts) and the four Dhaka city corporations (Dhaka North, Dhaka South, Narayanganj and Gazipur). FLW was determined as both quantitative losses as well as economic losses, as it includes all sales/donations to other destinations than the intended one.

2.1.2 Food flow (phase 2)

Based on a literature search and consulting experts from FAO Bangladesh, the actors in the supply chain were identified and grouped into six actors: Agricultural producers, intermediaries, wholesalers, retailers, institutional users and mobile vendors. Since the flow of the produce between actors was not completely clear based on the literature search and consulting experts, it was decided to include this part in the methodology of data collection as well, including the transport modalities that were being used between the actors. A roughly drawn food supply chain of onions produced in Bangladesh reaching the consumers located in Dhaka is shown in Figure 2.

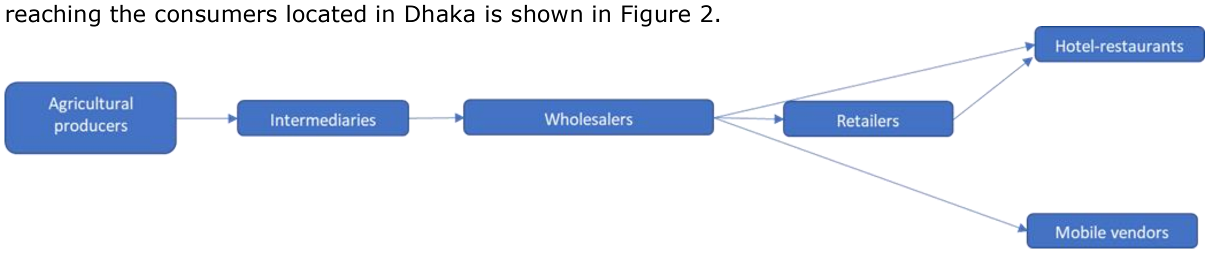

Figure 2 ***Food flow of the onion supply chain***

2.1.3 Data collection

Primary data about FLW was collected per actor by conducting 310 face-to-face executive interviews in the production areas and four city corporations of Dhaka. This sample size was selected in collaboration with FAO Bangladesh, and due to the inclusion of six type of actors and the differences in practices within every type of actor. Interviews were executed by Sher-e-Bangla Agricultural University (SAU) by field visiting study areas. In total 60 agricultural producers were interviewed, 50 intermediaries, 20 wholesalers, 60 retailers, 60 institutional users and 60 mobile vendors. The results from the interviews were analyzed and shared for discussion, feedback and validation in two sessions. One session took place with the FAO Bangladesh team members and one session took place with four city corporations experts from FAO Bangladesh.

2.1.4 Results

Per actor information was collected on the activities, production or purchase amounts, FLW percentage, destinations of FLW, causes of FLW, purchase and selling values, and opportunities and bottlenecks in the food value chain. A summary of the activities, destinations of unsold food, average FLW volumes per actor, FLW percentage, and lost money is visualized in Table 2. The highest percentages of FLW can be found at the mobile vendors and retailers. However, due to the large volumes of onions traded by the wholesalers, the FLW volume is highest at the wholesale level, which also results in the highest economic losses. Dependent on soft-criteria, like social and political preferences, leadership and sponsorships, the hotspots can be identified for further action.

Table 2 Summary of the primary data collection in the onion value chain

Stakeholders	Name actor	Activities	Destination	FLW volume		Potential annual benefit
				kg	%	Taka/year
Stakeholder 1	Producers	Harvest and Sorting	Domestic consumption, landfill and composting	213	2.4%	0.01
Stakeholder 2	Intermediaries	Collection and transport	Landfill, sold at lower price	6,108	0.1%	0.24
Stakeholder 3	Wholesalers	Selling	Landfill, domestic consumption	32,565	2.0%	1.07
Stakeholder 4	Retailers	Sorting and selling	Landfill, domestic consumption	2,088	4.1%	0.06
Stakeholder 5	Mobile vendor	Preparing food	Landfill, domestic consumption	1,473	4.6%	0.05
Stakeholder 6	Institutional users	Preparing food	Landfill, domestic consumption	62	1.0%	0.00

2.1.5 Conclusion

New primary data on FLW were collected for the onion value chain in Bangladesh. Data collection was based on FLW estimates via 310 individual interviews, which were validated in two different sessions with experts. Overall the FLW percentages were highest at the end of the supply chain at the retailers and mobile vendors. The lowest FLW percentages were found at the intermediaries and institutional users. Due to the large amount of traded onions per actor at wholesale level, the wholesalers had the highest volume of economic losses with on average 32,565 kg of onion per year. Destinations of these onions included landfill and domestic consumption (includes sales at very low prices to poor actors and consumers).

2.2 Bangladesh; the beef value chain

In Bangladesh, 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. Of all livestock products, particularly beef consumption is deeply linked to national, cultural and religious traditions, and it is a national development priority to further enhance the functioning of the sector. In 2019 there were 2.7 million heads of cattle (FAO, 2020a), supporting an estimated 8.7 million rural small-scale agricultural producers and 1.9 million medium and large-scale agricultural producers. The main reported reasons for FLW were mortality, for live cattle, and bad work accuracy during slaughtering, low quality meat, and lack of customers for beef.
As part of the work, and due to the scarcity of data, Wageningen Food & Biobased Research (WFBR) focused on collecting new primary data and performing a value chain analysis. For collecting the data, and identifying the leverage points for reducing food losses for beef in order to improve the performance of the beef value chain, the EFFICIENT Protocol light version was used.
Below findings are further elaborated by Kok et al. (2021c).

2.2.1 Scope (phase 1)

The scope of this case study includes beef produced in Bangladesh for the domestic market. The interviewees included agricultural producers, intermediaries and truck drivers in Dhaka, Narayanganj, Pabna, Sirajgonj and Faridpur districts, and wholesalers, retailers, mobile vendors, institutional users and abattoirs located in Dhaka North, Dhaka South, Narayanganj and Gazipur city corporation area.

2.2.2 Food flow (phase 2)

Based on a literature search and consulting experts from FAO Bangladesh, the actors in the supply chain were identified and grouped into seven actors: Agricultural producers, intermediaries, wholesalers, retailers, institutional users, mobile vendors and butchers/abattoir personnel. Since the flow of the produce between actors was not completely clear based on the literature search and consulting experts, it was decided to include this part in the methodology of data collection as well, including the transport modalities that were being used between the actors. A general overview of the beef supply chain in Bangladesh is presented in Figure 3.

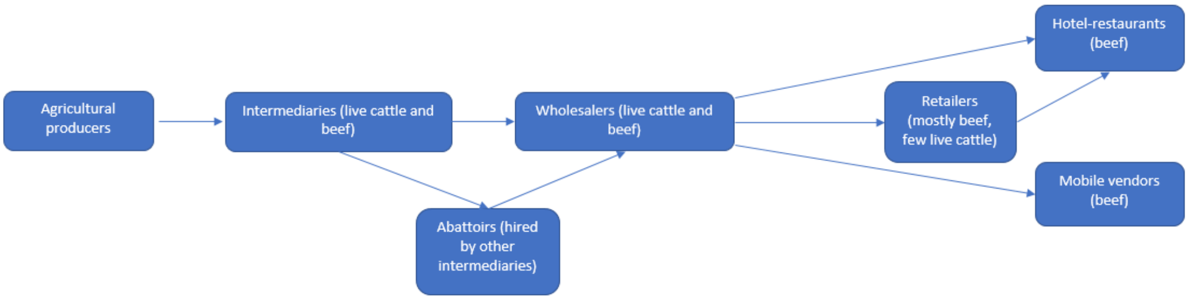

Figure 3 Food flow of the beef supply chain

2.2.3 Data collection

Primary data about FLW was collected from various actors by conducting 319 face-to-face interviews in the production areas and four city corporations of Dhaka. This sample size was selected in collaboration with FAO Bangladesh, and due to the inclusion of seven type of actors and the differences in practices within every type of actor. Interviews were executed by Sher-e-Bangla Agricultural University (SAU) by field visiting study areas. In total 60 agricultural producers were interviewed, 50 intermediaries, 20 wholesalers, 60 retailers, 60 institutional users, 60 mobile vendors and 9 abattoirs. The results from the interviews were analyzed and shared for discussion, feedback and validation in two sessions. One session took place with the FAO Bangladesh team members and one session took place with four city corporations experts from FAO Bangladesh.

2.2.4 Results

Information was collected on the activities, production or purchase amounts, FLW percentage, destinations of FLW, causes of FLW, purchase and selling values, and opportunities and bottlenecks in the food value chain. A summary of the activities, destinations of unsold food, average FLW volumes per actor, FLW percentage, and lost money is visualized in Table 3. The highest percentages of FLW can be found at the mobile vendors and retailers. However, due to the large volumes of onions traded by the wholesalers, the FLW volume is highest at the wholesale level, which also results in the highest economic losses. Dependent on soft-criteria, like social and political preferences, leadership and sponsorships, the hotspots can be identified for further action.

Table 3 Summary of the primary data collection in the beef value chain

Stakeholders	Name actor	Activities	Destination	FLW volume		Potential annual benefit
				kg	%	Taka/year
Stakeholder 1	Producers (cattle)	Breeding and fattening cattle (calves, cows, bulls)	Mortality	Unknown	Unknown	Unknown
Stakeholder 2	Intermedia-ries (cattle)	Buying and selling fattening cattle	Mortality	Unknown	Unknown	Unknown
Stakeholder 3a	Wholesalers (cattle)	Buying and selling fattening cattle	Mortality	Unknown	Unknown	Unknown
Stakeholder 3b	Wholesalers (beef)	Selling beef	Own consumption, given to poor/employees, sold on urban food markets or to industry/restaurants.	3,407	5%	1,780,393
Stakeholder 4a	Retailers (cattle)	Buying and selling fattening cattle	Mortality	Unknown	Unknown	Unknown
Stakeholder 4b	Retailers (beef)	Selling beef	Own consumption, given to poor/employees, sold on urban food market or to industry/restaurants, or it went to landfill.	951	5%	526,937
Stakeholder 5	Mobile vendors (beef)	Selling beef	Own consumption, given to poor/employees, sold on the urban food market or to industry/restaurants, used as animal feed, or it went to landfill.	339	5%	174,313
Stakeholder 6	Institutional users (beef)	Selling beef	Own consumption, given to poor/employees, sold to urban food markets or went to landfill.	4	0%	2,252
Stakeholder 7	Abattoirs	Selling beef	Own consumption, sold on urban food market or to industry/restaurants, or it went to landfill	244	5%	117,463

2.2.5 Conclusion

New primary data on FLW were collected for the beef value chain in Bangladesh. Data collection was based on estimates via 319 individual interviews, which were validated in two different sessions with experts. Overall the FLW percentages were 5% at the wholesalers, retailers, mobile vendors and abattoirs that handled beef only (not live cattle). The lowest FLW percentage (0%) was at the institutional users. Due to the highest volume handled at wholesale level, the beef wholesalers had the highest volume of economic losses with on average 3,407 kgs tonnes of beef per year.

2.3 Bangladesh; the mango value chain

In terms of production volume, mango is the most important fruit of Bangladesh with an annual production of 1,165,804 tonnes in 2018. During the last couple of years, an increase of the production was perceived and can be assigned to the introduction of improved varieties, production techniques and an increased market demand. Bangladesh mango production in ranked 10th worldwide, with 2.6% of the world production in 2019, but export of mangoes is almost equal to zero. In 2011 the FLW worldwide was estimated to be one-third of what is produced for human consumption with most losses taking place for the perishable fruits and vegetables food categories. FLW studies about mangoes produced in Bangladesh are scarce. An opportunity for the mango supply chain in Bangladesh is to work towards reducing food losses at various links of the chain in order to increase the amount of food that reaches consumers.
As part of the work, and due to the scarcity of data, Wageningen Food & Biobased Research (WFBR) focused on collecting new primary data and performing a value chain analysis. For collecting the data, and identifying the leverage points for reducing food losses for mangoes in order to improve the performance of the mango value chain, the EFFICIENT Protocol light version was used.
Below findings are further elaborated by Kok et al. (2021d).

2.3.1 Scope (phase 1)

The scope of this case study includes mangoes produced in Bangladesh that are produced for the domestic market. It includes all actors in the mango supply chain, from moment of harvest till and including retail, foodservice and mobile vendors. The geographical regions in scope included the main production areas (Rajshahi, Chapai Nawabganj, Natore, Dinajpur and Kushtia districts) and the four Dhaka city corporations (Dhaka North, Dhaka South, Narayanganj and Gazipur).

2.3.2 Food flow (phase 2)

Based on a literature search and consulting experts from FAO Bangladesh, the actors in the supply chain were identified and grouped into six actors: Agricultural producers, intermediaries, wholesalers, retailers, institutional users and mobile vendors. Since the flow of the produce between actors was not completely clear based on the literature search and consulting experts, it was decided to include this part in the methodology of data collection as well, including the transport modalities that were being used between the actors. A roughly drawn food supply chain of mangoes produced in Bangladesh reaching the consumers located in Dhaka is shown in Figure 4.

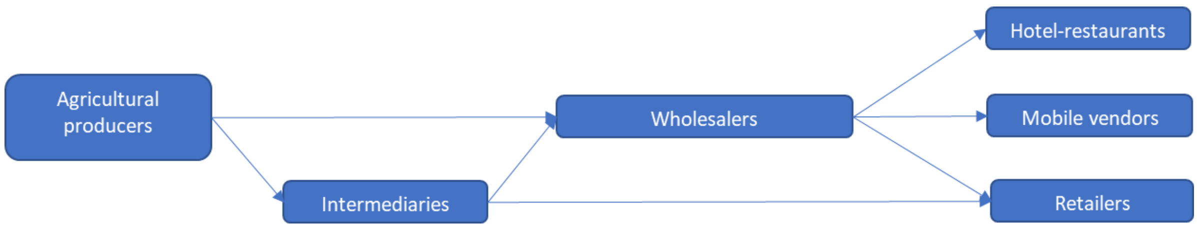

Figure 4 Food flow of the mango supply chain

2.3.3 Data collection

The data collection for Mango was performed directly after the data collection of the onion supply chain (Paragraph 2.1). So also here the primary data about FLW was collected per actor by conducting 310 face-to-face executive interviews in the production areas and four city corporations of Dhaka. This sample size was selected in collaboration with FAO Bangladesh, and due to the inclusion of six type of actors and the differences in practices within every type of actor. Interviews were executed by Sher-e-Bangla Agricultural University (SAU) by field visiting study areas. In total 60 agricultural producers were interviewed, 50 intermediaries, 20 wholesalers, 60 retailers, 60 institutional users and 60 mobile vendors. The results from the interviews were analyzed and the shared for discussion, feedback and validation in two sessions. One session took place with the FAO Bangladesh team members and one session took place with four city corporations experts from FAO Bangladesh.

2.3.4 Results

Per actor information was collected on the activities, production or purchase amounts, FLW percentage, destinations of FLW, causes of FLW, purchase and selling values, and opportunities and bottlenecks in the food value chain. A summary of the activities, destinations of unsold food, average FLW volumes per actor, FLW percentage, and lost money is visualized in Table 4. The highest percentages of FLW can be found at the mobile vendors and institutional users. However, due to the large volumes of mangoes traded by the wholesalers, the FLW volume is highest at the wholesale level, which also results in the highest economic losses. Dependent on soft-criteria, like social and political preferences, leadership and sponsorships, the hotspots can be identified for further action.

Table 4 ***Summary of the primary data collection in the mango value chain***

Stakeholders	Name actor	Activities	Destination	FLW volume		Potential annual benefit
				kg	%	Taka/year
Stakeholder 1	Producers	Harvesting, sorting and grading, and packaging	Domestic consumption, landfill and composting	668	1.8%	0.03
Stakeholder 2	Intermediaries	Collection, transport, and sorting and grading	Landfill, domestic consumption, given to employees	6,108	3.5%	0.46
Stakeholder 3	Wholesalers	Selling	Landfill, given to poor, given to employees	8,479	2.9%	0.70
Stakeholder 4	Retailers	Sorting and selling	Landfill, given to poor, domestic consumption	972	3.7%	0.14
Stakeholder 5	Mobile vendors	Preparing food	Landfill, given to poor, domestic consumption	826	5.7%	0.09
Stakeholder 6	Institutional	Preparing food	Landfill	77	5.1%	0.02

2.3.5 Conclusion

New primary data on FLW were collected for the mango value chain in Bangladesh. Data collection was based on estimates via 310 individual interviews, which were validated in two different sessions with experts. Overall the FLW percentages were highest at the end of the supply chain at the mobile vendors and institutional users. The lowest FLW percentages were found at the producers and wholesalers. Due to the large amount of traded mangoes per actor at wholesale level, the wholesalers had the highest volume of economic losses with on average 8.48 tonnes of mango per year. Destinations of these mangoes included landfill, given to poor and domestic consumption (given to poor includes sales at very low prices to poor actors and consumers).

2.4 Nigeria; the rice value chain

WUR collaborated with CGIAR to address the increasing challenge of global warming and declining food security on agricultural practices, policies and measures. As part of the program Climate Change Agriculture and Food Security, WUR started a cooperation with Olam Rice Nigeria to reduce food losses at smallholder rice farms, which can lead to promising business cases and climate smart solutions for the farmers.

Nigeria is the largest producer of rice in Africa, with approximately 90% of rice being produced by smallholder farms with limited resources (Erenstein et al., 2003; Ricepedia, 2012). Between 2015 and 2019, rice production in Nigeria has increased from 6.3 to 8.4 million tonnes, and the area of rice harvested increased from 3.1 to 5.3 million ha, implying that yield has in fact decreased from 2.0 to 1.6 tonnes/ha (FAO, 2020a). Rice exports are negligible, and production is predominantly for domestic consumption (FAO, 2020b). Increasingly, this growing demand for rice has been fulfilled with growing import volumes.
Research on reducing food loss in smallholder rice value chains is predominantly focused on storage (Affognon et al., 2015; Kumar & Kalita, 2017; Yusuf & He, 2011). However, harvesting and threshing activities have also been identified as critical loss points (Appiah et al., 2011; FAO, 2018; Kok & Snel, 2019), but so far with limited and ambiguous evidence on the magnitude of losses and effectiveness of interventions. Smallholder farmers who supply to industrial processors are particularly interesting because their connection to a formalized value chain is considered particularly promising for interventions. Together with Olam a study was done with the aim of reducing (post-)harvest food losses, increase farmer profit and decrease greenhouse gas emissions in smallholder production chains that supply to their factories in Nigeria. Based on the main inducing FLW activities in the smallholder supply chain, a controlled experiment was conducted to assess the impact of a switch to mechanized harvesting and mechanized threshing on smallholder rice farms in Nigeria.
Below findings are further elaborated by Soethoudt et al. (2021) and Castelein et al. (2022).

2.4.1 Scope (phase 1)

The scope of this study included rice produced in by five standard smallholder farmers in Nasarawa State in North Central Nigeria that deliver the packed rice to the collection centre of Olam Nigeria and its industrial mill. All five farms were involved in the Rice Outgrowers Initiative of Olam International, and are part of the same outgrower program, through which they received similar guidance and instructions. The farms are of similar plot sizes (approximately 5 ha) and produce the same rice cultivar (Faro44). Based on the loss percentages for the different activities from Kok & Snel (2019) the client (Olam) prioritized losses in harvesting and threshing as most relevant hotspots, and to explore technical interventions from that. Losses for different technology options (varying from traditional manual operations to medium-tech mechanization) were tested in dedicated experiments.

2.4.2 Food flow (phase 2)

The food flow of the smallholder rice supply chain, including all on-farm activities is presented in Figure 5. Only the first four activities (harvesting till and including winnowing) were in included to define the losses for manual and mechanized harvesting and threshing.

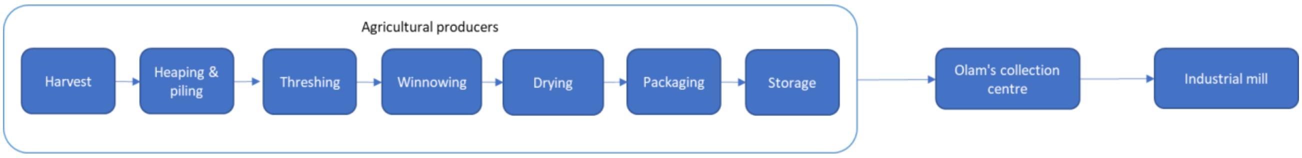

Figure 5 Smallholder rice supply chain of Olam Nigeria, including the on-farm activities

Based on a previous study and a literature study, it was concluded that harvesting and threshing are FLW hotspots. In order to compare food losses for different technology options under equal conditions, it was decided to do actual measurements (most data from literature was from a specific technology option; although comparison between the data gives indicative notions of differences in efficiency, situational differences may disturb the outcomes).

2.4.3 Data collection

A controlled experimental setup was used to conduct two experiments. One experiment investigated the effect of switching from manual rice harvesting to mechanized rice harvesting, holding everything else (including the threshing method, which was mechanical) constant. The second experiment investigated the effect of switching from manual rice threshing to mechanized threshing, holding everything else (including the rice being manually harvested) constant.
The measurements were all conducted by field experts from Olam International, following detailed instructions and using measurement templates developed by WUR. The field experts used one scale and one moisture meter for measurements on each farm, calibrated before every measurement. Three measurements were conducted at each farm, for a total of fifteen measurement cycles per experiment.

2.4.4 Results

Differences between losses through manual and mechanical harvesting and threshing are presented in Table 5 and Table 6.

Table 5 ***Average harvesting and threshing results of manual versus mechanical harvesting per plot of 24m2 (standard deviation in parentheses)***

	Manual harvesting	Mechanical harvesting
Harvested material and paddy after drying, before threshing (kg)	22.18 (1.58)*	22.99 (1.49)
Loss of paddy on land during harvesting (%)	9.55%	0.93%
Paddy yield after mechanical threshing (kg)	6.94 (0.55)**	7.58 (0.59)
Threshing efficiency (mechanical)	32.1%	32.9%

Table 6 ***Differences in threshing efficiency and losses between manual and mechanical threshing***

	Manual threshing	Mechanical threshing
Threshing efficiency (%)	31.1%	33.1%

The information obtained from the two experiments can be extrapolated from the 24m2 plots to one hectare. The differences in yield for different combinations of technologies are presented in Table 7.

Table 7 ***Paddy yield in kg per hectare for different combinations of technology***

		Threshing	
		Manual	Mechanized
Harvesting	Manual	2,789	2,968
	Mechanized	3,054	3,251

The business case and the positive effect on climate impact reduction per kg rice available for consumption are elaborated by Soethoudt et al. (2021) and Castelein et al. (2022).

2.4.5 Conclusion

This study – based on a minimal set of direct measurements – gives quantitative insight for dominant hotspots of post-harvest losses and the along going investment space for FLW interventions. The pragmatic approach using the EFFICIENT protocol resulted in identification of interventions with a very positive business case. Next step is the search for a business and investment model.

2.5 Vietnam; the dragon fruit value chain

Vietnam and The Netherlands are developing strong bilateral ties. This partnership is laid down in the Strategic Partnership Arrangement on Sustainable Agriculture and Food Security signed by the prime ministers of both countries. One of the central issues in this Strategic Partnership Arrangement (SPA) is the reduction of post-harvest losses to contribute towards sustainable food supply chains in Vietnam.
In the first phase of the project products were selected together with our Vietnamese partner AgroInfo. One of the selected products was dragon fruit, that showed potential for a business case in the context of FLW reduction.

Currently Vietnamese export dragon fruit to nearby countries like Japan and China, but the goal is to export to EU and USA as well to extend the market for dragon fruit. Unfortunately the container prices for shipment to EU are very high: 10,000-15,000 USD per container instead of 2,000-3,000 USD for the Asian region. The export to the EU is now by plane because the transport time by boat is about 35 days and the shelf-life is only 3 weeks. The air freight is so expensive that the consumer price is € 5,-/kg. A Dutch importer, who is interested in the dragon fruit, sees potential for this fruit if the price drops to € 2.50/kg. Hence air freight is not an option for them.

The challenge now is to transport dragon fruit by boat, in which case the targeted consumer price is no problem. To achieve this the supply chain has to be upgraded from farm to exporter and a seamless cold chain. We currently investigate if we have a business case to implement the required interventions and if FLW reduction can contribute to the corresponding investment.
Below findings are further elaborated by Axmann et al. (2021).

2.5.1 Scope (phase 1)

The project was aiming for a business case, and hence Vietnamese partners were listed, contacted and interviewed. At the end of this process one processing/exporting company was selected that showed interest in FLW reduction by investing in technology and knowledge. The business case was the dragon fruit supply chain from farmers in the Mekong Delta that supply via traders and wholesalers to this company until arrival in the Netherlands at the importer's facility.

2.5.2 Food flow (phase 2)

During the project AgroInfo (our Vietnamese partner) visited the Mekong Delta carried out several interviews per stakeholder type. The result of the dragon fruit supply chain at hand is shown in Figure 6. Note that the exporter has some farmers that supply to him only.

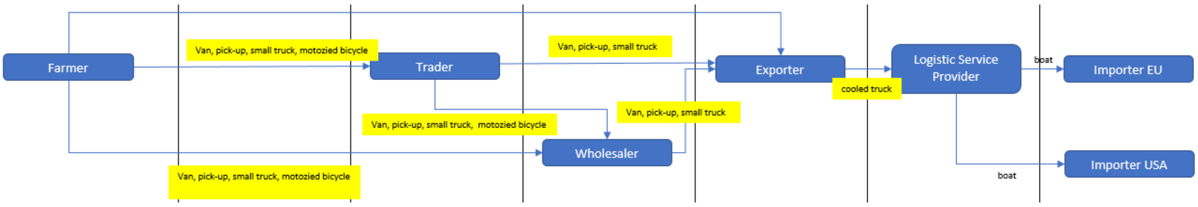

Figure 6 ***The dragon fruit supply chain of (one of three of) the Vietnamese processors considered in this project***

2.5.3 Data collection

Data collection was done by interviewing the stakeholders in this dragon fruit supply chain, including several experts from the processing company. The questionnaires were set up by WUR, and AgroInfo visited the stakeholders with these questionnaires. Now and then real measurements took place for validation of FLW hotspots (Figure 7Figure 6).

2.5.4 Results

The data collection showed ranges of prices and losses. To calculate the potential annual benefit there are a few options. One can take the average of the received data, or the lower bound to stay on the safe side. Moreover, the value loss can be calculated in cost and sales price. If you say the production costs of 1 kg of dragon fruit is 8,000 VND[2], and the selling price is 12,000 VND, then the value loss can be either 8,000 or 12,000. In our analysis below (Table 8) the average value is taken for FLW and sales price. The opportunity costs can be used to calculate the investment space.

The total value loss for the exporter equals 46,968M VND, which equals 2,067k USD. Looking at the value loss at farm level the value is 49,900M VND ≈ 2,196k USD.

Figure 7 ***Real measurement of transport weight***

[2] Note that 1000 VND = 0,044 USD

Table 8 ***FLW in weight and value for the dragon fruit supply chain at hand in one year***

Stakeholders	Name actor	Activities	Destination	FLW volume		Potential annual benefit
				kg	**%**	**Million VND/year**
Stakeholder 1	Farmers (not owned)	Harvesting	Throw away/animal feed	1,300		22,750
		Sorting	Animal feed	1,050		18,375
			Processor	650		8,775
Stakeholder 2	Farmers (owned)	Harvesting	Not harvested	130		1,040
Stakeholder 3	Trader/ Wholesalers	Transport (short distance)	No significant losses	0		0
Stakeholder 4	Exporter	Sorting	Sold at domestic market	3,411		30,699
		Packaging	Sold at domestic market/processor	341		3,069
		Storage	Processor	114		2,052
		Transport to EU	Fermentation or composting in NL	600		13,200

2.5.5 Conclusion

The potential annual benefit for the exporter is huge already. The intervention options discussed with the exporter are the following:

- Invest in controlled atmosphere storage (at the exporter and during transport)
- Invest in farm practices (optimize handling, harvest timing, transport packaging, etc.)

The investment is huge if we look at the numbers in paragraph 2.5.4. The question is now to what level the FLW reduction will drop if the investment is taking place. Therefore it is agreed to do some test with dragon fruit in CA-storage facilities.

In addition, it is advised to do more research on shelf life, since not much is known about the optimal conditions.
The training of farmers is relatively cheap, however the impact is low if it has a focus on the own farmers alone. It is an option to tighten the relationships with other farmers to profit from this kind of investment.

2.6 Honduras; the lettuce value chain

As part of a graduating project at the university “Escuela Agricola Panamericana Zamorano”, the EFFICIENT protocol was used to estimate FLW in the supply chain of Zamorano’s lettuce (Xico, 2021). It concerns an *internal* supply chain, where lettuce is grown by Zamorano and processed in mixed salads for consumption at the same university.

2.6.1 Scope (phase 1)

The stakeholder commissioning the study is the Department of Agricultural Science and Production of Zamorano University. The scope of the protocol implementation is limited to the local lettuce distribution chain at Zamorano itself, ranging from production, harvest, processing, to sale at Zamorano and consumption at the students’ cafeteria. Processed products (mixed lettuce bags) that are sold outside of Zamorano to supermarkets are out of scope for this study. Of the 4 lettuce varieties grown at Zamorano, only the Kristine and Versai varieties are included in the scope of this study due to them having the most complete supply chains within Zamorano.

2.6.2 Food flow (phase 2)

Four actors are involved in the in-scope part of the supply chain in question: The producer, processor, students’ cafeteria (food service provider) and the operator of the Zamorano sales stand (see Figure 8). All were interviewed for the purpose of this study. Transportation on the two main legs of the supply chain (from production to processing and from processing to the two points of sale) is done by truck.

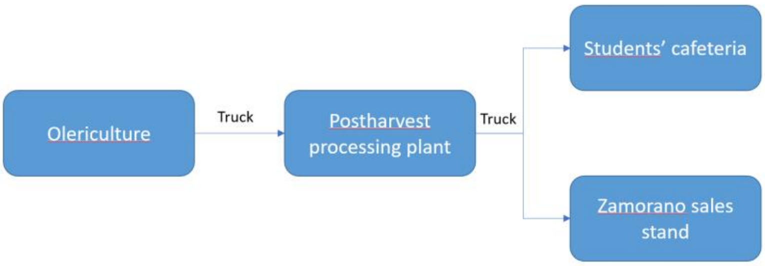

Figure 8 The lettuce supply chain

2.6.3 Data collection

For the four supply chain links included, information was obtained on volumes and losses – for the two main lettuce varieties and for the dry season as well as the rainy season. Different volumes are produced for processing into leaf lettuce mix (containing 70% Kristine lettuce) and for processing into salad mix (containing 47% Kristine Lettuce), but respondents reported single loss percentages except for the producer who did differentiate between losses of Kristine and Versai lettuce. FLW estimates are scaled by these percentages to total production volume.

2.6.4 Results

In total 8.62 tonnes of Kristine lettuce for leaf lettuce are produced per season, and 6.75 tonnes of Kristine lettuce for salad mix. The postharvest processing plants reports sales of 6.46 per season, at the cafeteria 4.46 tonnes of Kristine leaf lettuce is served per year. A small amount of lettuce (0.08 tonnes) is sold through the sales stand at Zamorano (see Table 9).

Table 9 Primary data collection on FLW of Kristine lettuce for processing into leaf lettuce mix and salad mix

Stakeholder	Name actor	Activities	Destination	FLW volume			Potential annual benefit
				Weight (tonnes) – Kristine for leaf lettuce	**Weight (tonnes) – Kristine for salad mix**	**Weight %**	**Honduran Lempira/ year**
Stakeholder 1	Olericulture	Growing and harvesting (dry season)	Composter at Zamorano	0.45	0.35	4.93%	-
		Growing and harvesting (rainy season)	Composter at Zamorano	0.94	0.74	9.82%	-
Stakeholder 2	Processing	Washing (dry season)	Composter at Zamorano	0.91	0.71	11.67%	-
		Washing (rainy season)	Composter at Zamorano	2.11	0.65	22.27%	-
		Classification (dry season)	Composter at Zamorano	0.26	0.20	3.33%	-
		Classification (rainy season)	Composter at Zamorano	0.60	0.47	6.36%	-
		Disinfection (dry season)	External agent / Remar	0.13	0.10	1.67%	-
		Disinfection (rainy season)	External agent / Remar	0.30	0.24	3.18%	-
		Packing (dry season)		0.00	0.00	0.00%	-
		Packing (rainy season)		0.00	0.00	0.00%	-
Stakeholder 3	Student's cafeteria	Order and reception		0.00	0.00	0.00%	-
		Storage		0.00	0.00	0.00%	-
		Preparation for consumption	Composter at Zamorano	0.58	0.39	11.52%	-
Stakeholder 4	Sales stand	Order and reception					
		Storage					
		Product on display	Composter at Zamorano	0.00	0.00	5.00%	-

The same producer also produces Varsai lettuce, 5.32 tonnes of which are sold for processing into leaf lettuce mix, and 4.13 tonnes for processing into salad mix. Loss percentages indicated by the producer differ from Kristine lettuce, but from processing onwards the loss percentages are not differentiated by lettuce variety (see Table 10).

Table 10 Primary data collection on FLW of Versai lettuce for processing into leaf lettuce mix and salad mix

Stakeholder	Name actor	Activities	Destination	FLW volume			Potential annual benefit
				Weight (tonnes) – Versai for leaf lettuce	Weight (tonnes) – Versai for salad mix	Weight %	Honduran Lempira/ year
Stakeholder 1	Olericulture	Growing and harvesting (dry season)	Composter at Zamorano	0.32	0.25	5.71%	-
		Growing and harvesting (rainy season)	Composter at Zamorano	1.03	0.80	16.20%	-
Stakeholder 2	Processing	Washing (dry season)	Composter at Zamorano	0.56	0.43	11.67%	-
		Washing (rainy season)	Composter at Zamorano	1.30	1.01	22.27%	-
		Classification (dry season)	Composter at Zamorano	0.16	0.12	3.33%	-
		Classification (rainy season)	Composter at Zamorano	0.37	0.29	6.36%	-
		Disinfection (dry season)	External agent / Remar	0.08	0.06	1.67%	-
		Disinfection (rainy season)	External agent / Remar	0.19	0.15	3.18%	-
		Packing (dry season)		0.00			
		Packing (rainy season)		0.00			
Stakeholder 3	Student's cafetaria	Order and reception		0.00			
		Storage		0.00	0.00	00.00%	-
		Preparation for consumption	Composter at Zamorano	0.25	0.17	11.52%	-
Stakeholder 4	Sales stand	Order and reception		0.00			
		Storage		0.00			
		Product on display	Composter at Zamorano	0.00		5.00%	-

2.6.5 Conclusion

The results show a large difference between losses in the rainy season and the dry season. During production of the Kristine variety, 9.82% is lost during the rainy season and 4.93% during the dry season. For the Versai lettuce, total FLW is 16.2% and 5.71% during the rainy and dry seasons respectively. In the main processing activities, 31.81% of the lettuce is lost during the rainy season, and 16.67% during the dry season. A particular loss hotspot is the first (washing) stage at the processor, where lettuce that does not meet quality standards is discarded. During the processing stage, lettuce of different types is processed and packaged in mixed bags, after which the product flow entails the flow of this combined product.

2.7 Mozambique; the industrial cassava processing value chain

WUR collaborated with CGIAR to address the increasing challenge of global warming and declining food security on agricultural practices, policies and measures. As part of the program Climate Change Agriculture and Food Security, WUR started a cooperation with DADTCO Philafrica, who developed a mobile cassava flour factory to process fresh cassava.

This project is oriented at the supply of cassava to a beer brewery in Ghana. Traditionally wheat from Australia is used as starch ingredient. Domestic cassava is considered a promising alternative, but losses due to long-distance transport are relatively high. In this study effects of alternative supply chain solutions are compared.
Commercial exploitation of cassava for processing industries is so far uneconomic because of the wide scattering of smallholder farmers and by the rapid deterioration in collection transport.
In this study, an intervention was analyzed that overcomes the hurdles:

- the product is preprocessed in the region of production (which largely reduces perishability)
- the preprocessing unit is mobile (which makes it possible to capitalize on different seasonality in different production regions).

Below findings are further elaborated by Dijkink & Broeze (2017).

2.7.1 Scope (phase 1)

The scope of the study was cassava that is produced for food processing in Mozambique. Cassava is traditionally processed to gari (fermented cassava flour) Besides gari, cassava can also be processed to cassava cake or cassava flour, which can be used in food processing, like un-malted grain in beer brewing, replacing maize or rice. The study was limited to the supply chain for starch crops from agricultural production in both Mozambique and Australia to a beer factory in Mozambique.

2.7.2 Food flow (phase 2)

In a situation of the intended central processing factory, the main problem is the root supply and the percentage rejected at the factory after collection at the farmers and transport to the factory (see Figure 9). Scenarios considered:

1. *Reference scenario: collect fresh cassava to the central factory:* The collecting and supply transport to the factory takes often more than 48h. This lead to large problem with postharvest physiological deterioration (PPD) as this already start 24h-48h after the harvest. The PPD rapidly renders the roots unpalatable and unmarketable. This results in reject of about 30% during raw material intake. This fraction is no longer suitable for starch cake or flour. In the most favourable situation part of this reject is used for non-food ethanol production industry.
2. *Mobile pre-processing factory scenario*: In the configuration with the mobile DADTCO processing about 10% is lost (related to peels) (DADTCO expert estimate).
3. *Wheat import scenario*: We assume no losses.

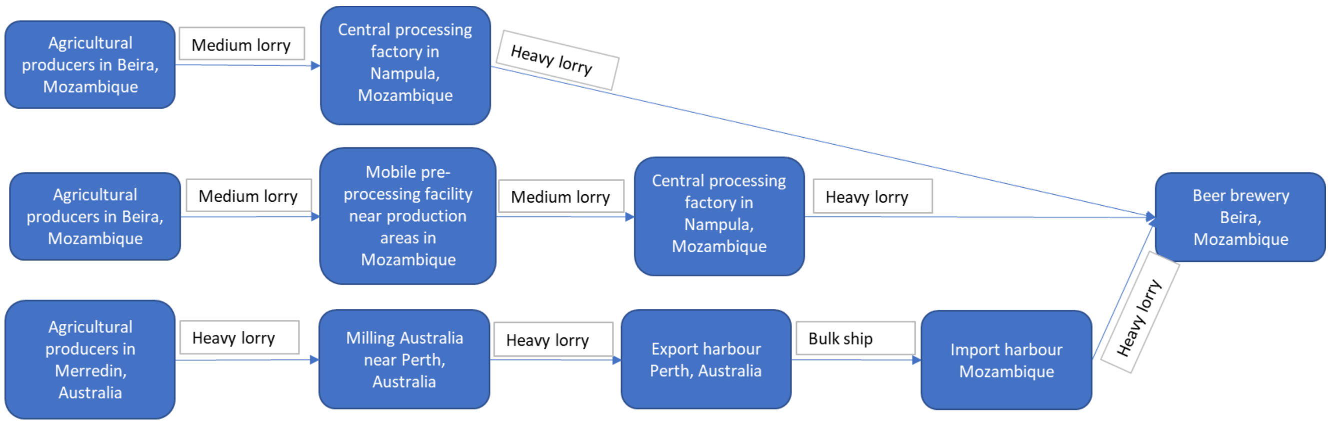

Figure 9 Supply chain configuration for starch crops to a beer factory

2.7.3 Data collection

Estimates of food losses were provided by DADTCO experts, who have a good understanding of the practical situation and average losses in different scenarios.

2.7.4 Results

Apparently the intervention significantly reduces total losses along the chain (Table 11).

Table 11 Cassava yield of different processing alternatives (total yield is after peel removal).

Scenario	Rejection % of raw material (= food loss)	Processing yield on dry matter	Total yield on dry matter	Product
1. collect fresh cassava to the central factory	30%	98%	62%	Cassava flour
2. DADTCO mobile factory	-	98%	88%	Cassava cake or flour

2.7.5 Conclusion

Overall, losses during processing depends on the degree of industrialization. In traditional farmhouse and village processing more than 40% of dry weight is lost, mainly during the processing activity. Using a central factory leads to reduced amounts of losses, but a higher share of rejection of raw materials due to quality decay in (relatively long) collection transport. Both inefficiencies can be minimized through using a mobile processing unit that operates close to the production area and produces a more stable product than the fresh cassava.

3 Conclusions

The premise of the project “Consortium for Innovation in Post-Harvest Loss and Food Waste Reduction – Innovation Platform to Gain Sustainable Efficiencies in the Global Food System” was that collection of data from primary producers has proven to be the most challenging aspect as part of Post-Harvest FLW measurement. Therefore the EFFICIENT protocol was developed with this as a starting point. The EFFICIENT protocol wants to support the users to efficiently collect, structure, and interpret relevant, reliable, and actionable information that supports action in the form of implementation of FLW reducing interventions and delivering to SDG 12.3 and many other related SDG’s. The protocol is action oriented and wants to avoid that unnecessary time and therefore money is spend on gathering the most accurate data possible. In this ‘collecting, structuring and interpretation of relevant and reliable information’ also primary data will be collected.

The seven case studies in this report show that the EFFICIENT protocol can be applied in different countries, and for different type of value chains and products. The EFFICIENT protocol is able to support primary data collection from different type of stakeholders, including primary producers, processors, intermediaries and vendors. Support is provided for data collection based on interviews, workshops and/or additional physical measurements.

Literature and references

Affognon, H., Mutungi, C., Sanginga, P., & Borgemeister, C. (2015). Unpacking postharvest losses in sub-Saharan Africa: a meta-analysis. World Development, 66, 49–68.

Appiah, F., Guisse, R., & Dartey, P. K. A. (2011). Post harvest losses of rice from harvesting to milling in Ghana. Journal of Stored Products and Postharvest Research, 2(April), 64–71. http://www.academicjournals.org/jsppr/PDF/pdf2011/Apr/Appiah et al.pdf

Axmann, H., Soethoudt, H., Kok, M., Anh, P. N., & Broeze, J. (2021). Roadmap post harvest loss reduction in selected Vietnamese value chains: Phase 1: hotspots and feasible interventions in dragon fruit and longan (No. 2161). Wageningen Food & Biobased Research.

Castelein, R. B., Broeze, J. J., Kok, M. M., Axmann, H. H., Guo, X. X., & Soethoudt, J. H. (2022). Mechanization in rice farming reduces greenhouse gas emissions, food losses, and constitutes a positive business case for smallholder farmers–Results from a controlled experiment in Nigeria. Cleaner Engineering and Technology, 8, 100487.

Delgado, L., Schuster, M., & Torero, M. (2017). Reality of food losses: A new measurement methodology.

Dijkink, B., & Broeze, J. (2017). Is industrialization in developing countries possible with minimal climate impact? processing cassava in mozambique. European Journal of Marketing.

Erenstein, O., Akande, S. O., Titilola, S. O., Akpokodje, G., & Ogundele, O. O. (2003). Rice production systems in Nigeria : A survey.

Fabi, C. and English, A. 2019. Methodological Proposal for Monitoring SDG Target 12.3. Sub-Indicator 12.3.1.a The Food Loss Index, Design, Data Collection Methods and Challenges. FAO. 60 pp. Available at https://www.fao.org/3/ca4012en/ca4012en.pdf.

FAO (2011). Global food losses and food waste — Extent, causes and prevention. Rome: Food and Agriculture Organization of the United Nations.

FAO (2013). Food wastage footprint. Impacts on natural resources. Summary Report. Rome: Food and Agriculture Organization of the United Nations.

FAO (2018) Food and Agriculture Organization of the United Nations. Food loss analysis: causes and solutions. www.fao.org Gummert, M. (2012). Improved postharvest technologies and management for reducing postharvest losses in rice. II Asia Pacific Symposium on Postharvest Research Education and Extension: APS2012 1011, 63–70. internal-pdf://146.163.194.199/4.pdf

FAO (2020a). FAOSTAT. http://www.fao.org/faostat/en/

FAO (2020b). New food Balances. http://www.fao.org/faostat/en/#data/FBS

GIZ (2015). Rapid Loss Appraisal Tool (RLAT) for agribusiness value chains. User guide for maize. Available at https://wocatpedia.net/images/2/2b/GIZ2015-en-RLAT-user-guide_webAnsicht.pdf.

Kok, M. G., & Snel, H. (2019). Food loss measurements in the rice supply chain of Olam Nigeria. https://doi.org/https://doi.org/10.18174/508838

Kok, M.G., dr. R.B. Castelein, J. Broeze & J.C.M.A. Snels (2021a). The EFFICIENT protocol. A pragmatic and integrated methodology for food loss and waste monitoring, analysis of causes and intervention design. Wageningen Food & Biobased Research

Kok, M. G., Soethoudt, J. M. & Vernooij, D. M. (2021b). Analysis of the onion value chain in Bangladesh: Towards a strategic action agenda for the Dhaka city corporations (No. 2214). Wageningen Food & Biobased Research. https://doi.org/10.18174/557275

Kok, M. G., Soethoudt, J. M., Vernooij, D. M., & Chowdhury, K. B. (2021c). Analysis of the beef value chain in Bangladesh: Towards a strategic action agenda for the Dhaka city corporations (No. 2216). Wageningen Food & Biobased Research. https://doi.org/10.18174/557278

Kok, M. G., Soethoudt, J. M., Vernooij, D. M., & Hetterscheid, S. (2021d). Analysis of the mango value chain in Bangladesh: Towards a strategic action agenda for the Dhaka city corporations (No. 2215). Wageningen Food & Biobased Research. https://doi.org/10.18174/557277

Kumar, D., & Kalita, P. (2017). Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. Foods, 6(1), 8. https://doi.org/10.3390/foods6010008

Ricepedia (2012). *Nigeria*. http://ricepedia.org/nigeria

Soethoudt, J.M., J. Broeze & H.B. Axmann (2021). The impact of mechanization in smallholder rice production in Nigeria. www.wur.nl/nl/The-impact-of-mechanization-in-smallholder-rice-production-in-Nigeria.htm

Tostivint, C., Östergren, K., Quested, T., Soethoudt, J. M., Stenmarck, A., Svanes, E., & O'Connor, C. (2016). Food waste quantification manual to monitor food waste amounts and progression. BIO by Deloitte.

UN (United Nations) (2015), Transforming our world: the 2030 Agenda for Sustainable Development, United Nations, New York. https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

UNEP (United Nations Environment programme (2021). Food waste index Report 2021. Nairobi. Available at https://www.unep.org/resources/report/unep-food-waste-index-report-2021.

WRI (2016). Food Loss + Waste Protocol: Food Loss and Waste Accounting and Reporting Standard. Available at https://flwprotocol.org/.

Xico, Anderson Estuardo Xicay (2021). Validación del protocolo Efficient Food Loss & Waste en lechuga (Lactuca sativa) variedades Kristine y Versai en Zamorano. Escuela Agrícola Panamericana, Zamorano. Departamento de Administración de Agronegocios. Ingeniería en Administración de Agronegocios.

Yusuf, B. L., & He, Y. (2011). Design, development and techniques for controlling grains post-harvest losses with metal silo for small and medium scale farmers. *African Journal of Biotechnology*, *10*(65), 14552–14561. https://doi.org/10.5897/ajb11.1845

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