Food and Agriculture Organization of the United Nations

Food loss analysis: causes and solutions

Case study on the teff value chain in the Federal Democratic Republic of Ethiopia

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Contents

TABLES

FIGURES

Foreword

Widescale global food losses and waste affect the sustainability and efficacy of food and nutrition systems, especially in the developing world. While food loss measurements are often limited by a dearth of data, high loss estimates in developing countries result from food supply chain failures. In 2011, the Food and Agriculture Organization of the United Nations (FAO) and the Swedish Institute for Food and Biotechnology published its Global Food Losses and Waste study which estimated that approximately one third of the total food produced for human consumption is either lost or wasted. While numerous studies have been undertaken to quantify food losses at the national level, information regarding the critical loss points, or areas where food loss in a specific food supply chain is most prevalent, is often unclear. Compounding the challenge, the underlying reasons for loss-inducing food supply chain failures also require further examination.

In order to improve global, regional and local knowledge about the underlying reasons for food loss, as well as to assess where critical loss points occur, FAO undertook a series of case studies involving numerous food supply chains in developing countries. Utilizing a defined food loss and waste analysis framework, the Organization and its partners identified nationally-important food products, and commissioned local-level studies of the losses in these chains. The findings of the study will be used to develop technically, economically, environmentally and socially feasible solutions to reduce food losses. These solutions will be developed both in the chains examined, as well as in similar chains in other countries, with due considerations for economic parity, agro-ecology and social conditions.

Teff is a dietary staple food crop and the most important cereal in Ethiopia in terms of agricultural land use and total value. It is adapted to a wide-range of environments and is presently cultivated under diverse agroclimatic conditions. The crop is critical for incomes and food and nutrition security across the country and is grown by 6.5 million smallholder farmers. Many of these farmers consume as much as 70-80 percent of their production and market the surplus to consumers. The findings documented in this publication provide an evidence base for the development of interventions in teff supply chains and markets.

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Abbreviations and acronyms

ADLI	Agriculture Development-Led Industrialization
AGP	Agriculture Growth Program
ATA	Agricultural Transformation Agency
BDS	Business Development Services
CIMMYT	International Maize and Wheat Improvement Centre
CLP	Critical Loss Point
CRGE	Climate Resilient Green Economy (Ethiopia)
CSA	Central Statistics Agency
CWRS	Community Warehouse Receipt System
ECEA	Ethiopian Commodity Exchange Authority
ECX	Ethiopian Commodity Exchange
EGTE	Ethiopian Grain Trade Enterprise
EIAR	Ethiopian Institute of Agricultural Research
EPA	Environmental Protection Authority (Ethiopia)
ESA	Ethiopia Standards Agency
ESE	Ethiopian Seed Enterprise
ETB	Ethiopian birr
FAO	Food and Agricultural Organization of the United Nations
FSC	Food Supply Chain
FTC	Farmers Training Centre
GHG	Greenhouse Gas
GTP	Growth and Transformation Plan
Ha	Hectare
HLI	Higher Learning Institution
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
Kg	Kilogram
Km	Kilometre
LLP	Low Loss Point
MCH	Multiple Crop Harvester
MoANR	Ministry of Agriculture and Natural Resource
MoI	Ministry of Industry
MoFED	Ministry of Finance and Economic Development
MoT	Ministry of Trade
NARS	National Agricultural Research System

NGO	Non-Governmental Organization
PASDEP	Program for Accelerated and Sustainable Development to End Poverty
PFL	Prevention of Food Losses
PHFL	Post-harvest Food Loss
PHL	Post-harvest Loss
PICS	Purdue Improved Crop Storage
PSE	Public Seed Enterprise
RARI	Regional Agricultural Research Institutes
RATES	Centre for Regional Agricultural Trade Expansion Support
RSE	Regional Seed Enterprise
SD	Standard Deviation
SDC	Swiss Agency for Development and Cooperation
SG-2000	Sasakawa Global 2000
SHF	Smallholder Farmers
SNNP	Southern Nations, Nationalities and Peoples
USD	United States Dollar
UNJP	United Nations Joint Project
USDA	United States Development Agency
WFP	World Food Programme

Introduction to the case studies

About 1.3 billion tonnes of food losses and waste are estimated to occur every year globally (FAO, 2011), affecting the efficiency and sustainability of global food systems and nutrition. Accurate estimates of the magnitude of losses and waste are still lacking especially in developing countries where most smallholder farmers produce and consume grains and pulses as a staple food; nevertheless, the high loss estimates suggest that food losses are significant and have a negative impact on food and nutrition security.

In light of the above, the Food and Agriculture Organization of the United Nations (FAO) and its partners launched the Global Initiative on Food Losses and Waste, to reduce food losses and waste using various approaches including awareness-raising and developing a methodology to research post-harvest losses among other initiatives. Multiple partners have supported efforts at the national and regional levels through various projects including the Project on Food Loss Reduction through partnerships and evidence-based interventions, also known as the United Nations Joint Project (UNJP). The UNJP, which is funded by the Government of Ireland, is a collaborative initiative on food loss reduction between FAO and the International Fund for Agricultural Development (IFAD).

Food losses refer to the decrease in edible food mass throughout the different segments of the food supply chains: production, post-harvest handling, agroprocessing, distribution (wholesale and retail) and consumption. Food losses and their prevention have an impact on the environment and climate change, food security and livelihoods for poor people and economic development. The exact causes of food losses vary throughout the world and are very much dependent on the specific conditions and local situation in a given country, region or production area.

Literature reviews, statistical data and stakeholder interviews have been used in studies to assess the quantities of food lost at the various stages of food handling in various countries.

These studies have established some certainties and existing knowledge gaps. Certainties include quantitative estimations of food losses and the major causes of food losses. What is not clear are the kinds of losses that are important for specific food chains, the impact of suggested solutions, and which are feasible economically, environmentally and socially.

It is clear that food loss reduction will greatly benefit all actors in the food supply chains, ensure food security for poor people, improve resilience to climate change and increase the efficiency of how natural resources are used. The solution to food loss should not be more expensive than the value of the food lost, nor should it cause any negative impact or risk to consumer health. Also it should not place more of a burden on the environment or increase greenhouse gas (GHG) emissions. Instead, it should make more food available to the people that need it most, and should be socially and culturally acceptable.

Therefore, the Save Food Initiative has designed the 'food supply chain' case studies for the most important food subsectors in developing countries for the generation of data relating to the different causes of food loss. Solutions for food losses are analysed for their feasibility. Up to now, no standardized methodology has been used to conduct loss assessments. This has made it very difficult to compare results between countries and regions. Using a standardized methodology across the participating countries is very useful in terms of being able to compare results and sharing information.

A case study is just a one-moment recording of what is happening in a specific food supply chain in a specific season and in a specific location; in another season or in a different location the situation can be very different again. Consequently, the Save Food Initiative considered it important that it undertakes many case studies in different locations so that the various study results would provide significant trends and solutions. Further, the strategy aimed to use the results of the case studies to target opportunities for investment programmes and interventions, during formulation a wider geographical scope and the seasonality will be analysed.

The assessment of post-harvest losses along teff supply chains used the methodology developed by FAO under the Save Food initiative and adapted it to the specific conditions and local context. The Government of Ethiopia has identified the teff subsector as a priority for the reduction of post-harvest

losses. The supply chain examined involved smallholder farmers, cooperatives, transporters, traders, millers, warehouse managers of cooperatives and daily labourers.

The main objectives of this study were to:

- obtain a clear view of the weak points in the selected teff supply chain where food losses occur;
- evaluate quantitative and qualitative losses;
- analyse their main causes; and
- identify key interventions to reduce food losses and improve the efficiency of the food supply chain (FSC), eventually leading to concrete proposals to implement a food loss reduction programme.

An effective food loss assessment in a supply chain involves the collection of data and its analysis. Quantitative and qualitative field methods were used for the assessment. Subsequently, the results and conclusions of the assessment were used to formulate solutions and strategies to control food loss.

Through the formulation of food-loss reduction strategies, the project adopts a holistic approach based on the entire supply chain, recognizing the strong role of multiple actors, including the role of institutional structures and the policy environment.

Given the magnitude of food losses, making profitable investments in reducing losses and improving the efficiency of the food supply chain could help bring down the cost of food to the consumer, increase access to food, while improving economic returns to farmers and other actors in the value chain.

> *The objective of this study is to identify the main causes of food losses in the selected food supply chains, and provide an analysis of the various options available for reducing food losses including their technical and economic feasibility, social acceptability and environmental impact, leading to concrete proposals for the implementation of a food loss reduction programme. Although attempts have been made to quantify actual losses after an activity along a supply chain, the final loss figures used are mostly estimates. Where there is need to use accurate loss figures, for instance in tracking achievements in loss reduction efforts, this requires a more detailed statistical analysis, which is beyond the scope of this study.*

IMPLEMENTATION METHODOLOGY OF FIELD STUDY

The assessment of post-harvest losses along the teff supply chain used the methodology developed by the Save Food Initiative. The supply chain food-loss assessment involves the collection of data and its analysis, using qualitative and quantitative field methods. Subsequently, the results and conclusions of the assessment are used to formulate solutions to food losses. The methodology used in the 'food supply chain' case studies is described below.

Selection of countries and subsectors

In order to make it possible to work with partners in the field, existing and ongoing programmes were used to select countries and subsectors for the study cases.

Subsectors were chosen from the important food commodities in Ethiopia, which included cereals; roots and tubers; fruits and vegetables; oilseeds and pulses; fish and seafood; and animal products (meat, milk, eggs, etc.).

Identification of Consultants

Three national consultants conducted the fieldwork including a subsector specialist, who could be an actor in the food supply chain, an agricultural economist and a sociologist.

Selection of Food Supply Chains

The criteria used to rank the main supply chains were importance in terms of economic impact and food security and contribution to national development objectives such as employment, poverty reduction and the generation of foreign exchange. Based on the information obtained, one or two FSCs in the subsector were selected for in-depth survey and sampling.

The basic criteria for selection of the FSCs were:
- based on smallholder producers;
- significant scale of food production;
- preferably including agroprocessing and urban market; and
- if possible, included in an ongoing support programme for the subsector

Uniform methodology

The methodology of the case studies was uniform for all countries, so that the results would be comparable and extrapolation would be possible. It is comprised of four ('S') elements:
- *Preliminary food losses (Screening)* are screened based on secondary data, documentation and reports, and expert consultations without travel to the field.
- *Survey Food Loss Assessment (Survey)* uses different questionnaires for producers, processors or handlers or sellers for example warehouse managers, distributors, wholesalers, and retailers and other knowledgeable people in the supply chain being assessed, complemented by ample and accurate observations and measurements.
- *Load Tracking and Sampling Assessment (Sampling)* is useful for quantitative and qualitative analyses at any step in the supply chain.
- *Monitoring and Solution Finding (Synthesis)* is used to develop an intervention programme for food losses, based on the previous assessment methods.

The consultants physically follow the product and the process from production site to final retail outlet, make direct observations and measurements and discuss the causes and solutions of food losses with supply chain actors. Finally, the consultants draft a proposal for a food-loss reduction strategy or plan.

Stakeholder validation

Stakeholders from the public and private sectors meet in a one-day workshop to discuss and endorse the study results and the proposed food-loss reduction strategy. A concept for a programme to finalize and implement the food-loss reduction strategy or plan is prepared.

Methodology adapted for teff

Researchers selected teff for this investigation because of its economic and social importance, production and cultivation areas, and marketability through multiple paths and long supply chains, reaching and covering a large community. Other criteria considered included its importance as food and income sources for a large portion of the population in both rural and urban areas, employment opportunities for a large number of people, and the crop's contribution to food security.
- The *screening method (desk review and consultations)* was used to gather data and information on the range of losses and some of their main causes.
  Collection of secondary data was through reviewing documents of secondary sources from relevant institutions. Beside relevant published and unpublished reports, the researchers browsed websites, and bulletins to generate relevant secondary information focusing on teff production and marketing. Furthermore, from these secondary sources, data on prices, outputs, numbers of licensed teff traders, and information on the marketing system etc. were collected.
  The method was instrumental in identifying the critical and low loss points in the supply chain. It also provided some background information for implementation of the *survey* and *sampling* methods. This method helped to develop a qualitative understanding of losses and provided indicative quantitative data for the entire loss assessment. It provided an overview of the food supply chain.
- The *survey method* employed a questionnaire that was given to small farmers and the 'Key Informant Interview – KII', which was a qualitative instrument developed for other actors and stakeholders involved in the FSC (e.g. traders, processors, etc.). The sources of primary data were smallholder farmers who were randomly selected from one rural *kebele*, the farmers' service cooperative association (union) and traders at different levels, ranging from farmer traders to regional level wholesalers.

The teff case study was carried out in December 2015 in Workima Kebele, Machekal Woreda, in Amhara Regional State. The following methods were used to collect data:

- Interviews, used a pre-tested semi-structured interview scheduled questionnaire. The formal survey was based on 25 farmers in the selected *kebele* – the *kebele* is also included in the IFAD project site for the Participatory Small-scale Irrigation Development Programme (PASDIP).
- Qualitative data was also gathered during focus group discussions with key informants. The checklist–based qualitative survey relied heavily on the internal assessment of the actors (traders, processors, etc.) in the chain. 42 key informants were interviewed.
- Observations of FSC activities and stakeholders complemented the survey. Post-harvest operations, percentages of losses at each level of the supply chain helped generate primary data. Data generated from the questionnaires was used to compute the percentages of losses (kg/100 kg of grain) along the supply chain. The monetary values were based on the price of 1 kg of teff grain (USD 0.81).
- The *load tracking and sampling method* was employed to evaluate the quantitative and qualitative teff losses at specific steps in the supply chains and to identify the respective causes of these losses. Sampling was at the threshing stage as the *screening* and the *survey* revealed this was a critical loss point (CLP).

The researchers selected three villages for the study. Sampling was in two stages in each village in order to measure qualitative and quantitative losses. Three units (30 percent) were used from the harvest produced by nine farmers (three farmers were selected in each village) at the first sampling stage. For the second stage sampling, one random sample of 1 kg was used from each selected unit as a measurable unit, thus making a total of nine sampling units for the three villages.

This process was carried out before and after each of the two steps studied (threshing and storage).

Samples were analysed at the laboratory. Samples of teff were threshed using two different methods, manual threshing and animal trampling, these traditional methods are used by most farmers. Teff losses were estimated.

POLICY-MAKING AND NATIONAL STRATEGIES

Before 2000, post-harvest grain management issues were given limited policy attention, compared to that given to increasing agricultural production and productivity. Since 1993, Ethiopia has been following an overarching agriculture development policy called *Agriculture Development-Led Industrialization (ADLI)* in response to challenges related to prevailing food security and agricultural productivity. Since the adoption of ADLI, the Government of Ethiopia has implemented a number of national economic growth and development plans, which are described below.

The *Programme for Accelerated and Sustainable Development to End Poverty (PASDEP, 2004/5-2009/10)* stressed the need to promote post-harvest technologies to improve the performance of market chains through training, development and dissemination of post-harvest loss reduction technologies.

Ethiopia's Growth and Transformation Plan (GTP, 2010/11-2014/15) briefly touched on the issue of product storage in the context of promoting market access (MoFED, 2010)1. The corresponding five-year agriculture sector plan only mentioned improving storage infrastructure, without providing any details of an implementation strategy, or an action plan that specifies targets for the expected outputs of the sector.

The *Agriculture Growth Programme (AGP)*, as the main government programme addresses agricultural growth in Ethiopia, and is focused on attaining reduced post-harvest losses. In line with this programme, the Agricultural Transformation Agency, in collaboration with the Ministry of Agriculture, multi-lateral agencies, non-governmental organizations (NGOs) and the donor community are aggressively working to enhance the value chains of selected crops. This value chain approach aims to ensure

[1] MoFED. 2010. Ministry of Finance and Economic Development (MoFED). Growth and Transformation Plan 2010/11-2014/15, Addis Ababa, Ethiopia.

that all components of the grain sector are addressed in a comprehensive and coordinated manner, considering:

- research and technology development;
- access to inputs;
- on-farm production;
- post-harvest processing and storage; and
- trade and marketing.

With regard to post-harvest handling of grain crops, the focus intervention areas are:

- to increase access to post-harvest processing equipment and technologies;
- raise the awareness of farmers and facilitate access to effective on-farm storage; and
- increase farmers' access to community-level storage facilities with skilled personnel.

The current *Agriculture Sector Growth and Transformation Plan II (2015-2020)* aims to reduce the post-harvest losses of major crops from 25 to 5 percent by aspects of agricultural mechanization and post-harvest losses including:

- enhancing harvesting, threshing and shelling operations using mechanical technologies and
- improving transportation and storage of agricultural produce using modern and mechanical technologies.

In the Growth and Transformation Plan (GTP) II, agricultural extension will address the needs of women farmers through gender-sensitive approaches. Focus areas of implementation include awareness creation, encouragement of the participation of women and rural youth in agricultural extension, and provision of training to enable development agents to support women and rural youths in agricultural activities.

Although the attention given to post-harvest loss issues in these strategic plans vary, the reduction of post-harvest losses has recently received closer attention. In response to GTP II, the Ethiopian Institute of Agricultural Research (EIAR) has given special emphasis to post-harvest loss reduction and developed a separate strategy for post-harvest research. Strict implementation of these strategies with the synergetic effort of various actors will bring about significant differences in the reduction of post-harvest losses.

Identifying solutions to food losses could add value to the Ethiopia Climate Resilient Green Economy (CRGE) strategy (EPA, 2011[2]). Reduction of food losses will contribute to the realization of the first pillar of the CRGE, which is 'Improving crop and livestock production practices to increase food yields, hence food security and farmer income, while reducing emissions'. Ensuring food security and improving farmers' income would indirectly impact the remaining three pillars: i.e. reducing deforestation, improving access to renewable energy and energy efficient technologies.

Food safety and quality policies

There are four classes for teff standards based on seed colour and there are also four grades for the maximum limits of impurities (Table A). The highest quality teff has a high percentage of white grains and less foreign matter.

RELEVANT INSTITUTIONS AND THEIR ROLES

The Ministry of Agriculture and Natural Resources (MoANR) and the Regional Bureaus of Agriculture (RBoAs) are the major institutions for food loss management and are responsible for the development of agricultural policies. Besides their mandate for leading agricultural development activities, they have an organizational structure down to the grassroots level that enables the Ministry to disseminate post-harvest loss reduction technologies. This makes it the most relevant institution having a major stake in the improvement of agricultural production and food loss reduction.

[2] EPA (Environmental Protection Authority). 2011. The path to sustainable development, Ethiopia's Climate-Resilient Green Economy Strategy. Federal Democratic Republic of Ethiopia.

TABLE A
Classes and Grades of Teff grain

Class	Description	Characteristics	Maximum limits of impurities (%)			
			Grades			
			1st	2nd	3rd	4th
Very white	98-100 % of white grains	Foreign matter	1.5	2.5	3.5	5.0
		Stone	0.6	0.6	0.6	0.6
White	95-98 % of white grains	Foreign matter	1.5	2.5	3.5	5.0
		Stone	0.6	0.6	0.6	0.6
Brown	94-100 % of brown grains	Foreign matter	1.5	2.5	3.5	5.0
		Stone	0.6	0.6	0.6	0.6
Mixed	Mixture of white and brown grains	Foreign matter	1.5	2.5	3.5	5.0
		Stone	0.6	0.6	0.6	0.6

Source: ESA. 2001. *Ethiopian standard for grading of Teff grain (Eragrostis Teff).* ES 671:2001, 3pp. First edition. Reaffirmed: 2012.

The National Agricultural Research System (NARS) incorporates the EIAR, the Regional Agricultural Research Institutes (RARIs) and Higher Learning Institutions (HLIs) with agricultural faculties. Particularly, EIAR and RARIs have the mandate to generate improved post-harvest technologies, information and knowledge. HLIs are primarily responsible for the production of skilled post-harvest professionals who can take part in research and development programmes and undertake relevant food loss research. NARS also plays an important role in the dissemination of post-harvest technology through demonstrations.

The Ministry of Trade (MoT) has a mandate to manage the licensing and registration of traders, the MoT works on stabilizing local grain marketing and improving the country's competitiveness in foreign markets. It does this through the formulation and implementation of relevant and appropriate trade policies and strategies, and collection, analysis and dissemination of trade-related information to relevant members of the business community.

The Ministry of Industry (MoI) has a mandate to develop agroprocessing industries by creating conducive conditions to encourage investment in the sector. The Ministry is also involved in generating agroprocessing industrial project ideas and linking them to relevant stakeholders and attracting joint ventures from abroad. The MoI supports agroprocessors in line with the country's industrial development strategy.

The Ethiopian Standards Agency (ESA) mainly focuses on standard formulation, training and technical support, organizing and disseminating standards, and the formulation of conformity assessment procedures and handles technical regulation for the customers.

Farmers' Associations and Cooperatives play important roles in the development of the grain sector through providing farm inputs such as fertilizers, seeds and pre and post-harvest pesticides, facilitation of market linkages and credit system to farmers.

The Private Sector's increased investment and involvement contributes to the reduction of post-harvest losses, particularly through participation in production and distribution of improved harvesting, transportation, and threshing or shelling, cleaning, storage and preservation technologies. The private sector can also supply the necessary consumable inputs to the post-harvest value chains (e.g. Shayashone Agribusiness Consultant).

Non-Governmental Organizations (NGOs) have a critical role in post-harvest loss reduction. NGOs help in building the capacity of stakeholders, especially smallholder producers through provision of technical training and infrastructure and dissemination of improved post-harvest technologies (e.g. Sasakawa Global (SG)-2000).

Public Seed Enterprises (PSEs) include the Ethiopian Seed Enterprise (ESE) and Regional Seed Enterprises (RSEs) in Amhara, Oromia, and SNNP regions. PSEs are responsible for implementing government targets to produce sufficient quantities of high-yielding improved seed for key crops, including teff, while also functioning as independent profitable businesses.

The Agricultural Transformation Agency (ATA) continues to provide implementation support in the form of continued problem solving, resource mobilization, project management, and coordination at various levels of the Ethiopian agriculture system.

Executive Summary

Eragrostis Teff (Teff) is the staple food for most Ethiopians. It can grow well in moisture-stressed and waterlogged conditions, better than other cereals. It is mainly cultivated in the central and northwest highland areas, and is mainly grown in Oromia; South Nations, Nationalities, and People's (SNNP); Amhara and Tigray, in that order. East Gojjam, East Shewa, West Shewa and North Shewa are the four most important teff producing areas.

6.5 million smallholder farmers grow teff, and it is indispensable to the livelihoods of many Ethiopians. Although the proportion may vary between individual farmers, generally 70 to 80 percent of the crops production is for the farmers' own use, while the remaining is for sale.

The field loss study activities were carried out in Workima *Kebele,* Machakel *Woreda*[3] District, Amhara Region. The primary data sources were smallholder farmers (SHF) who were randomly selected from the study *kebeles*, representatives of the farmers' service cooperative associations (unions) and traders at different levels, ranging from farmer traders to regional level wholesalers. Secondary data sources were various reports and documents.

Most post-harvest operations are traditional, time-consuming and labour-intensive, and they have been used for centuries in the same way, with little or no improvement. Farmers harvest both crops manually. Threshing of teff involves a group of animals trampling on the threshing floor.

Traditional and improved *gotera*[4] as well as polyethylene sacks are widely used for storage in the region. Crops are mostly transported by labourers or pack animals from the fields to stacking or threshing sites, and from the threshing floors to storage facilities. Transportation is an important marketing function, which enables producers in surplus producing areas to obtain better market prices, and consumers in deficit areas to get reduced marketing prices. As a result of the poor local market infrastructure, most farmers have to transport their produce 30 km to a major market within a *woreda*, using pack animals, human labour or when available, vehicles.

Post-harvest food losses are economically significant in Ethiopia for a broad range of commodities such as teff and maize, resulting in a substantial negative impact on food security and import substitution. Results of the assessment indicated that average post-harvest teff losses incurred in the study area were 5.6 percent for harvesting, 6.3 for piling or stacking, 7.7 for threshing, 2.2 for transport and 3.2 percent for storage. The cumulative teff post-harvest quantity losses are thus estimated to be 25 percent, without taking into account quality losses.

The causes of losses are many and varied. They include moisture levels; harvesting, threshing and storage methods, drying techniques and attacks by insects, rats and other pests. Among the major causes for teff losses, harvesting and threshing practices are of highest significance.

In the absence of appropriate and feasible technologies, traditional and uneducated post-harvest operations (handling, processing and distribution) are the major factors leading to post-harvest losses. There is a lack of awareness among farmers, agricultural personnel, policy-makers and other stakeholders of the negative impacts of post-harvest losses and how they hinder reduction of post-harvest food losses at the farmers' level.

Promotion of the post-harvest sector is also constrained by an inadequate policy framework, lack of technical and technological support for farmers, and financial constraints faced by post-harvest technology generators, private distributors and smallholders. Moreover, areas of concern in the sector's development include lack of focused training and education about the country's post-harvest problems and remedies, poor linkages among education, research and extension services and absence of institutions responsible for coordinating and facilitating operational and policy research and activities.

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[3] *Kebele* is the lowest administrative unit in Ethiopia and *woreda* is a district.

[4] *Gotera* is a structure constructed from wood and sticks fixed together in cylindrical or rectangular form or splits of bamboo woven into a big basket and plastered with mud and straw.

To address these challenges, the study recommends the introduction and promotion of proven and affordable post-harvest technologies such as metal silos, hermetic bags, multiple crop harvesters (MCH) mechanical threshers, shellers, and pre-storage protectants. These technologies have proven to provide significant benefits to farmers based on productivity gains, quality improvement and reduced labour costs. These technologies must be popularized through awareness-raising about the costs and impacts of post-harvest losses (PHL), dissemination of training and knowledge and increased financial access to machinery for farmers and small enterprises. Strengthening institutional support and post-harvest research would encourage the adoption of modern technologies and enhance post-harvest loss reduction efforts.

Chapter 1
Introduction and background

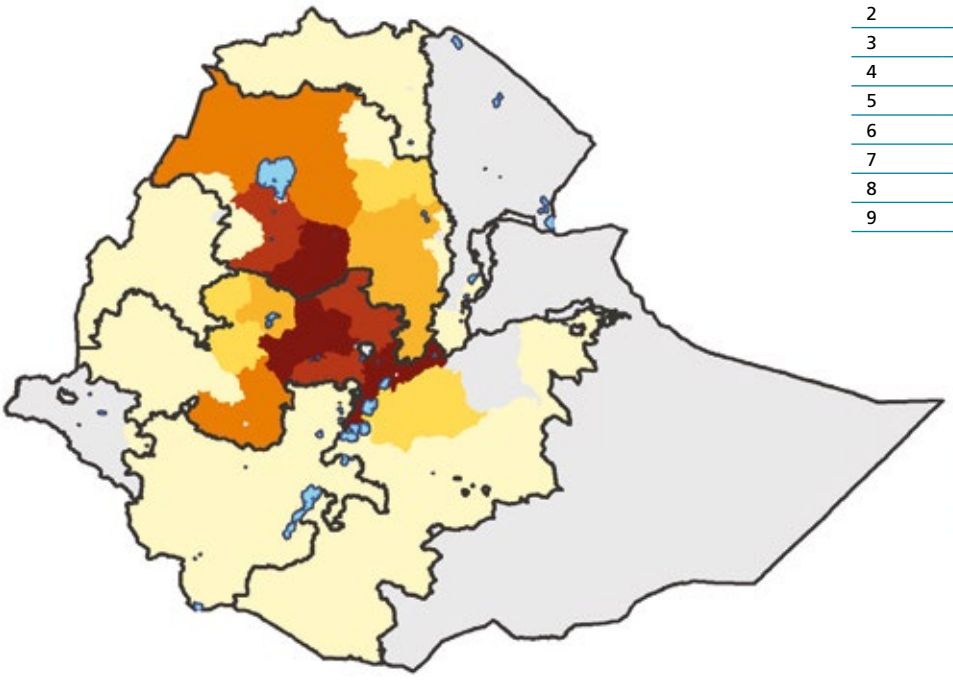
STATUS AND IMPORTANCE OF THE TEFF SUBSECTOR: DEVELOPMENTS OVER THE LAST 15 YEARS

*Eragrostis Teff (*Zucc.) Trotter is a dietary staple food crop and the most important cereal in Ethiopia, in terms of area planted and value. Its grain is mainly used for making different kinds of pancake-like flat bread, *injera* and *k'itt'a*, porridge and feed. The largest group of teff producers are small-scale subsistence farmers with minimal access to production inputs such as fertilizers, pesticides, improved seeds, good soil and water and improved credit facilities for their purchase. The crop can grow well in moisture-stressed and waterlogged conditions, better than other cereals. Teff is adapted to a wide-range of environments and is presently cultivated under diverse agroclimatic conditions. It grows from as low as sea level all the way up to 2 800 m under various rainfall, temperature and soil regimes.

In the 2014/2015 meher production season, which is the main growing season between July and November, teff ranked first in total cropland and second, next to maize, in quantity produced among other cereals. According to the Central Statistical Authority (2015), more than 6.5 million

FIGURE 1.1
Teff Production areas in Ethiopia

Average Teff Production Rank by Zone
(2006/2007 to 2010/2011)



Rank	Zone
1	East Gojjam
2	East Shewa
3	West Shewa
4	North Shewa (Oromia)
5	West Gojjam
6	South West Shewa
7	Jimma
8	North Gondar
9	South Gondar

Sources: Seneshaw Tamru, 2013

TABLE 1.1
National production information for Teff

		Annual production (tonne/2014/15)	**Cultivated area (ha)**	**Average yield (tonne/ha)**
Product (Grain)		4 750 700	3 016 050	1.6
Average annual growth over the last 10 years (%)		9.3	3.4	5.6
Average cost of production (USD / tonne)		238.1-333.8		
		On-farm consumption	**Marketed**	Other*
Percentage of production		51.7	28.6	19.7
Item		**Volume (tonne/ year)**	**Value (USD/year)**	
Market product#1, Grain		1 358 700	905 793 330	
Market product#2, straw		NA	NA	
Number, sex, age of	**Number Female**	**Number Male**		**Total**
Producers	NA	NA		6.5 million
Traders (in Machakel Woreda)	22	178		200
Wholesaler (in Machakel Woreda)	0	1		1
Processors/millers (in Machakel Woreda)	15	39		54
Item		**Small**	**Medium**	**Large****
Level of processing operations		x		
Level of trading/ wholesale operations			x	
Level of retail operations				x

* Seed, wages in kind, etc.; ** Number of employees/workers: Small: <10, Medium: 10-50 and Large: >50; NA: Not Available
Source: CSA (2015) and primary data

resource poor households were engaged in teff production in the 2014/2015 cropping season. It is mainly cultivated in four (Figure 1.1) of the nine regions in the country: Oromia, SNNP, Amhara and Tigray in that order, on 3.02 million ha (30 percent of total cultivated land) with a total production of 4.75 million tonnes (20 percent of total cereal grains production) (Table 1.1).

About 30 thousand tonnes of teff flour exported in 2005 earned the country about USD 13.7million. However, because of policy reasons, teff flour exports fell in 2006 with only USD 3 million earned. *Injera* exports increased to 2 500 tonnes in 2012 and during 2008 there was a +270 percent increase. Nevertheless, according to the data from the customs authority, starting in 2008, Ethiopia has been exporting processed teff, especially in the form of fresh *injera* and dry *injera* ('*dirkosh*'), and the export of such products has been steadily increasing (Bekabil *et al*., 2013).

INVENTORY OF ACTIVITIES AND LESSONS LEARNED FROM PAST AND ONGOING INTERVENTIONS IN TEFF LOSSES

Different organizations have been trying to address the issue of post-harvest losses. Some have focused on the modification of traditional storage structures, e.g. *gotera*, and others were involved in introducing warehouses and post-harvest mechanization at the cooperative level or for mechanization, and in training smallholder farmers in harvesting and threshing such as the World Food Programme – (WFP), SG-2000. A number of institutions in Ethiopia have promoted modified and improved storage structures. SG-2000 started to promote improved stores in 1995 in several areas, while later the Ministry of Agriculture and Natural Resource (MoANR) (Anon, 1996) took over the work of promotion.

Over the last two decades, the Swiss Agency for

TABLE 1.2
Food safety management mechanisms

Controller	Control	Actual situation in the FSC		Responsible agent
Government regulation and requirements	National food safety/ quality standards	Exists and applies to the whole FSC		Quality and Standards Authority of Ethiopia
		Exists but not rigorous	x	
		Does not exist		
	Frequency of checking (None, Low, Medium, High)	Harvest	None	Ministry of Health, Ministry of Agriculture and Rural Development, Ministry of Trade and Ministry of Industry, and Quality and Standards Authority of Ethiopia
		Transport	None	
		Storage	Low	
		Process	Low	
		Market	Low	
	Obligatory registration of the food processing/ preparation unit	Exists	x	Ministry of Industry, Ministry of Trade
		Does not exist		
FSC actors - food safety management system	GHP/ GAP/ HACCP/ voluntary standards			
	Identification of potential Hazards			

Source: Preliminary screening data

Development and Cooperation (SDC), FAO, and the International Maize and Wheat Improvement Centre (CIMMYT) (Dawn, 2012) have developed and deployed the metal silo technology in developing countries in Africa, Asia and Latin America. According to the World Bank Research Report (2011) on the impact of metal silos in Central America, it was observed that metal silos delivered a variety of benefits, including the fact that families had to buy less food and had greater flexibility in deciding when to sell their surpluses, rather than being forced to sell all the harvest, right after threshing.

Metal silos and hermetic bags clearly do offer continuing opportunities for the reduction of post-harvest losses in Ethiopia. SG-2000, in collaboration with the CIMMYT, introduced and demonstrated the use of metal silo technology for grain storage. Bags and other storage structures made of plastic have the advantage that they can be airtight (hermetic) and their use delays biodeterioration. One such method currently being extensively promoted is the use of 'triple-bagging' for grain storage.

Lessons learned from the failed attempts to push for post-harvest improvements by focusing only on the technical aspects have highlighted the limitations of this approach. For example, early experiences of the FAO Prevention of Food Losses (PFL) programme, which farmers implemented in the 1970s and 1980s focused on farm storage for subsistence farmers, had very low adoption rates and proved to be unsustainable. The effectiveness of technology in reducing post-harvest losses is important; however, a critical factor in creating an impact is not only the technology per se, but also its relevance to the situation, its acceptability, its affordability and its benefits, which can be determined by other factors and constraints downstream in the chain — not necessarily at the farm level.

In addition, the primary focus of the federal extension system has been on increasing production and productivity, but not on reducing PHL. Research into PHL reduction has also been apparently weak and uncoordinated. Farmers' cooperatives have not been involved in marketing of inputs for post-harvest grain management. The advisory service on PHL has been very weak compared to that provided on production. There has been no serious and adequate agricultural extension service for PHL activities, with the exception of demonstrations of modified and improved *gotera* at Farmers' Training Centres (FTCs).

OVERVIEW OF THE MOST IMPORTANT FSCS IN THE SUBSECTOR, SELECTION OF THE TEFF SUPPLY CHAIN

Researchers selected four FSCs in Workima *Kebele*, Machekal *Woreda*, of Amhara Regional State. From among them, researchers selected the FSC transacting the largest volume of teff for the study.

FSC 1 (Rural consumer supply chain): The first and the shortest supply chain, involves farmers, traders (assemblers and wholesalers) and users. This chain is the largest in terms of reaching out rural households.

The steps in the chain include Harvesting → Stacking/Piling → Threshing → Storage → Transport → Rural traders/Consumers.

Studies indicate that about 30 to 70 percent of teff supply passes through millers. Surplus teff grain produced by smallholder farmers from Workima *Kebele* is supplied to consumers, traders and assemblers in the district of Machakel.

FSC 2 (Informal wholesale supply chain): The second supply chain enters the largest national grain markets through traders. It involves smallholder farmers and traders (assemblers and wholesalers).

The steps in the chain include Harvesting → Stacking/Piling → Threshing → Storage → Transport → *Woreda*/Zone traders→ Consumers.

In this channel, a study indicates that smallholder farmers supply around 85 percent of their produce to assemblers, collectors, local traders or rural traders. These assemblers or traders supply 75 percent of the teff to wholesalers at the *woreda* and zone level.

FSC 3 (Farmer group supply chain): The third chain involves smallholder farmers, multipurpose marketing cooperatives (primary and union), consumer's cooperatives and traders (wholesalers). In terms of volume, these channels do not represent more than 10 percent of the teff grain flow, less than for any other supply chain. However, this channel was developed more recently and was highly promoted by the Government because of its greater benefit to the consumer in terms of price, quality and traceability. A study indicates that consumer cooperatives in towns source a large quantity of teff from traders (e.g. zone traders) instead of cooperatives.

The steps in the chain include: Harvesting → Stacking/Piling → Threshing → Storage → Rural assemblers → Transport → *Woreda*/Zone town traders → Transport → Wholesalers in major cities (e.g. Addis Ababa, Hawasa) → Transport → Retailers/Millers (Grain/Flour/Injera) → Consumers.

FSC 4 (Agro-industry supply chain): This supply chain involves smallholder farmers and traders.

The steps in the chain include Assemblers → Wholesalers → Processors → Outlets/Shops. This chain feeds teff into *Injera* industries.

Table 1.3 presents the data on the food supply chains of the study area: Workima *Kebele* of Machekal *Woreda*, in Amhara Regional State. This chain's role is limited in terms of grain volume transacted and shows the lowest scores as shown in Table 1.4.

Tables 1.4 and 1.5 show the criteria for selection, which highlight the importance of the FSCs identified.

Accordingly, researchers chose FSC 3 (Farmer group supply chain) for further analysis in this case study as it scored the highest value/grade for importance.

PRESUMED FOOD LOSSES IN THE SELECTED FSC

Reducing post-harvest losses along food chains can provide more cost-effective and environmentally sustainable means of promoting food and nutrition security than investments focusing on

TABLE 1.3
Food supply chains in the teff subsector

No. FSC	Geographical area of production	Final product	Volume of final product (ton/year)	Number, age and gender of smallholder producers	Market of final product, location, buyers3	Project support
1-4	Workima *Kebele*, Machakel *Woreda*, Amhara	Teff grain	525.6	848 (Age 41, M 811 and F 37)	Hamusit Market (Cooperatives & local assemblers)	IFAD

Note: Since it was difficult to obtain data for each supply chain, the total data for the crop was used
Source: Preliminary screening data

TABLE 1.4
Importance of food supply chains at national level

No. FSC	Economic importance	Generation of foreign exchange	Contribution to national food consumption	Contribution to national nutrition	Environmental impact
1	2	2	3	2	1
2	3	3	3	3	1
3	3	3	3	2	1
4	1	2	2	2	1

Note: 1 = Low, 2 = Medium, 3 = High
Source: Preliminary screening data

TABLE 1.5
Importance of food supply chains for the actors

No. FSC	Percentage of produce by smallholders	Income generation	Involvement of the poor	Employment provision
1	2	3	2	1
2	2	2	2	2
3	3	3	3	3
4	2	2	2	2

Note: 1 = Low, 2 = Medium, 3 = High
Source: Preliminary screening data

increasing production. It can serve to reduce the wastage of scarce production resources (land, water, inputs), thus ensuring more sustainable food supplies and fostering economic growth in Ethiopia.

Even though accurate estimates of PHL in the supply chains are still lacking, the level of losses remains unacceptably high. Significant quality and quantity losses in selected cereal supply chains occur during harvesting, piling, threshing, storage and transporting to market by the different actors (farmers, retailers, wholesalers, etc.). Losses of grain stored by wholesalers, retailers and cooperatives are high because of damage by rodents and birds.

Post-harvest food losses in the supply chain are a major concern and occur in most cereal supply chains. The causes of losses are many and varied. Technical causes may include types of storage; moisture levels; harvesting and threshing methods; drying techniques and attacks by insect pests, rats and other pests.

Data to quantify these losses is lacking. Some studies suggested that losses of 2 to 3 percent, 1 to 2, 4 to 6, 2 to 5, and 1 to 3 could occur in cereals during harvesting, drying, threshing, winnowing, and transportation, respectively (Anon, 1996). Estimates are for average post-harvest losses of food crops such as teff, sorghum, wheat and maize 12.9 percent, 14.8, 13.6 and 10.9, respectively (Dereje *et al.* 1989).

As understood from the desk reviews, Table 1.6 below presents the levels of losses across activities in the teff supply chain. Threshing is the step that exhibits the highest loss by proportion, as compared to other activities in the chain.

Similarly, various experts have identified the same critical loss points in the teff supply chain. Table 1.7 below presents the critical loss points (CLP) and low loss points (LLP) identified, during discussions with experts, and the literature review. The most important critical loss points are harvesting and threshing.

TABLE 1.6
Preliminary screening of food losses in the teff FSC

FSC 1: Major producing area in Ethiopia, Teff Grain Market			
Step in the FSC	***Presumed Losses***		***Comments***
	Quantitative (%)	Qualitative	Causes of losses
Harvesting	1.9		Shattering of grains as a result of weather and method of harvesting
Piling /Field storage	0.6		Experts advise immediate harvesting for proper piling.
Threshing	2.9	Food safety risks if animal waste is mixed with teff grain in the process	During separation of seed from straw, eaten by cattle, stick to soil, threshing field and soil mixture. Waterlogging can also cause severe losses.
Storage at the farmer's house	0.5	Odour of animal droppings, moisture, dampness	New storage facilities (e.g. sacks) and well separated from other grains and from the house premises. This can revert in situation where the storage is old and in house, increasing the risk of losses caused by rodents, water/flood and fire.
Transport from farm to home	2.6		Transportation mainly by donkey on bad roads. The loss occurs during loading and unloading, combined with the poor roads.
Transport from home to market	0.3		
Transport by wholesalers	0.5		
Cleaning and handling by wholesalers	0.3		
Storage by wholesalers	0.2		
Transport by retailer	0.9		
Cleaning and handling by retailers	1.8		Spillage during cleaning and storage by rodents/ birds.
Source: Preliminary screening and farmers' survey data			

TABLE 1.7
Preliminary screening of food losses in the selected teff food supply chains

FSC3: Machakel Woreda, Amhara region, Teff grain			
Step in the FSC	***Expected loss points***		***Comments***
	Quantitative CLP or LLP	Qualitative CLP or LLP	
Harvesting	CLP	CLP	Shattering
Piling/Stacking	CLP	LLP	Damage by termites, birds and animals
Threshing	CLP	CLP	Soil, animal waste
Transport	LLP	LLP	Leakage
Store	LLP	LLP	Rodents
Transport by wholesalers	CLP	LLP	Loading and unloading
Storage by wholesalers	CLP	LLP	Rodents
Transport by retailers	CLP	LLP	Leakage
Cleaning and handling by retailers	LLP	LLP	Spillage
Source: Preliminary screening data			

Chapter 2

The teff supply chain – situation analysis

STATUS AND IMPORTANCE OF THE TEFF FOOD SUPPLY CHAIN

For the teff subsector, FSC 3 (Farmer group supply chain) was found to score the highest value or grade of importance based on the different criteria evaluated (cf. previous section) and was selected for further analysis in this case study.

Description of the teff supply chains

Teff supply chains are long and complex. The main actors in the teff FSCs involve producers, retailers, wholesale traders, millers and *injera* processors. The selected supply chain for teff does not therefore seem very different from those of other cereals as they all involve producers, traders (local assemblers and wholesalers), retailers, processors and consumers.

The case study was conducted in December 2015 at Workima *Kebele* of Machekal *Woreda* in Amhara Regional State. There are 848 teff smallholder producers, 811 are men and 37 women at the *kebele*, where teff was cultivated on 438 ha with an annual production of 525.6 tonnes in the 2014/2015 production season. The estimated average production cost per hectare was USD 68 (Muhammed, 2011).

Farming and production – Producers are at the forefront of the teff FSCs and include smallholder farmers who use local technologies to produce, harvest, thresh and transport teff. The results of the household survey show that an average area of 1 ha per household is allocated to teff production in Workima *Kebele*. This figure accounts for more than 90 percent of the total average farm holdings reported by the survey respondents.

Only 8 percent of farmers employ traditional production methods. Most (36 percent) grow improved teff varieties and use fertilizers, and only 8 percent apply the full package by using fertilizers, improved varieties and improved agronomic practices. However, the majority (96 percent) of the farmers apply fertilizers.

In the 2015/2016 *meher* production season, total teff production was 1.22 tonnes per household (Table 1.8). The data shown are averages computed from data collected from 25 farmers interviewed in the *woreda,* and not from the total area and production of the *woreda*. The calculations therefore are derived from the surveyed data.

Table 1.9 shows distribution of the main actors in the teff supply chain, Tables 1.10 and 1.11

TABLE 1.8
Description of the teff study site, Machakel Woreda (2015/2016)

Item	Average	SD
Total average farm holding (ha)	1.5	0.7
Total cultivated teff area per household (ha)	1.0	0.3
Total harvested teff per household (tonne)	1.22	0.4
Major farming technology applied for teff (multiple responses)	(%)	
Traditional	72	
Improved variety	68	

Source: Farmers survey primary data
SD = Standard deviation

TABLE 1.9
Distribution of main actors in the teff food supply chain by gender

Actors	East Gojjam Zone			Machakel Woreda		
	Men	*Women*	*Total*	*Men*	*Women*	*Total*
Retail traders	1 365	291	1 656	178	22	200
Wholesale traders	204	21	225	1	-	1
Millers	636	144	780	39	15	54
Injera processors	3	1	4	-	-	-

Source: Farmers survey primary data

TABLE 1.10
(Intermediary) products and conversion factors in the FSC

Activity in the process	Duration	Product out	Weight in tonnes from 100	Cumulative Error (± %)	Conversion factor
Harvesting	Nov.-Dec.	Unthreshed teff harvest	4.52	5	100
Threshing	Dec.-Jan.	Straw	3.3	5	73
		Grain	1.22	5	27
Storage	Jan.-Dec.	Grain	1.22	5	100

Figures refer to an average household in the study area.
Source: Farmers survey primary data, secondary data

TABLE 1.11
Detailed description of the food supply chain – BASICS

Stage in food supply chain	Geographical location	Months of the year		Main products	Quantity (tonne)	By-products	Quantity (tonne)	Services
		from	*to*					
Primary Production	Hamusit	July	Nov./ Dec.	Teff farm				
Harvesting	Hamusit	Nov.	Dec	Unthreshed teff harvest	4.52			
Post-harvest handling	Hamusit	Dec.	Jan.	Teff grain	1.22	Straw	3.30	Promotion of teff thresher by NGOs and Cooperatives
Storage	Farm store	Jan.	Dec.	Teff grain	1.22			Promotion of PHL reduction technologies by MoA, NGOs and Plcs
Transportation		Jan.	April	Teff grain	0.33			
Market sales	Hamusit	Jan	April	Teff grain	0.33			

Figures refer to an average household in the study area.
Source: Farmers survey primary data, secondary data

present available information on products and conversion factors in the FSC, as well as a detailed description of the food supply chain (Basics).

Harvesting and threshing – Farmers harvest *teff* manually and thresh it on an animal dung-plastered ground, using mainly cattle or labourers. Farmers use bags to transport *teff* from the threshing fields to the homestead. The farmers use a combination of traditional (72 percent) and improved *teff* seed varieties (68 percent) and the conventional ox-plough.

Storage – After the grain is threshed, cleaned, and measured at the threshing ground, it is stored in the house or outside. Teff grain is stored to reserve seed for the next cropping season, for human consumption, trade and at the cooperative and governmental level for food reserves. Farmers commonly use different sizes and shapes of storage facilities inside or outside their houses. The grain is commonly stored in sacks (polyethylene bags) inside their residence. Some farmers use structures such as traditional *gotera* and *dibignit*.

Sales – There appear to be two types of market outlets for teff producers. Producers near the major markets supply their produce to these markets. Producers located far from major markets may supply rural assemblers or travel to the major markets. Rural assemblers collect teff grain from rural areas and supply major markets. They assemble the grain, and sell it to woreda or zone traders, who in turn sell it on to wholesalers in major cities. There may also be assembly wholesalers who collect the grain from both farmers and rural assemblers and who transport the grain to the terminal market in trucks. To be effective, the assembly wholesalers should have working capital, a weighing scale, a canvas, negotiating skills in the local language, knowledge of different varieties of teff, price information, etc. At the terminal market, assembly wholesalers sell teff directly to wholesalers, retailers and consumers through brokers. These wholesalers are responsible for temporarily storing and negotiating with purchasers until the produce is sold. Retailers/grain shops/millers source grain/flour from wholesalers and sell it to users/consumers.

The regional markets in surplus-producing areas receive their supplies from farmers and assemblers. The farmers often use animals such as donkeys to transport the grain to village or regional markets. They might also sell to rural assemblers who transport the grain in small trucks to sell at the regional markets.

Retailers said they buy teff directly from farmers who bring teff to the market on pack animals or by hauling. Wholesale traders buy grain from woreda traders and their purchasing capacity might range from 3 000 to 24 000 quintals in a given year, depending on the size of their wholesale business and availability of the crops. They often use trucks for transportation and their businesses are in the zone (Debre Markos) and regional (Bahir Dar) capitals. The retailers then sell their purchases to government institutions such as universities (e.g. Bahir Dar University) and public hospitals.

Major wholesale markets in surplus producing regions supply teff to the central market in Addis Ababa (*Ehil Berenda*). There may also be brokers who link the regional sellers to buyers at the central market for ETB 1 to 3 per 100 kg. In the absence of large-scale teff milling firms, the main buyers at the central markets are small retailers and millers. The number of small flourmills that retail teff has increased substantially in recent years, and most consumers in Addis Ababa can buy teff grain from these millers (Woldu *et al.* 2013). Some regional traders in deficit areas can also buy from the central market.

Small-scale traders dominate the regional and central teff markets because there are no large traders with larger storage and trucking capacities. Assemblers at village markets and wholesalers at regional markets pay close attention to the quality of teff. Three general colour-based teff grades were identified being white, mixed and red. White fetches the highest price and red the lowest.

Milling or processing – Millers are an important group of actors in the teff supply chain as they provide milling services to the community.

Injera makers are another group of actors in the teff supply chain who handle large quantities of teff in a year, and this is especially true of *injera* processors who operate micro and small enterprises, which are mostly found in the towns of Debre Markos and Bahir Dar. Large quantities of *injera* are provided to universities, health institutions and hotels in the towns.

Cooperatives (both primary and unions) also play an important role in the teff FSC. For example, the Ghion Agricultural Cooperative Union in Dejen town, East Gojjam zone, with 134 000 members, women account for 18 percent, can handle large volumes of teff annually (16 000 quintals in 2014/2015, for example) and has a noticeable presence in the teff supply chain. Primary cooperatives, such as the Gozamen Woreda Primary Agricultural Cooperative, also have direct links with member teff producers.

TEFF MARKETING SYSTEMS

Teff can be stored for a long period without damage by weevils. Indeed, its small size makes it difficult for insects to manoeuvre and survive in the grain. It is also possible to store in any locally made storage container. Some wholesalers usually store the grain until the price is at its highest level,

which requires a huge investment for warehouses and working capital. However, since most rural grain traders have very small storage-holding capacity and poor facilities, the stock is usually transported immediately to the central grain market so they can recoup their working capital.

The two types of markets are conventionally termed major (formal) and village markets (informal). Major markets are connected to zone cities, regional cities and Addis Ababa by all-weather highways. In a *woreda,* there are also towns that are considered to be major markets, which do not have outlets to zone cities, regional cities and Addis Ababa on all-weather roads. These major markets have easy access to transport facilities. The study revealed that farmers travelled as far as 30 km to reach the major markets. Farmers gave details on the specifics of each marketing transaction: 25 percent of the sales are to consumers and retailers, about 20 percent sell directly to consumers, retailers and cooperatives, and 12.5 percent do not sell at local markets.

Assembly wholesalers at the major markets traditionally grade teff into five categories for quality as follows: *Magna* (very/super white), *Nech* (white), *Sergegna* (mix between white and red), and *key* (brown). Super white is the best quality and fetches farmers a premium price. The price paid for teff varies with quality, marketplace and time of sale (FAO, 2015), for example, there was a price peak for teff in June, which was about 46 percent higher than the price at the time of harvest. Indeed, at harvest time, farmers supply the grain to the market to meet their cash needs and to pay the loans for fertilizers and other inputs, while June is for preparation for planting teff. Grain in stores decline rapidly, as well as the quantities supplied to markets. The price of teff grain during the case study in Addis Ababa (*Ehil Berenda*) was USD 0.81 per kg.

According to Engida (2009), village markets are located off the highway and most of the time they supply the marketable surplus to the nearby major markets in a given *woreda*. Farmers establish village markets to provide a market outlet for their produce and to obtain consumable items when they are unable to visit major markets. At times, when family members engage in agricultural activities, farmers provide, as they have to, their teff produce to rural assemblers at village markets. Moreover, village markets feature one or two types of agricultural products that are eventually supplied to major markets through rural assemblers.

In general, cereal market supply chains in Ethiopia are long and complex (Rashid and Asfaw, 2011). According to Bekabil *et al.* (2013), the teff supply chain features heavy involvement of brokers and intermediaries, as observed for the teff supply chain at Addis Ababa market. Roughly, 70 percent of the marketed production of teff in Ethiopia routes through channels and markets in Addis Ababa (ATA, MOA and EIAR, 2013). Brokers are the major players at Addis Ababa *Ehil Berenda* market. Most trades operate on the spot every day, except Sunday, from 8 am to 10 am. Brokers at regional markets work as agents of traders and negotiate prices and grade levels with farmers, who often have limited bargaining power (Fufa *et al.,* 2011) and arrange for teff purchases by making a phone call to a wholesale trader in a surplus area. Brokers and traders typically form long-term relationships to minimize the risk of cheating. There is very little apparent stocking of teff with *Ehil Berenda* traders, as they store only enough to satisfy petty trade during the day. The authors were not able to observe storage of teff at any point along the value chain, either with traders at surplus areas or with millers in Addis Ababa.

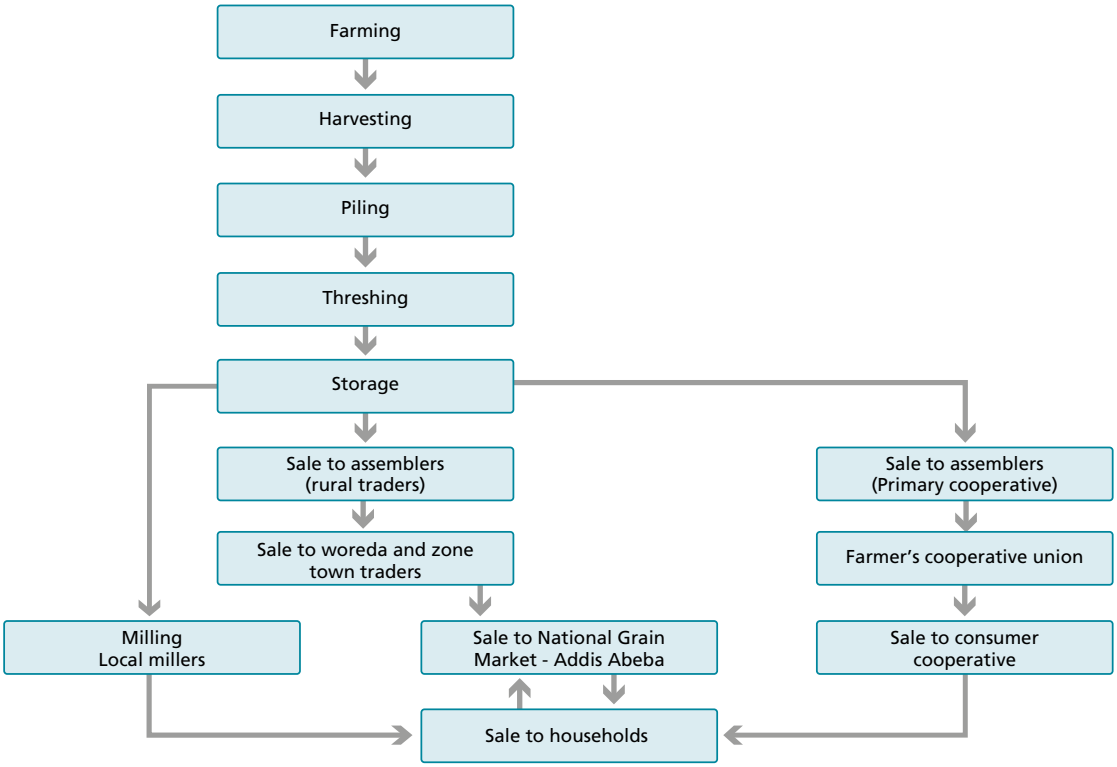
Eleni (2001) notes that the structure of the value chain, including the reliance on brokers, is rational from the traders' viewpoint, given the high variation in teff quality observed and the difficulty in testing at the point of sale.

Adding teff to the Ethiopian Commodity Exchange (ECX) would improve the transparency of the teff market and enforce existing standardization. The Ethiopia Standards Agency has already established a standard grading system. However, this system is not well known or used and teff is not among the main commodities traded on the ECX thus far. Trade is largely limited to coffee, sesame and beans. Teff should be included in the ECX suite of traded commodities and high-priority crops. This will lead to more efficient transaction opportunities and wide-scale prevalence of market information on teff. The development of grades and standards, which are commercially meaningful and enforced, is an important element in the creation of a reliable and effective market. This will also promote a price premium for better-quality grain.

SUPPLY CHAIN ACTORS' INVOLVEMENT, BENEFITS, JOB CREATION AND INCOME

Women play a key role in teff production, harvesting, and post-harvest activities, including piling, transporting, storage, and food preparation.

FIGURE 1.2
Flow diagram of the selected teff supply chain showing the specific points and stages



Source: field data.

Because of their critical role, women should be involved in efforts to reduce teff losses at all stages of the value chain, but specifically during storage and processing where women are most involved. Surveys in a wide-range of countries show that *women are responsible for 85 to 90 percent of the time spent on household food preparation* (WFP, 2013) and this shows that focusing training on women for food preparation may reduce most of the food losses occurring at the preparation stage.

Women's critical role in post-harvest activities is evident from the responses provided by survey respondents in Machakel *Woreda*, as indicated in Tables 1.12 and 1.13. From the results, women are in the majority, except in the area of transporting grains to the market where men seem to take a leading role. Even in the latter's case, women along with men actively participate in transporting food grains to the market. This shows that targeting women in grain loss reduction strategies is crucial to having a meaningful impact on efforts to reduce grain loss at all stages of the grain chain. Traditional methods of primary production, harvesting and post-harvest handling (Tables 1.14 and 1.15) all contribute to losses in the supply chain, which negatively impact the environment.

TABLE 1.12
Views of women's role in post-harvest handling, Machakel Woreda

Item	Frequency (N=25)	%
Do women participate in stacking or piling harvested grains? (Yes responses)	25	100
Who is responsible for making traditional storage facilities? Mostly women	18	72
Who is responsible for managing traditional storage facilities?		
▪ Mostly women	11	44
▪ Men	1	4
▪ Both women and men	13	52
Who is responsible for transporting grain to the market?		
▪ Mostly women	-	-
▪ Mostly men	6	24
▪ Both men and women	18	72

Source: Farmers survey primary data

TABLE 1.13
Description of the Food Supply Chain – social structures

Steps in Food Supply Chain	Involvement of women		Involvement of men		Who is mainly involved: women, men, children	Organization level of FSC actors	Gender / social patterns Observations and remarks that explain the chosen qualifiers and/or give additional information
	Girls	Adult women	Boys	Adult men			
	*Qualifier**	*Qualifier*	*Qualifier*	*Qualifier*			
Primary production	1	1	3	4	Men	Individual level	Boys mostly help men to do field work
Harvest		1	2	4	Men	"	Women are rarely involved
Post-harvest, handling	1	2	2	3	Men	"	Women and boys are actively involved in stacking and threshing
Storage		4		3	Women	"	Women are more active in storage management
Transportation		2		3	Men	"	
Market sales		2		3	Men	"	
Agroprocessing		1		3	Men	Traders	
Storage		1		4	Men	"	
Transportation				4		"	
Wholesale		1		4		"	
Retail		3		3	Men	"	

*Qualification of the gender participation level, 4 - high, 3 - good, 2 - moderately good, 1 - low.
Source: Farmers survey primary data and secondary data

TABLE 1.14
Description of the food supply chain – Environment

Production		**Quantity**	**Unit**
Tools, Equipment, Facilities	Ox-plough set	1	Set
	Knapsack sprayer, sickle	1 each	Piece
Materials, Chemicals	Fertilizer	200	kg
	Herbicide	1	Litre
Energy	Oxen power	1	Pair
Water	Rainfed		
Land		1.0	ha
Storage		**Quantity**	**Unit**
Tools, Equipment, Facilities	Traditional storage structure	2	Piece
Materials, Chemicals	Polypropylene bags	12	Piece
Transportation		**Quantity**	**Unit**
Tools, Equipment, Facilities	Polypropylene bags	12	Piece
Energy	Pack animal	1	Individual

Figures refer to an average household in the study area.
Source: Farmers survey primary data and secondary data

TABLE 1.15
Factors considered for the environmental assessment

Factors	**Description**	**Details**
Type of production system	Traditional	Oxen drawn ploughing, manual harvesting, threshing, etc.
Land preparation practices	Oxen drawn ploughing	
Soil quality and land degradation	High	Loss of top soil because of repeated ploughing
Ecosystem impacts	Land degradation	
Sources of GHG emissions	Low	
Utilization of residues in the Supply chain	Teff straw for sale, feeds and used in Construction	

Source: Farmers survey primary data and secondary data

Chapter 3

Food losses – study findings and results

DESCRIPTION OF THE SUPPLY CHAIN – RISK FACTORS

Teff faces a number of risks. The first has to do with production and shortage of rain is an important determinant. In Mechakel, teff production is entirely dependent on rain and when there is not enough, farmers face the risk of total or partial crop failure. Harvesting, piling, threshing, transportation and storage activities all pose risks of both quantitative and qualitative losses.

Farmers are likely to lose production if they do not harvest teff on time. Moreover, respondents indicated that teff is lost during threshing, both in quantitative and qualitative terms. Although there is a lack of quantitative data on loss during threshing at the farm level, it is known that farmers mix a good amount of teff with straw given to animals as feed. This occurs during threshing when using animals. The use of mud-plastered ground during threshing causes teff to become mixed with soil, a critical factor that adversely affects the quality. During transportation the use of old, perforated bags with holes for packaging may result in teff losses from spillage. Further, farmers store teff in traditionally constructed and mud-plastered containers that are vulnerable to infestation by rats and other pests. Also, loading and unloading present their own risks, since bags might be broken because of rough handling at the time of loading and unloading.

An average of 2 to 4 kg of teff is lost per quintal, according to an estimate given by one retailer. Primary cooperatives train farmers on how to reduce losses. Teff loses value as it passes through the different stages before it reaches consumers. Cooperative unions use new bags to store teff and encourage their members to do the same to reduce the losses linked to the use of old bags, but shortage of new bags is a problem.

Table 1.16 below describes the relationship of some risk factors and food losses. Here, the purpose is to have some idea of the most important factors influencing teff losses, though they are difficult to quantify properly using statistical methods for one season and one FSC. Accordingly, the important food loss risk factors are considered to be pest resistance, training, knowledge and awareness of farmers, amount of rainfall, and practising good farming methods such as the right time for planting and harvesting, and storage practices.

TABLE 1.16
Food loss risk factors

Variable	Unit	Expected Status	Reducing Loss – Percentage of estimated value contribution (observed in the case study)
Crop variety	Type	Pest resistant variety	10
Good Agricultural Practices (GAP)	Y/N	Yes	20
Rainfall during production	mm	Optimum range	15
Training and knowledge about the causes of losses	Y/N	Yes	20
Others			35

Source: Farmers survey primary data
Others include inaccessible markets, poor storage facilities and diseases.

CRITICAL LOSS POINTS IN THE TEFF SUPPLY CHAIN

The combined results of the survey and sampling methods were used to estimate losses d along the teff supply chain.

Table 1.17 presents the average losses at farm and community levels estimated by the actors in the FSC. The highest average loss was recorded at wholesaling (8.5 percent) followed by threshing (7.7 percent). The average estimates of grain losses during harvesting, stacking or piling, farm storage and transport were 5.6 percent, 6.3, 3.2 and 2.2 respectively. The cumulative estimate of quantitative post-harvest loss is therefore 25 percent, without considering the quality losses. Load tracking assessment showed an 11 percent loss at threshing.

The equivalent monetary losses were USD 4.5 (harvesting), USD 5.1 (piling), USD 6.2 (threshing), USD 1.8 (transport), USD 2.6 (storage), USD 6.9 (wholesaling) and USD 6 (retailing), per 100 kg of grains.

Some estimates, especially for the wholesalers, appear to be exaggerated, although the possibility of exceptionally high losses is real. The problem is that there is often confusion between loss and damage. Losses are a measureable reduction in quantity or quality, while damage is a visible sign of deterioration, for example broken or punctured grain and can only be partial.

Farmers are aware that losses occur not only during storage but also at different stages of the post-harvest system, at harvesting, drying or threshing, winnowing and transporting. It was mentioned that harvesting losses are high when the grain is over dried, which causes shattering.

Generally, the magnitude of losses reported to occur at each stage is not negligible, and the combination is significantly high. Although not measured, survey loss estimates are not very far from the data reported in other parts of the country.

Low loss points

The low loss points were identified as transportation (2.2 percent) and storage (3.2 percent). The low losses during transportation are largely because of good packing and careful handling of the harvested crop by farmers. Losses during storage are low because there are no major insect pests that attack teff. Another reason for low losses is the use of clean polyethylene bags.

LOAD TRACKING AND SAMPLING METHOD

Quality and quantity losses of teff at the threshing stage were measured on the basis of the results obtained from 1 kg teff samples collected from nine farmers (one sample per farmer) in three villages of Workima *Kebele* (three farmers per village), as explained in the section describing the methodology earlier in this report.

In each of the three selected villages, the researchers manually threshed some of the harvest to obtain three 1 kg grain samples before farmers did their own threshing. Farmers then threshed some of the harvest using the traditional method of trampling by animals to provide three 1 kg grain samples. The researchers were focusing on assessing the traditional threshing method with respect to its impact on grain quality and levels of quantitative and qualitative losses. The objective was not to compare the impact of the two different threshing methods on losses.

All samples were then analysed in the laboratory to determine the losses as per the parameters set for teff (Table 1.18).

Quality analysis

The results show that the quality of the samples obtained with the traditional threshing method (animal trampling) is lower than the quality of the samples obtained with manual threshing. Table 1.19 shows why teff samples have higher impurities after traditional threshing. Traditional threshing is time-consuming, laborious and involves significant losses in quantity and quality. The threshing floor exposes the grain to soil, sand and other foreign matter. In addition, waste contaminates the grain unless the animal's mouth is tide closed as the oxen feed off teff grain and straw.

Foreign matter such as sand and soil, which are difficult to separate from the small-sized teff grain during cleaning, contribute significantly to a decrease in market value.

Labour and access to oxen is crucial for traditional threshing to ensure full scale threshing to ensure minimum loss. The lack of labour, limited access to oxen and overall poor traditional threshing practices lead to 22 percent grain quality losses as indicated in Table 1.20, mainly because of the high presence of sand, straw and soil, which result in 11 percent loss.

The data showed that all the properly threshed initial samples are good quality while samples taken from the grain threshed by the farmers had a high level of straw and soil mixture. Poor farm-

TABLE 1.17
Summary result matrix of food losses

FSC Stage/Process		Percentage quantity lost in the activity/ step	Cause of loss/Reason for low loss	Economic loss (ETB/100 kg of grain)	CLP/LLP	Impact/ Stake-holders affected (men/ women)	Perception of stakeholders (men/women)	Suggested solutions
Production	Harvesting	5.6	Shattering of the seeds, head breakage and spoilage resulting from excessive moisture	95.2		Farmers		Harvest when the moisture content is right. This is achieved through training and being able to test moisture content
	Stacking/ Piling	6.3	Damage by rats, rain and domestic animals	107		Farmers		Creating pest barrier or placing the grain on raised wooden frames with metal baffles
	Threshing	7.7	Contamination of grain with soil/waste of trampling animals	130.9		Farmers	Manual threshing is time consuming and significant losses occur, both qualitative (presence of impurities) and quantitative	Use of machinery, such as a thresher with a teff cleaner, would reduce the work burden on people and animals
Farmers' transportation		2.2	Spillage of grains when sacks punctured	37.4	Low loss because farmers transport their grain with care	Farmers	Use clean bags	Avoid careless handling of the grain
Farm storage		3.2	Rodents, discoloration	54.4	Relatively low loss since there is no major storage insect pests	Farmers	Poor storage structures. Not aware of improved storage structures.	Use modern storage facilities such as hermetic bags, metal silos, supper bags
Wholesale		8.5	Losses during loading and unloading and transportation by trucks, when old sacks and bags are used and storage	144.5		Wholesalers		Training and use of good bags, specially designed carts to transport farm produce.
Retail		7.4	Spillage during loading and Unloading, during storage	125.8		Traders		

* Loss figures are estimates from the actors of the FSC, with a possibility of overestimation or underestimation.
1 USD = 21 ETB; Price of 1 kg teff grain = ETB 17 (USD 0.81
Source: Primary farmers survey data

TABLE 1.18
Quality scoring for teff grain

Product	**Teff grain**	
Quality score	***Description of the quality***	***Percentage reduction of market value***
0	Foreign matters equal or greater than 5 % and overall impurity (that is foreign matter and stone) equal or greater than 5.5 %	24
1	Foreign matters equal or greater than 3.5 % and overall impurity (that is foreign matter and stone) not exceeding 4 %	18
2	Foreign matters equal or greater than 2.5 % and overall impurity (that is foreign matter and stone) not exceeding 3 %	8
3	Foreign matters equal or less than 1.5 % and overall impurity (that is Foreign matter and stone) not exceeding 2 %	Market price (USD 0.81) per kg

Source: Sample data

TABLE 1.19
Quality analysis of sampled units before (pile) and after threshing stage at farmer level

Before (pile) and after traditional (animal trampling) threshing stage	**Unit Evaluated**	**Overall Quality Score**	**Type of damage (Deterioration) if any**	**Potential causes and symptoms**
Before (Pile) traditional threshing stage	1	2	Presence of moderate foreign matter	Threshing properly done (manually) Foreign matters such as sand and soil, which are difficult to separate from the small sized teff grain
Before (pile) traditional threshing stage	2	2	Presence of moderate foreign matter	Threshing properly done (manually) Foreign matters such as sand and soil, which are difficult to separate from the small sized teff grain
Before (pile) traditional threshing stage	3	3	Presence of moderate foreign matter	Threshing properly done (manually) Foreign matters such as sand and soil, which are difficult to separate from the small sized teff grain
Before (pile) traditional threshing stage	4	3	Presence of moderate foreign matter	Threshing properly done (manually) Foreign matters such as sand and soil, which are difficult to separate from the small sized teff grain
Before (pile) traditional threshing stage	5	2	Presence of moderate foreign matter	Threshing properly done (manually) Foreign matters such as sand and soil, which are difficult to separate from the small sized teff grain
Before (pile) traditional threshing	6	2	Presence of moderate foreign matter	Threshing properly done (manually) Foreign matters such as sand and soil, which are difficult to separate from the small sized teff grain
After traditional (animal trampling) threshing stage	7	1*	Non-compliance with standards and physiological damage	Symptoms: moderate presence of straws, sand and soils Cause: poor farming practices during threshing and cleaning
After traditional (animal trampling) threshing stage	8	1*	Non-compliance with standards and physiological damage	Symptoms: moderate presence of straws, sands and soils Cause: poor farming practices during threshing and cleaning
After traditional threshing Stage	9	0*	Non-compliance with standards and physiological Damage	Symptoms: high presence of straws and soils Cause: poor farming practices during threshing and Cleaning

Source: Load tracking and sampling data

TABLE 1.20
Presentation of load tracking and sampling results

A	Product	Teff grain			
B	Event	Threshing			
C	Duration of the event	One day			
D	Location	At the homestead			
	Before the event	**Experimental Unit**	**Weight of Unit kg**	**Percentage of unit**	**Total weight in kg**
E	Load	Group of farmers/ farmer field (expected yield of farmers)	500	27	13 500
F	First stage sample	Group of farmers/ farmer field (expected yield of farmers)	500	9	4 500
G	Second stage sample	Grain sample /scoop		9	9
		Value (score/%)	Observation /Causes		
H	Sample size second stage	9 kg			
I	Average quality score (0-3)	2.7	Less quality deterioration noticed due to presence of moderate foreign matters		
J	Percentage unfit (0)	0			
K	Percentage low quality (1)	0			
	After the event (threshing)	**Experimental Unit**	**Weight of Unit kg**	**Percentage of unit**	**Total weight in kg**
L	Load	Group of Farmers/ farmer harvest (expected yield of farmers)	500	27	13 500
M	First stage sample	Group of Farmers/ farmer harvest (expected yield of farmers)	500	9	4 500
N	Second stage sample	Grain sample/scoop	1	9	9
	After the event	**Value (score/%)**	**Observation /Causes**		
O	Sample size second stage	9 kg			
P	Average quality score (0-3)	1.8	High presence of straws and soils are the main factors for quality deterioration caused by poor farming practice during threshing and cleaning.		
Q	Percentage unfit (0)	11			
R	Percentage low quality (1)	22			
	Quantity loss	**Value (%)**			
S	Percentage lost (E-L)/E	0			
	Quality loss	**Value (%)**	**Observation /Causes**		
T	Percentage lost (Q-J)	11			
U	percent age quality Reduction (R-K)	22			

Source: Load tracking and sampling data

ing practices during threshing and cleaning are the main factor for quality deterioration. Foreign matter ranges from 0.6 to 3.24 percent. The figures marked with an asterisk (*) in Table 1.19 are thus an average of 88 percent quality deterioration (increase in impurity). These three samples with high impurity are those from the third replication in the third village located at a distance from Hamusit town. The cause is poor farm practices resulting from limited access to extension services.

CAUSES OF LOSSES AND POTENTIAL LOSS REDUCTION MEASURES

Losses occur at different stages of harvesting, stacking and threshing, storage and transporting. In Ethiopia, most of the post-harvest operations are traditional and the activities are time consuming, labour intensive, and they often reduce the quality and quantity of the final product through the unintended mix of grain and straw. A significant amount of teff is lost because of shattering, both during and after harvesting.

Harvesting – Teff is not suitable for mechanized harvesting because of waterlogging and shattering of seeds during harvesting. For example, if harvested along with teff, grass and weeds lower the quality of the product. Farmers usually do their best not to harvest grass and weeds along with teff. Losses at harvesting are usually because of shattering of the seeds when the grain is very dry, head breakage and spoilage from excessive moisture content. Late harvesting and poor handling leads to shattering, which is another source of significant yield loss in teff production.

Farmers attempt to reduce post-harvest losses at different levels by using indigenous knowledge developed over time. Traditional best practices include timely harvesting of the crop before it is too dry and avoiding wet harvesting that might result in significant losses from mould infestation.

Piling/stacking – The harvested crop is 'piled' near the threshing ground in the village where a large stack or pile is built. Causes of losses at this stage include attacks by animals, insects (especially termites), rodents and birds. Grains stacked for a long time will suffer huge losses because of untimely rains.

The base of the stack is made of stones, to prevent termites from entering the crop and to protect the stalks from roaming animals. In areas without termites, the stacks can be placed on bare ground. Farmers build the stacks in a way that protects the grain from the damp and from animals. The crop remains in the stack until the farmer is ready to thresh.

Threshing – Farmers thresh teff crop by using animals to trample it. Loss in quality also results from the contamination of the grain with soil and waste from trampling animals. Unless the animals' mouths are tied, they feed on the teff sheaves, chaff, and grain while threshing, which results in even higher quantity losses. During threshing, losses also occur because of spilling out grains from the threshing floor.

Threshing on a smooth and wide threshing plot reduces loss during threshing. Tying the mouths of the animals prevents them from feeding on the grain, thus reducing losses. The use of a thresher with teff cleaner can significantly reduce losses during threshing.

Transporting – People or pack animals transport the harvest from the field to the threshing floor. Losses at this stage result from shattering of seeds off the panicles. To transport grain from store to market, farmers use animals or hire trucks depending on availability and quantity of grain. Losses could occur as a result of leakage of grains when the sacks are damaged.

Losses could be minimized by use of clean sacks with openings that are tied up or sewn together to prevent leakage.

On-farm storage – Rodents and weevils cause losses in storage. These pests threaten stored grain through feeding, contamination and structural damage.

Different traditional practices could be employed such as cleaning the store before the new harvest reduces grain losses. The use of improved storage structures, i.e. metal silos, hermetic bags or super bags can minimize losses in storage. The use of pesticides is also a common practice used to control pests and reduce losses. Storing properly dried grain, and inspecting and following up with good hygiene of the store are important in minimizing the risk of storage losses. Most farmers in the surveyed district used sacks inside their houses. In general, there is low adoption of improved post-harvest technologies by Ethiopian teff farmers.

Marketing – Grain losses when handled by non-farmers such as traders, retailers, wholesalers, primary cooperatives and cooperative unions occur mainly during loading and unloading, transporting and storage of the grain. Teff grains are stored in sacks or in bulk in relatively improved storage structures with concrete floors and ventilation. Rats are a major threat and farmers use rodenticides to minimize losses.

Specifically, teff losses occur during collection from producers. Farmers bear most of the losses at this stage and during transfer from sellers' bags to traders'. Traders experience teff loss while transferring grain from collection points to storage

as labourers sometimes drop the teff load while standing, leading to broken bags. Retailers also face teff losses during storage because of poorly constructed and maintained storage structures, which are often vulnerable to pest infestation and moisture. However, most rural teff traders handle small amounts of teff, no more than 70 quintals per year, according to a respondent from Workima *Kebele*, Machakel *woreda*, and the loss could be 1 to 3 kg per quintal. Wholesale traders experience losses during transportation as bags may be broken during loading and unloading and storage, which can result in pest infestation and spoilage from excessive moisture.

Milling and processing – Grain loss occurs at the point of milling during weighing and pouring grains into the milling machine. Losses occur when old, leaking bags are used and when grain handlers fail to carry the bags properly. Interviewed millers indicated that the loss is often borne by customers who bring their grains to the millers for milling. Customers may lose 1 to 3 kg per quintal.

Injera processors face losses when preparing the grain for milling, when separating teff grain from impurities. The greatest loss occurs when fine particles of sand are mixed with teff (*ketch-kech*) resulting in customers rejecting the *injera*. *Injera* processors also face teff losses when power is interrupted at the time of baking, which can lead to the *injera* being half-baked.

Important interviews with primary cooperative officials revealed they experience grain losses when collecting small quantities of grain from farmers and transferring it into small bags, which may be old and broken. Grain losses may also result from poor quality storage facilities that are often made of mud-plastered walls and floors exposed to excessive moisture. Union cooperatives, on the other hand, are less susceptible to losses as they are relatively better organized with transportation, storage facilities and store management.

LOW LOSS POINTS IN THE TEFF SUPPLY CHAIN

The identified low loss points are transportation (2.2 percent) and storage (3.2 percent). The low losses during transportation are largely because of good packing and careful handling of the harvested crop by farmers. Losses during storage are low because there are no major insect pests that attack teff. Another reason for low losses is the use of proper clean polyethylene bags

IMPACT OF FOOD LOSSES ON THE TEFF SUPPLY CHAIN

Impact on food security

Many smallholder teff farmers in Ethiopia live on the margins of food insecurity and a reduction in food losses would have an immediate and significant impact on their livelihood. The issue of food losses should be the highest priority in the effort to combat hunger, raise incomes and improve food security in Ethiopia.

Teff loss reduces food availability at the household level. Labour is also wasted as it is used for the production of unused food. Farmers also invest their limited financial resources to buy chemical fertilizers and improved seed to increase teff production but some of grains are lost without reaching the producers' storage. Overall, grain loss leaves smallholder farmers at risk of food insecurity since it negatively impacts the amount of food available to the household.

Traditional and regressive handling of post-harvest operations may occur as a result of the lack of appropriate and feasible technologies and represent the main constraints to the reduction of post-harvest losses. The lack of awareness among farmers, agricultural personnel, policy-makers and other stakeholders of the negative impact of post-harvest losses are hindrances to reducing post-harvest losses at the farmer level. The promotion of the post-harvest sector is also constrained by an inadequate policy framework, the lack of technical and technological support to farmers, and the financial constraints that are faced by post-harvest technology generators, private distributors and smallholders. Moreover, the areas of concern regarding the sector's development include the lack of focused training and education about the country's post-harvest problems and solutions, poor linkages among education, research and extension services, the absence of institutions in charge of coordinating and facilitating operational and policy research and related activities.

Environmental impact

In Machakel, farmers allocate the greater part of their holdings to teff production. Because teff is a primary crop in the area, losses at various stages of the food chain affect farmers directly.

Teff requires several rounds of turning the soil and this leads to soil erosion and depletion of the natural resource base. This may also impact smallholder farmers' vulnerability to climate change and their ability to adapt or become resilient to climate change. Production of teff is also chemical

TABLE 1.21
Farmers' views regarding environmental impacts of food loss, Machakel *woreda*

Item	Machakel/Teff	
Do you think food loss impacts the environment negatively?	Yes (%)	No (%)
	0	100
Do you think food loss aggravates depletion of the natural resource base (e.g. land, etc.)	Yes (%)	No (%)
	12	88
What kind of impact has agriculture on the environment in general:	Yes (%)	
▪ Positive	36	
▪ Negative	4	
▪ Neutral	40	
▪ Not sure	20	
Do you think the application of chemical fertilizers in the production of grains impacts the environment negatively?	Yes (%)	
▪ Yes	52	
▪ No	48	

Source: Farmers survey primary data

fertilizer intensive, which is not good for the soil, the land and the environment in general. However, farmers do not seem conscious of the negative impact of losses on the environment as indicated by the response to the question: *do you think food loss impacts the environment negatively?* All of them said '*no*' (Table 1.21). Most do not think agriculture negatively impacts the environment. It is only the application of chemical fertilizers, perhaps based on their own experience, that Machakel farmers see as having some negative impact on the environment (52 percent). It is clear that the linkage between food loss and the environment is not obvious to farmers, a fact that indicates there is a need to educate farmers on the impact of efforts to combat food losses related to the environment.

Interventions and strategies to reduce losses

Although some marked increases in production volumes were recorded in recent years because of the adoption of improved varieties and growing techniques, the payoff after harvest is still insignificant. This is because of costly losses, high labour requirement, inappropriate facilities and poor product quality resulting from poor post-harvesting and handling systems.

Technologies recommended

Harvesting – Farmers use hand-held sickles to harvest teff, which is both laborious and inefficient. A hectare of teff requires 210 hours of harvest time (Friew and Lake, 2013). Almost all varieties of teff are susceptible to waterlogging, particularly those with thin and tall stems. Modern harvesters can provide for harvesting severely waterlogged crops, such as teff, if proper adjustments are made between the header and the pickup reel. A study by Friew and Lake (2013) on teff harvesters indicated that the loss from the modified pickup reel was about 6 percent while the loss from the original harvester was about 18 percent.

On the other hand, as shattering is also a cause of significant yield losses in teff, timely harvesting of the crop helps.

Threshing – Lack of labour is one of the major challenges in the post-harvest processing step. Based on farmer focus group discussions in three high-producing teff zones, traditional threshing can take 20 to 30 days of human labour and 10 oxen days/ha. The use of machinery, such as a thresher with teff cleaner, would reduce the work burden and harvest the crop before the onset of the rains.

The mechanical thresher provides significant benefits to farmers based on gains in productivity, improvement in quality and reduced labour costs. A threshing-shelling machine that has been developed at Melkassa Agricultural Research Centre had a teff-threshing capacity of 0.1 tonne/hour (Friew *et al.* 1994). This machinery has not been widely adopted by small-scale farmers because of the price (ETB 40 000 to 50 000), which is beyond their reach. Estimated annual income

TABLE 1.22
Summary of teff food losses, causes and solutions

Critical Loss Point	Magnitude of losses in the FSC			Cause of loss	Intervention to reduce losses	Loss reduction		Cost of intervention (USD) on 10 years	Economic implications	Social implications	Food security implications	Environmental and climate change implications	Policy implications
	Percentage	Weight tonne/year	USD /year			Percentage	Savings USD						
Threshing	7.68 (Qn)	0.094	76.6	Contamination of grain with soil/waste of trampling animals	Use of machinery, such as a thresher with teff cleaner	75	57.5	2,381	- 181 Not profitable for individual smallholder farmers	Improved livelihood, better education and health, would reduce the work burden on people and animals	Contributes to food security	Free from chemicals	Ensured food security, better society for better development
Threshing	22* (Ql)		179										
Storage	3.2 (Qn)	0.039	32	Rodents, discoloration	Metal silo (500 kg capacity)	75	24	165	7.4 Profitable solution, Increased income	Improved livelihood, better education and health	Contributes to food security	Free from chemicals	Ensured food security, better society for better development

Source: Farmers survey and load tracking primary data and secondary data
* Result of the load tracking and sampling assessment
NB. Qn = quantitative and Ql =qualitative
The qualitative losses at threshing are estimated at 22 percent (results of the analyses on samples). The product loses 18 percent of its market value.

of smallholder farmers is ETB 20 000 to 30 000. Private suppliers and unions or cooperatives can provide services to individual farmers or groups on a rental basis.

Storage – Metallic silos effectively protect stored grain from rodents, birds and fungi. With proper management, the grain can be stored for longer periods without loss of quantity and quality. Local blacksmiths at zone or *woreda* levels can produce metal silos of different storage capacities.

Maize farmers in Kenya and Malawi who adopted metal silos are food secure, they have one month more of sufficient food supply than non-adopters. Silo adopters save an average of USD 134 in grain and USD 18 on insecticides (FAO, 2010). Large wholesalers and retailers may also benefit from this type of storage facility.

GENERAL MEASURES FOR REDUCING POST-HARVEST FOOD LOSS

- Minimal attention is given to the reduction of post-harvest food losses by research and development institutions (extension). Therefore, all levels should address this lack of attention.
- Increase awareness of the benefits of post-harvest improvements at all levels since increasing production without attention to post-harvest management is a waste of resources.
- Training of extension staff and farmers about how to reduce post-harvest food losses should be organized and implemented periodically.
- Institutionalize the post-harvest sector and all post-harvest food losses reduction activities: research, extension and education should be coordinated among the different stakeholders.
- Focus on the distribution of post-harvest bags to poor farmers, particularly women.
- Needs assessments should guide the improvement or introduction and promotion of post-harvest technology.
- Improve traditional storage structures to address problems of moisture and rodents and regulate the use of storage insecticides to ensure proper marketing and application of pesticides.
- Introduce and validate warehouse receipt systems at unions and cooperatives.
- Women play a significant role in post-harvest handling, processing, marketing, and household food security. Institute interventions that reduce women's workload and that facilitate their access to and control over grain.
- Create linkages among the private sector, microfinance institutions, agriculture research and extension, and other stakeholders to advance the reduction of post-harvest food losses.
- Test and validate a farmer-field school approach to reduce post-harvest losses with robust links to Farmer Training Centres (FTC), agricultural research centres and other stakeholders.

Cost-benefit analysis for measures identified at the critical loss points

Budget calculation for food loss reduction

Tables 1.23 and 1.24 show an assessment of the economic feasibility of two interventions recommended to reduce teff qualitative and quantitative losses at farm level. Small farmers are the main beneficiaries of the proposed interventions. However, the use of improved storage technologies would greatly benefit wholesalers and retailers who suffer significant losses in terms of transport and storage.

Threshing – Table 1.23 shows the solution is not profitable for one farm household despite the reduced losses realized. The cost of buying and operating a threshing machine is too high for a farm household. It is advisable that unions and private suppliers provide threshers to rent, as is the case in the Shashemene area.

Improved post-harvest processing also results in high quality grain and straw, which are marketable at competitive prices. In short, enhanced mechanization of teff can drive sustainable development needed by Ethiopian smallholder agriculture.

Storage – Table 1.24 demonstrates the metal silo is profitable for the individual farmer. Metal silos have different storage capacities, ranging up to 1 tonne, with prices varying between ETB 2 900 to 4 000. A farmer can therefore decide on the number of silos that meet his or her requirements. A metal silo can be used for more than ten years. Buying a metal silo with cash might be expensive, in which case it is advisable to provide financial assistance.

Hermetic bags are effective in protecting grain from spillage during transportation and storage. Farmers can now buy these locally at affordable prices USD 1.60 at factory prices, or USD 1.80 from retail outlets. Farmers can reuse Purdue Improved Crop Storage (PICS) bags over 2 to 3 seasons with proper use, which brings down the price of the bag.

TABLE 1.23
Budget calculation for one mechanical thresher

	Item	Value	Unit
a	Product quantity	1.22	Tonne/year
b	Product value	814.67	USD/tonne
c	Loss rate	7.68	%
d	Anticipated loss reduction	75	%
e	Cost of intervention	2 380	USD
f	Depreciation	10	Years
g	Yearly costs of investment	238.1	USD/year
h	Yearly costs of operation	Negligible	USD/year
i	Total yearly costs of solution	238.1	USD/year
j	Client costs per ton product	195.16	USD/tonne
k	Food loss	0.094	tonne/year
l	Economic loss	76.6	USD/year
m	Loss reduction	0.0705	tonne/year
n	Loss reduction savings	57.5	USD/year
o	Total client costs	238.1	USD/year
p	Profitability of solution	-181	USD/year

Source: Farmers survey primary data and secondary data

TABLE 1.24
Budget calculation for a 500 kg metal silo

	Item	Value	Unit
a	Product quantity	1.22	tonne/year
b	Product value	814.67	USD/tonne
c	Loss rate	3.2	%
d	Anticipated loss reduction	75	%
e	Cost of intervention	165	USD
f	Depreciation	10	years
g	Yearly costs of investment	16.5	USD/year
h	Yearly costs of operation	Negligible	USD/year
i	Total yearly costs of solution	16.5	USD/year
j	Client costs per ton product	13.5	USD/tonne
k	Food loss	0.039	tonne/year
l	Economic loss	31.8	USD/year
m	Loss reduction	0.0293	tonne/year
n	Loss reduction savings	23.9	USD/year
o	Total client costs	16.5	USD/year
p	Profitability of solution	7.4	USD/year

Source: Farmers survey primary data and secondary data

Chapter 4

Food loss reduction strategy – conclusions and recommendations

The interventions suggested need a thorough analysis of their economic feasibility, environmental impact as well as social acceptability before they can be adopted and implemented.

The food-loss reduction plan should include:

- formulating and implementing post-harvest management policies;
- promoting post-harvest loss reduction and information through agricultural extension;
- introducing and promoting affordable post-harvest loss reduction technologies and practices such as metal silos, hermetic bags, crop harvesters pre-storage pest control and providing technical training to farmers, development agents; and
- post-harvest sector capacity-development and institution building.

The use of marketing platforms Warehouse Receipt System and providing farmers with improved storage facilities and financing options so that they can procure post-harvest facilities and services.

FOLLOW-UP ACTION PLAN – CONCEPT NOTE

An average loss of 2.2 percent in quantity occurred during transport of the grain to the marketplace because of leakage when sacks were damaged. The estimated loss during storage was 3.2 percent because of rodent damage and discolouration. These steps are *low loss points* (LLP), specifically for the surveyed area. However, the two losses combined account for 5.4 percent, which has a significant impact on farmers' income, considering the current price of teff.

The highest estimated quantitative and qualitative losses during threshing at farm level were 7.7 percent and 11, respectively. Causes of loss were spillage, contamination of grain with soil or waste from trampling animals and chaff. Moreover, loss of quantity during stacking or piling was 6.8 percent, and threshing 5.6 percent are critical loss points that need interventions through appropriate technologies.

The losses estimated during loading and unloading, transportation by trucks using old bags and storage at wholesaler (8.5 percent) and at retailers (7.4 percent) were high. Negligence and improper handling of the grain during storage also play a role in losses, which results in economic losses of ETB 119 and 103.6 respectively per quintal of purchased grain in one year.

To address these losses, the following solutions are proposed as concepts that may be piloted.

Mechanical threshers – Threshing teff is a difficult job and can take 20 to 30 days of human labour and 10 oxen days/ha. Experiences in other teff producing areas have shown that mechanical threshers improved or reduced losses of both quality and quantity and increased the income of smallholder farmers. However, the budget analysis for a thresher revealed that individual farmers cannot afford the technology.

On the other hand, private suppliers (e.g. rich farmers) and unions or cooperatives can provide services to farmers or groups on a rental basis. Provision of credit services is needed to encourage groups of farmers to purchase or hire threshers, and cooperatives to buy threshers and allocate services to farmers on a rental basis. Farmers should be empowered to come together and access financial services so that they are able to buy or rent post-harvest machinery and equipment.

Providing services through technical training and financial support will create jobs for rural youth.

Metal silos for teff storage – Local small-scale trained enterprises can manufacture metal silos of different capacities. The adoption of this technology can be afforded by smallholder farmers to reduce losses at household level.

Hermetic bags – Improved hermetic bags (e.g. PICS) were found to be effective in protecting grain from damage by rodents. Farmers can reuse PICS bags for 2 to 3 seasons, if properly managed.

Warehouse receipt system – The establishment of communal and improved storage facilities and the introduction of a grain-warehouse receipt system at primary cooperative level will considerably reduce post-harvest losses and improve the quality of stored grains.

POST-HARVEST POLICIES FOR TEFF

The promulgation of implementable policies that effectively promote the generation, development, dissemination and adoption by smallholders of post-harvest technologies should be a priority. Moreover, the following recommendations are suggested to minimize the economic, food security and reduce the negative impact of post-harvest losses on the environment:

- establish an institution that can be responsible for the coordination of all activities in the promotion of the post-harvest sector;
- formulate policies that can cover credit services to facilitate farmers' uptake of post-harvest technologies;
- design policies for farmer training in post-harvest loss management;
- raise awareness of farmers and other stakeholders about the importance of post-harvest losses and their impact;
- develop and implement policies that promote research and development in post-harvest loss technologies, practices and management;
- consider the relevance and acceptability of post-harvest loss management technologies, and the economic and financial feasibility, cultural or social acceptability, availability, accessibility; and
- establish market policies that motivate all actors to invest and participate in post-harvest activities.

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