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How big are post-harvest losses in Ethiopia? Evidence from teff

Bart Minten, Ermias Engida, and Seneshaw Tamru

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ABSTRACT

Based on a unique large-scale data set on teff production and marketing, Ethiopia's most important cash crop, we study post-harvest losses in rural-urban value chains, specifically between producers and urban retailers in the capital, Addis Ababa. We analyze the structure of the value chain and rely on self-reported losses by different value chain agents (farmers, wholesale traders, and retailers). We estimate that post-harvest losses in the most prevalent pathway in the rural-urban value chain, amount to between 2.2 and 3.3 percent of total harvested quantities. The variation in this figure depends on the storage facilities used and on assumed losses during transport at the farm. These losses are significantly lower than is commonly assumed for staple foods, possibly because of the rather good storage characteristics of teff due to its low moisture content. These findings, nonetheless, point to the need to gather further solid evidence on post-harvest losses in staple foods in these settings to ensure appropriate policies and investments.

I. INTRODUCTION

Wastage and post-harvest losses in food value chains are increasingly being debated, along with the design of policies to try to reduce this waste (World Bank 2011; FAO 2011, 2012). The debate is receiving increasing attention seemingly for two reasons. First, it is believed that by reducing food waste, food security will improve as lower food losses would ensure the availability of more food at lower prices. Second, using resources for producing food that is ultimately wasted raises important environmental issues due to the misuse of water, land, and fertilizer. Reducing food wastage would alleviate these environmental concerns.

Despite the presumed importance of food waste, there is large variation in estimates of its actual importance and volume. Developed countries often have different food waste levels than developing countries, with more waste produced before the farmgate in developing countries and after the farmgate in developed ones (Hodges et al. 2011). Recent evidence shows that losses might be lower than commonly thought in developing countries. For example, based on nationally representative surveys, Kaminski and Christiaensen (2014) estimate that on-farm post-harvest losses made up 1.4 to 5.9 percent of the national maize harvest in the case of three African countries. Affognon et al. (2015) question the assumption of high post-harvest losses in a review of the available evidence. On the other hand, in the case of South Africa, it was estimated that food waste made up 2.1 percent of South-Africa's annual GDP (Nahman and de Lange 2013), due primarily to wastage at the consumption level (Oelofse and Nahman 2013). In the US, it was estimated that 10 percent of the amount spent on food was wasted (Buzby and Hyman 2012), while others estimate that one-third of total planned food production is lost or wasted (FAO 2011 2012; Buzby 2013).

Post-harvest losses differ according to the type of food, being higher for fresh produce. Kader (2005) estimates global losses of fresh produce at around one-third of the total produced. Gustavsson et al. (2011) estimate losses between 19 and 32 percent in the case of cereals, between 33 and 60 percent for roots and tubers, and between 37 and 55 percent for fruits and vegetables. The World Bank (2011) however, places grain losses between 10 percent and 20 percent in sub-Saharan Africa. At the global level, FAO (2011) evaluates global food losses and waste at 32 percent of all food produced. Lundqvist et al. (2008) posit that about 50 percent of all food grown is lost either before or after it reaches the consumer. This compares to the estimate of Lipinski et al. (2013) of 23 percent and that of Kummu et al. (2012) at 25 percent. In sum, the upshot of this analysis of the literature on food wastage is that there is limited information on wastage estimates at different stages of the food value chain and that what estimates there are vary widely, especially so for developing countries (Parfitt et al. 2010).

In this paper, we analyze the level of post-harvest losses in the case of an important staple crop in Ethiopia, teff. We implement an innovative method where surveys were fielded at each level of the teff value chain to allow us to analyze the structure of the value chain; to better measure important variation between value chain agents; to capture post-harvest losses at each level; and thereby to evaluate post-harvest losses over the most prevalent segments of the value chain, except for consumption. We look in particular at the size of post-harvest losses in the domestic value chain for teff that supplies the grain to Addis Ababa from major production areas. This is the most important value chain in the country given the high consumption of teff in urban areas.

Current estimates of post-harvest losses have come under some criticism, suggesting that: (1) the methods used are based on experts' hypotheses rather than on detailed field survey estimates; (2) they are biased toward perishables and thus

far over-state losses; and (3) they are not focused on the products that make up the bulk of calories consumed, like potatoes, grains, tubers, or pulses (see Cassman 2014, Meagan and Barrett 2015). We address these critiques in this study, and therefore contribute to the literature as we make estimates on post-harvest losses based on large-scale surveys with different agents in the teff value chain in Ethiopia, from farmers to urban retailers.

Our results from analysis of these surveys challenge the conventional view on presumed large post-harvest losses in staple value chains in Ethiopia and more broadly. We estimate the post-harvest losses between rural producers and urban consumers in the teff value chain at between 2.2 and 3.3 percent of the quantity of grain produced, depending on the storage facilities adopted (or not) and on the level of losses occurring during transport by farmers.

The structure of the paper is as follows. In Section 2, we discuss the data and methodology used. In Section 3, we present the descriptive statistics on the data obtained in our surveys. Section 4 dwells on the structure of the teff value chain and the role storage plays in it. We then present our major findings for post-harvest losses in the teff value chain in Section 5 and finish with overall conclusions in Section 6.

2. DATA AND METHODOLOGY

We rely on information collected from major teff producing areas and follow the teff value chain from these areas to Addis Ababa, the capital of Ethiopia and, along with its metropolitan area, home to approximately 4 million people. To get at this information, two types of data collection activities were organized. Interviews were conducted with key informants engaged in the teff value chain during September and October 2012. Using this information, questionnaires were designed for each level in the value chain and then fielded at the end of 2012 (November and December). These surveys were implemented upstream in the value chain with teff producers and communities, midstream with rural and urban wholesalers and truckers, and downstream with cereal shops, mills, and cooperative retail.

Upstream in the value chain, we selected 1,200 teff farmers through a process that involved several steps. First, the five zones with the highest commercial surplus of teff in the country were identified and chosen. These five zones combined represented 38 percent and 42 percent in 2011/12 of the national teff area and commercial surplus, respectively. Second, within each production zone, *woredas* (districts) were ranked from the smallest to the largest producer (in terms of area cultivated). We then divided the *woredas* in two, the less productive and the more productive *woredas* (each group of woredas cultivating altogether 50 percent of the area). Two *woredas* were randomly selected from each group. Third, a list of all the *kebeles* of the selected *woredas* was then obtained. Two *kebeles* were randomly chosen from the top producing 50 percent *kebeles* and one from the bottom producing 50 percent *kebeles*. Fourth, a list of all teff producers in the selected *kebeles* was then compiled. They were ranked from small to large teff producers (based on the area cultivated). We then divided the farmers in two groups, small production and large production farmers, each group of farmers cultivating altogether 50 percent of the area. A total of 20 farmers were then selected: ten from the group of small production farmers and ten from the large production farmers. In total, 240 farmers were interviewed per zone.

For the midstream value chain investigations, the following strategy was followed. First, 40 rural wholesalers were interviewed in each rural zone. For each *woreda*, the major trading town or temporary wholesale market used by farmers in that *woreda* was selected. A census of all traders in that market/town was then made. As the focus of the study is to understand the value chain from rural areas to Addis Ababa, ten traders that ship teff to Addis Ababa were then randomly selected from this list in each of these towns/markets. Four such towns/markets were selected for each zone. Second, in Addis Ababa, 75 wholesale traders and brokers were interviewed in total. Reflecting the approximate size of the wholesale market for teff, one-third was interviewed from the Ehil Beranda wholesale market and two-thirds from the Ashwa Meda market. Twenty-five wholesalers were randomly selected from Ehil Beranda (13 without and 12 with shops) and 50 (25 with and 25 without shops) from Ashwa Meda. Wholesale traders were asked to identify the zones from which they obtained teff. It is estimated that 92 percent of the teff that is sold in Addis Ababa comes from one of the five production zones covered in our upstream farmer survey.

Downstream in the value chain, we relied on a stratified sampling scheme to select a representative sample of teff retail shops in Addis Ababa. Based on a city map, we created five geographical strata with two similar neighboring sub-cities in each stratum. We then randomly selected one sub-city from each stratum, for a total of five sub-cities. Next, we collected information from the city's Trade and Industry Office to compile a complete list of teff outlets in each sub-city. We then randomly selected outlets to include in the interview process. First, all the consumer cooperatives and *kebele* shops selling

teff were surveyed at the sub-city level. Second, in each selected sub-city, four *kebeles*[1] were selected randomly. In each selected *kebele*, all the flour mills were surveyed and five cereal shops were randomly selected and surveyed. In total, 282 retail outlets in Addis Ababa were interviewed.

Table 2.1 gives an overview of the selected agents for each level in the teff value chain. We note significant differences between agents. The level of education among farmers is lowest with, on average, 5 years of education. This compares to about eight years for the other value chain agents downstream. Few women are directly involved in the value chain post-farm: 5, 0, and 15 percent of the rural wholesalers, urban wholesalers, and urban retailers, respectively, are women. At the farm level, only 5 percent of the households are headed by women. Value chain agents have significant experience in handling teff, between 8 and 10 years on average. The value of assets owned by these traders is highest for the urban retailers, often because of the mills that they own. We see also significant variation in each category, as shown by the large standard deviations. A farmer's annual sales amount to 0.5 tons. This compares to 252, 694, and 36 tons per year for the rural wholesalers, urban wholesalers, and urban retailers, respectively. Therefore, a rural wholesaler requires, on average, about 5,000 farmers to buy from on a yearly basis for his teff business.

Table 2.1: Descriptive statistics on respondents to teff value-chain surveys

	Unit	Mean	Median	Standard deviation
Farmers				
Number of observations		1,200	-	-
Gender head of household	share male	95.3	-	-
Level of education (years of schooling)	number	4.6	4.0	2.9
Experience in teff business	years	9.6	10.0	1.5
Rural wholesalers				
Number of observations		205	-	-
Gender	share male	94.6	-	-
Level of education (years of schooling)	number	7.9	9.0	3.9
Experience in teff business	years	9.5	8.0	7.8
Truck drivers				
Number of observations		90		
Age	years	29.7	29.0	7.1
Gender	share male	100.0		
Level of education (years of schooling)	number	9.4	10.0	1.8
Experience in teff business	years	6.5	5.0	5.9
Urban wholesalers/brokers				
Number of observations		75	-	-
Share brokers	share	65.3	-	-
Share traders	share	64.0	-	-
Gender	share male	100.0	-	-
Level of education (years of schooling)	number	8.7	8.0	3.4
Experience in teff business	years	8.9	7.0	6.7
Urban retailers				
Number of observations		282	-	-
Share mills	share	83.3	-	-
Share cereal shops	share	9.9	-	-
Share consumer cooperatives	share	6.7	-	-
Gender	share male	84.7	-	-
Level of education (years of schooling)	number	7.7	8.0	4.4
Experience in teff business	years	8.2	5.0	7.8

Source: Authors' calculations based on teff value chain surveys.

[1] *Kebeles* represent the second administrative level for the city under a given sub-city (recently *kebeles* have been re-organized to *woredas* with slight changes in geographical coverage).

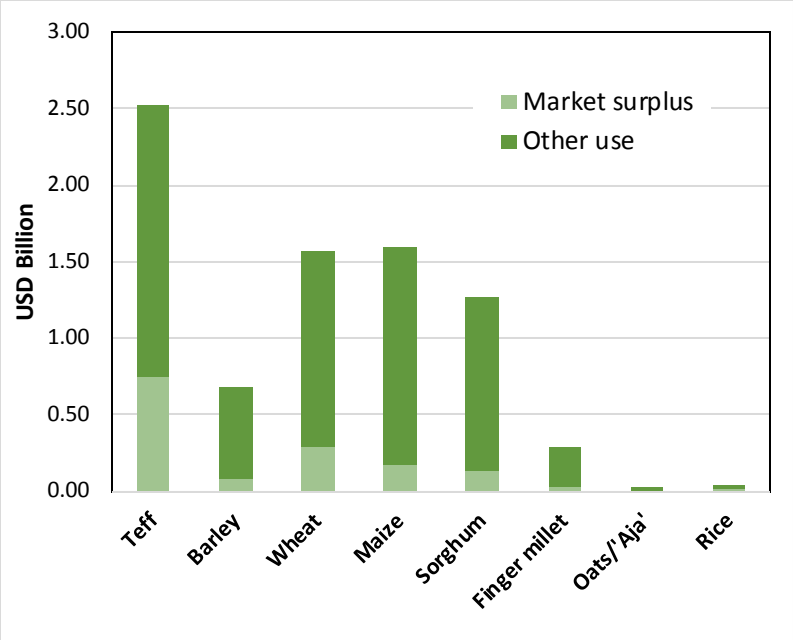
3. BACKGROUND

Teff is the most important crop in Ethiopia's agricultural economy based a number of indicators. In 2013/14, it was estimated by the Central Statistical Agency (CSA) that teff made up 22 percent of all the area cultivated by private smallholders in the main *Meher* cropping season, covering about 3 million hectares, and was grown by 6.6 million farmers.[2] As there are 15.3 million farmers in Ethiopia in total, this implies that 43 percent of all Ethiopian farmers grow teff. The second most important crop is maize at 15 percent of all cultivated land, followed by sorghum accounting for 12 percent. Teff makes up 31 percent of all the cultivated land in the cereal sector. This latter sector is the most important in Ethiopia's agricultural economy and accounts for 72 percent of all cultivated land.

While teff is the most important single crop area-wise in Ethiopia, its importance as a share of agricultural production is, however, far less. This is due to the relatively low yields of teff compared to most other crops, and especially other cereals. The total national production of teff in 2013/14 (4.4 million metric tons) was lower than maize (6.5 million mt) but higher than wheat (3.9 million mt) and sorghum (3.8 million mt) (CSA 2014a). The average yield of teff in that year was 1.46 mt/ha, less than half the yield of maize (3.25 mt/ha).

Within the cereal sector, teff is the most commercialized crop, with an estimated 30 percent of the production sold (CSA 2014b). The value of this commercial surplus (the part of production that is sold) for teff was estimated to be 750 million USD in 2013/14, making up half of the value of the total commercial surplus of the cereal sector. This equals the commercial surplus of all other cereals combined in the country, as shown on Figure 3.1. Moreover, the value of the commercial surplus of teff is approximately equal to the value of coffee exports from the country during the same period, which amounted to 714 million USD from July 2013 to June 2014. However, when the cash value accrued by farmers from the sales of teff is compared with the income gained through the sale of coffee and sesame, two of the major export crops, income from teff is 34 percent higher than income from coffee, and almost triple the income that farmers make from the sales of sesame. Teff is thus by far the most important cash crop in the country.

Figure 3.1: Production value and use of cereals in 2013/14



Source: Authors' calculations, CSA agricultural sample surveys, 2013/14

Teff is consumed more by urban households than by rural households. Urban consumption per capita is 81 kg per year based on national household consumption data. In comparison, this figure is only 24 kg per capita per year for rural areas. Teff is further characterized by high income elasticities, evaluated at 1.10 in rural and 1.20 in urban areas. These figures demonstrate that teff is an economically superior commodity, implying that with an increase in income, this leads to a

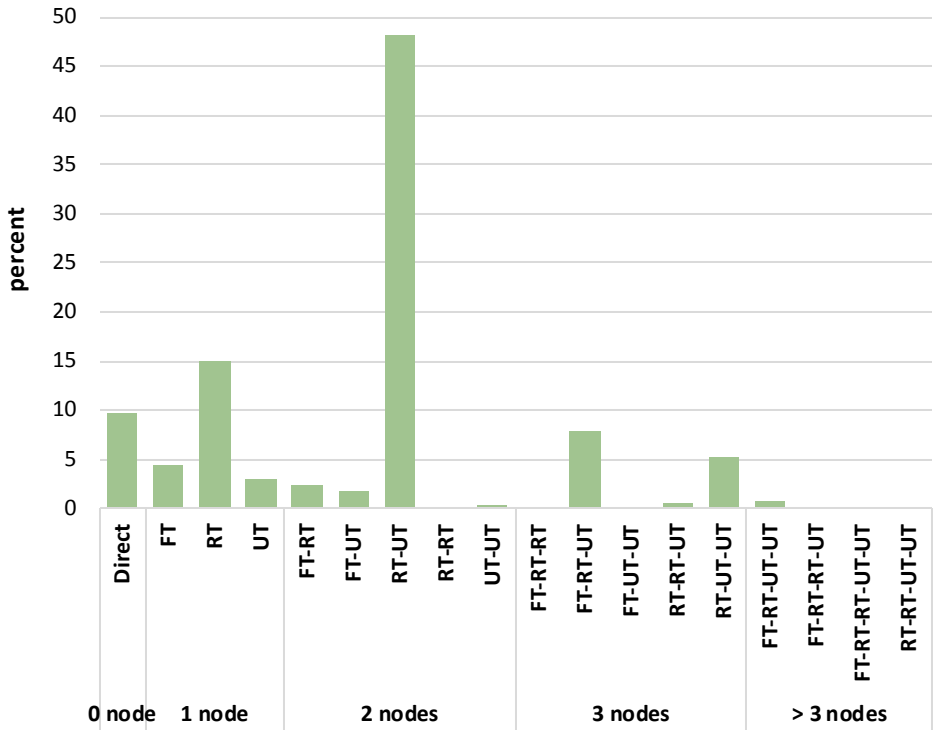
[2] Taffesse et al. (2012) show that smallholders generate 95 percent of the total production of the main crops in Ethiopia, and that 97 percent of the total crop production is in the main *Meher* season. The *Belg* season is, therefore, relatively less important.

disproportional increase in teff consumption. Moreover, teff will continue to be a product that is consumed in mostly urban areas and in greater quantities by the rich than by the poor. The lower consumption by the poor is partly explained by the high prices of teff which are typically twice as high as prices for maize. Given the fast economic growth that Ethiopia is experiencing and the rapid increase in urbanization, the importance of teff in food systems is expected to increase in the future.

4. STRUCTURE OF THE TEFF VALUE CHAIN

To understand the structure of the teff value chain, rural and urban wholesalers and urban retailers were asked from whom they obtained supplies and to whom they sold. Over the 15 months prior to the survey, the wholesalers were asked in three month intervals about the importance of each type of seller in terms of total supplies. This procurement information at each level allows us to quantify the prevalence of different value chain structures. We identify three main players in these value chains, i.e., the farmer-trader (FT) or rural assembler who operates in the village, the rural trader (RT) who operates in rural markets or in regional towns, and the urban trader (UT) or broker who operates in urban markets. We categorize the different value chains by the number of nodes between the urban retailer and the teff farmer.[3] Based on procurement responses of the different value chain agents, there are 18 possible chains from farmer to retailer, ranging from zero nodes where retailers buy directly from farmers to five nodes (FT-RT-RT-UT-UT). For example, the FT-RT-UT supply chain represents a chain with three nodes where teff is sold to a farmer-trader (FT), who sells to a rural trader (RT), who then sells to an urban trader (UT).

Figure 4.1: Prevalence of different value chain structures between urban teff retailers and farmers



Source: Teff trader surveys. Note: FT: Farmer-trader; RT: Rural trader; UT: Urban trader.

Figure 4.1 shows the surprisingly short supply chains that are commonly employed to ship teff to Addis Ababa. Figure 4.1 illustrates that there are zero, one, two, three, or more than three nodes in the teff value chain for 9.8, 22.4, 52.8, 13.9, and 1.0 percent, respectively, of the teff sold by urban retailers. In 85 percent of the cases, there are two trade nodes or less

[3] To be able to make these calculations, some assumptions were made. First, simple averages over traders were calculated. No large differences were noted when weighted averages were used. Second, small alternative channels (such as cooperatives) were added to the rural traders' category. Third, some traders reported to purchase from other traders at the same level (1.3 percent of the rural traders; 9.8 percent of the urban traders/brokers). This was taken into account in the first stage and other sources of procurement were set proportionally in the second stage of procurement to the first stage except for the trader of the same level, which was set to 0 percent. This assumption was needed to avoid indefinite loops; it however affected less than 0.5 percent of the supply chain allocation.

between retailers and farmers.[4] The results are largely consistent if we triangulate the sales and procurement patterns at different levels. The most prevalent structure of the value chain from these major production zones to the urban city follows from producer to regional trader to urban trader/broker to urban retailer (used in 48 percent of the teff supply transactions to Addis). In 28 percent of cases, urban retailers obtain their products directly in rural areas, bypassing the urban wholesale markets and making the value chain shorter. On the other hand, the value chain can also be longer, as rural traders procure 13 percent of their produce from rural assemblers or farmer-traders, and 10 percent of the urban wholesalers/brokers obtain produce from other urban wholesalers/brokers.[5] However, in the most common case, there are three intermediaries found between farmers and urban consumers. The finding of such a structure is against conventional wisdom.[6]

5. POST-HARVEST LOSSES ESTIMATES

We estimate post-harvest losses using the most prevalent structure of the value chain discussed above, from farmer to rural wholesaler to urban wholesaler to urban retailer. To get at the level of post-harvest losses in the teff value chains, we asked at each level in the chain how much was lost in storage as well as during their last complete trade transaction (the time between acquisition and sales of teff, possibly including transportation). We then simply add up the stated post-harvest losses at each level in the chain for this most prevalent structure. This method should give a reasonable approximation of the total post-harvest losses in the value chain at harvest time and after storage. We proceed in a number of steps with our analysis, looking first at losses at farm level, then storage, transportation, and finally assess losses over the whole value chain.

a) Post-harvest losses at farm level

Farmers were asked to quantify their grain losses in the teff threshing process. It is to be noted that threshing of teff in Ethiopia, as for most other products, is almost exclusively carried out using traditional methods. Table 5.1 gives some ideas on prevalent practices. Farmers allow teff to dry for an average of 40 days before the threshing process takes place. In almost all the cases, threshing is done on a threshing floor made from dried cow dung and is mostly done by animals (97 percent). However, there is still a small percentage of farmers that thresh using sticks (2.5 percent). The majority of the farmers (59 percent) prepare their own threshing floor, while 40 percent work cooperatively with other farmers to prepare the floor.

The second panel of Table 5.1, presents statistics on reported losses during this process. 57 percent of the farmers reported to have lost harvest during the threshing process. Of those that reported losses, this amounted to 0.25 quintals on average (and a median of 15 kg). When we compare this to the total quantity that was harvested for those farmers that reported losses (12.3 quintals on average), this amounts to a loss of 3.1 percent of the total harvest. If we take into account the large number of farmers that did not report any losses, the estimated amount of loss during the threshing process equates to 1.8 percent of the total teff harvest.

[4] Note that 86 percent of what these retail shops sell is sold directly to consumers. The rest of the buyers are mostly *injera* sellers and restaurants.

[5] Ninety-two percent of all the teff sales by the interviewed urban wholesale traders was destined for Addis Ababa. While Addis Ababa was seen in the past as a clearing house for national cereal trade, i.e., the national cereal trade went through Addis Ababa, as all major traders were stationed there (Gabre-Madhin 2001), this is seemingly less so now than before. The larger agricultural marketing flows in the country, as well as improved communications, might have contributed to that change (Minten et al. 2014). Urban traders were also asked to indicate from which zone they procured teff. The five production zones where the producer surveys were fielded are the source of 91 percent of all teff coming to Addis Ababa. In our survey set-up, we thus did well to capture the major suppliers to Addis Ababa as well as end-users, rarely the case in surveys of food value chains.

[6] Fufa et al. state "The teff value chain is fragmented and involves many players. Most farmers sell to assemblers individually, who then sell on to traders and wholesalers. Most teff is sold at harvest when prices are low." (2011, 2)

Table 5.1: Descriptive statistics on the teff threshing activities of farmers

	Unit	Mean	Median	Standard deviation
Threshing activities				
Time between threshing and harvesting	days	40	30	29
Type of threshing floor				
- dried cow dung	%	99.7		
- cement floor	%	0.1		
- shera	%	0.1		
- other	%	0.1		
Type of threshing				
- by animals	%	97.3		
- by humans using sticks	%	2.5		
- thresher	%	0.2		
Threshing on own or joint threshing floor				
- own	%	58.8		
- joint	%	39.3		
- others	%	1.5		
- belongs to other person	%	0.4		
Main use of straw				
- sales	%	3.5		
- fodder	%	93.1		
- construction	%	0.4		
- mix	%	2.8		
- other	%	0.3		
Losses during threshing				
Share of farmers reporting losses	%	56.9		
For those reporting losses				
- average quantity lost	quintal	0.25	0.15	0.32
- teff harvest	quintal	12.30	8.00	15.33
- share lost	%	3.1	1.9	3.7
For all farmers				
- average quantity lost	quintal	0.14	0.04	0.27
- teff harvest	quintal	11.00	8.00	13.02
- share lost	%	1.8	0.5	3.2

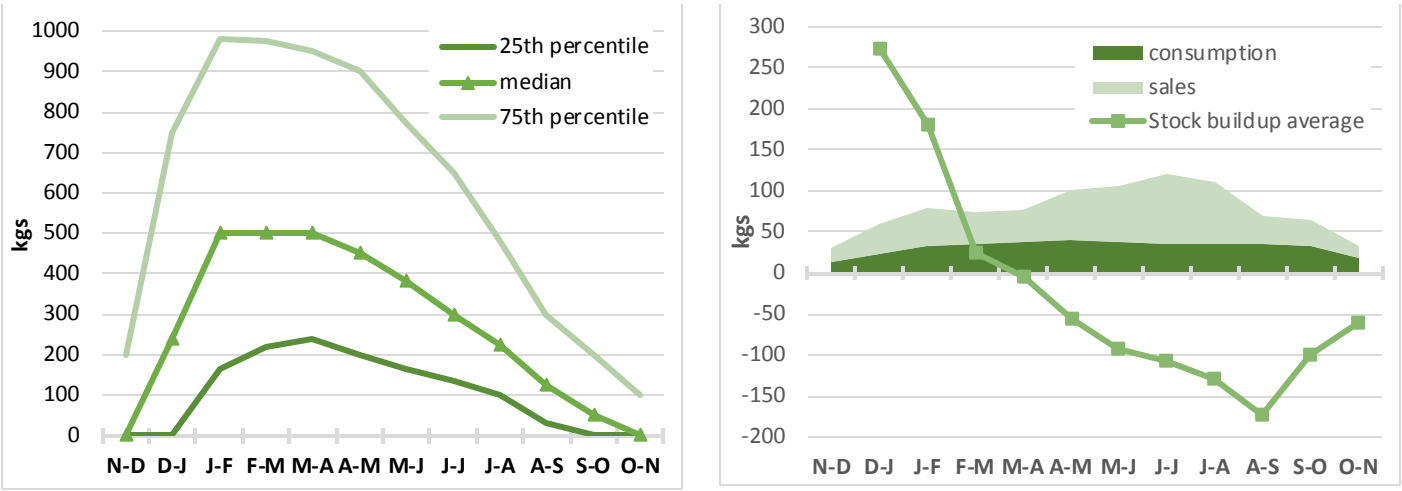
Source: Authors' calculations based on teff value chain surveys.

b) Losses during storage

Storage of teff is done at several levels, i.e., by farmers, by traders, and by retailers. Figure 5.1 shows how stocks at the household level vary over time. Stock changes are calculated by comparing monthly changes in stock position, i.e., positive values indicate a stock buildup while negative values signal stock release. This is calculated for the median, the 25th, and the 75th percentile of storage levels in the household dataset. Stock buildup occurs during the months of November until March. Stock release (or withdrawal) occurs mainly between March and October. Stock release is highest during the period of July and August (*Hamle-Nehassie*), coinciding with the period when teff is sown. The main uses of teff production are consumption and sales.[7] Teff consumption increases immediately after harvest and stays stable over the rest of the year. But, over the months prior to harvest, the level drops to half. As expected, we also note strong seasonal patterns in the sales of teff. Surprisingly, our survey data shows the peak of sales not immediately after harvest, as one might expect, but a couple of months afterwards.

[7] Sales and consumption are the most important activities of teff production. They made up 46 and 33 percent, respectively, of total production activity in the year prior to the survey.

Figure 5.1. Seasonality in quantity of teff in storage by producer household (left side) and average monthly use of teff by household (right side), kg



Source: Teff producer survey. Note: N-D = November-December period; D-J = December-January period; and so on.

Table 5.2: Descriptive statistics on types of storage used by farmers and estimates by farmers of losses during storage

	Unit	Mean	Median	Standard deviation
The farmer sells mainly:				
- Immediately after harvest	%	31.7		
- In the middle between current harvest and next harvest	%	59.6		
- Just months before the next harvest	%	8.7		
Type of storage structure				
Share of households that use *gotera* (traditional storage structure)	%	35.2		
If yes, capacity	quintal	10.5	10	6.5
Share of household that use modern *gotera*	%	1.1		
If yes, capacity	quintal	26.5	20	24.3
Share of household that use *gudegade* (traditional storage pit)	%	0.8		
If yes, capacity	quintal	11.7	7	8.2
Share of household that store in house	%	40.7		
If yes, capacity	quintal	32.6	20	35.5
Share of household that use *dibignet* or other traditional means	%	22.3		
If yes, capacity	quintal	6.3	6	3.8
Losses during storage				
Share of farmers reporting losses	%	11.6		
For those reporting losses				
- average quantity lost	quintal	0.24	0.15	0.28
- teff harvest	quintal	16.54	12.00	21.58
- share lost	%	2.0	1.4	2.7
For all farmers				
- average quantity lost	quintal	0.03	0.00	0.12
- teff harvest	quintal	11.00	8.00	13.02
- share lost	%	0.2	0.0	1.1

Source: Authors' calculations based on teff value chain surveys.

Looking at monthly stocks, Figure 5.1 illustrates that significant storage of teff occurs on the farm. Table 5.2 gives a further description of storage infrastructure used as well as storage losses. In a qualitative attempt to better understand sales and storage behavior, farmers were asked to indicate when they sell their produce. Only 32 percent of the farmers indicate that they sell teff immediately after harvest. 60 percent of the farmers stated that they sell mainly in the middle of the period between the current and the next harvest, while 9 percent report selling mainly before the next harvest. These percentages,

combined with the presented graphs, indicate that the practice of on-farm storage of teff is very important in Ethiopia. Nevertheless, very few modern storage facilities are actually adopted. 41 percent of the farmers indicated that they stored teff in their house. This compares to 35 percent of farmers that store teff in a traditional *gotera* storage structure, and 22 percent use a *dibignet*, large mud-plastered storage jars. Modern *gotera* are relatively less used (1 percent of farmers).

Despite the use of traditional storage methods, reported losses of stored teff grain are low, however. Only 12 percent of farmers reported to have lost teff during storage at the farm. Notably, the timing of these questions came just before the delivery of the new harvest, and therefore this enabled farmers to make a full assessment of their total storage over the previous post-harvest period. For those that reported storage losses, 0.24 quintals were lost or about 2 percent of the total harvest. If we aggregate this over all the households producing teff, it is estimated that a low 0.2 percent of all teff harvested is lost during storage at the farm level.

We also asked for information on storage behavior and storage losses by traders, brokers, and urban retailers. This information is presented in Table 5.3. In the case of wholesalers or brokers, we see that few stored teff, with only 11 percent reported doing so. Often these traders acquire a truck full of teff from farmers and then sell it to clients, only keeping teff for a short while. Eight percent of wholesalers reported losses of teff, amounting to 0.4 percent of the whole transaction. If this is aggregated over all wholesalers that reported storage in the last transaction, it is estimated that 0.3 percent was lost.

A similar exercise was done at the retail level. As retailers take some time to sell their produce, we assume that they all store teff. Almost one quarter of the retailers reported losses during their last transaction. For those that reported losses, the loss made up 0.7 percent of their total purchase. When we aggregate this over all retailers, 0.2 percent of the purchased teff is presumably lost at the retail level.

Table 5.3: Storage losses by traders and retailers

	Unit	Mean	Median	Standard deviation
Wholesalers/brokers				
Share of wholesaler reporting losses during storage	%	8.0		
For those reporting losses				
- average quantity lost	quintal	0.15	0.13	0.13
- size transaction	quintal	79.00	79.50	41.30
- share lost	%	0.4	0.1	0.7
Share of wholesalers that stored	%	10.8		
For those that stored				
- average quantity lost	quintal	0.11	0.08	0.13
- size transaction	quintal	75.63	77.00	36.96
- share lost	%	0.3	0.1	0.6
Retailers				
Share of retailers reporting losses during storage	%	24.5		
For those reporting losses				
- average quantity lost	quintal	0.12	0.05	0.21
- size transaction	quintal	23.27	16.00	25.86
- share lost	%	0.7	0.3	0.8
Aggregated over all retailers				
- average quantity lost	quintal	0.03	0.00	0.12
- size transaction	quintal	21.11	15.00	20.87
- share lost	%	0.2	0.0	0.5

Source: Authors' calculations based on teff value chain surveys.

c) Losses during transportation

Losses during transportation might be another important factor accounting for post-harvest losses. Again, we work through the different levels in the teff value chain, from farmers to retailers. Unfortunately no data were collected on losses at the farm level during the use of different types of transportation. Two transport operations can be distinguished before commercialization, i.e., transport of teff from field to the house and from the house to the market. While we have no data on actual losses, data were collected for some indicators (Table 5.4). For example, the average time taken to walk between

house and plots is 17 minutes. The median is 10 minutes. This indicates that most of the teff plots are located close to the house in the case of most teff farmers. Information was further collected on sales transactions. In an average sales transaction, 3 quintals of teff exchanged hands. Teff was mostly sold at traders' shops (60 percent) or at local markets (35 percent). Teff producers sell over 80 percent of their produce to traders that ship the teff to Addis Ababa or elsewhere, about 11 percent to other farmers or assemblers, with the remaining proportion sold to consumers (7 percent) or other buyers (0.7 percent). Most farmers travelled 1.5 hours to get to the point of sale, and then stayed a further hour at these selling places. The large majority (70 percent) used donkeys as their means of transport, be it their own or rented donkeys. In 14 percent of the cases, teff was transported by cart. These results indicate that the distances covered by farmers to transport produce were not that large, and that losses in the transport process were likely to be minimal. In further scenarios, we will assume an arbitrary low zero percent and a high 0.25 percent loss in that process.

Table 5.4: Transport by farmers from field to house and house to market

	Unit	Mean	Median	Standard deviation
Time to walk from plot to house	minutes	16.9	10.0	19.0
Characteristics of marketing transactions				
Number of transactions per teff farmer for producing households	number	1.75	1.00	1.52
Type of buyer:				
Farmer	%	0.6		
Farmer-assembler (farmer trader)	%	5.2		
Assemblers from outside village	%	5.5		
At wholesale market: traveling trader going to Addis Ababa	%	17.5		
At wholesale market: traveling trader going elsewhere	%	16.3		
Trader with fixed shop, selling teff to Addis Ababa	%	29.8		
Trader with fixed shop, selling teff elsewhere	%	17.4		
Consumer	%	7.0		
Other (miller, cooperative, EGTE or government)	%	0.7		
Sale location:				
On the farm or home	%	3.1		
Trader shop (fixed)	%	60.3		
Local(weekly) market	%	34.7		
Other (roadside, cooperative, at mill)	%	1.9		
Most important means of transportation:				
own donkey	%	37.2		
other donkeys	%	12.3		
own and other donkeys	%	20.6		
by foot	%	4.1		
own cart	%	2.9		
rented cart	%	11.5		
motorized vehicle	%	9.3		
other	%	0.5		
none	%	1.6		
Time between departure from home and arrival at sale location	minutes	92.0	80.0	65.3
Time spent at sale location	hours	0.9	0.5	1.0
Total quantity of teff sold per transaction	quintal	2.99	2.00	6.85

Source: Authors' calculations based on teff value chain surveys. Note: EGTE – Ethiopian Grain Trade Enterprise parastatal firm.

Wholesalers, brokers, and retailers were also questioned about the losses that they incurred during transportation. Wholesalers and brokers were first asked whether they transported the teff in their last transaction. Only 9.5 percent of these traders indicated that they did. 6.7 percent of the wholesalers and brokers indicated that they had losses during the transportation process. For those that reported losses, 0.2 percent of their total load was lost. When we aggregate for all that transported teff, we find a 0.1 percent loss on average during transportation. Most retailers obtain teff through these wholesale markets. They were also asked to indicate how much they lost during the transportation of teff from the wholesale market to their shop. One-third of the retailers indicated losses during transportation. For those that had experienced losses,

their estimation of the loss was 0.4 percent of the whole transaction. When we aggregate losses over all retailers – assuming that all retailers transported teff, since the majority of retailers that buy their produce at wholesale markets bring it afterwards to their retail outlet – we estimate that 0.1 percent of the teff transaction is lost at that level.

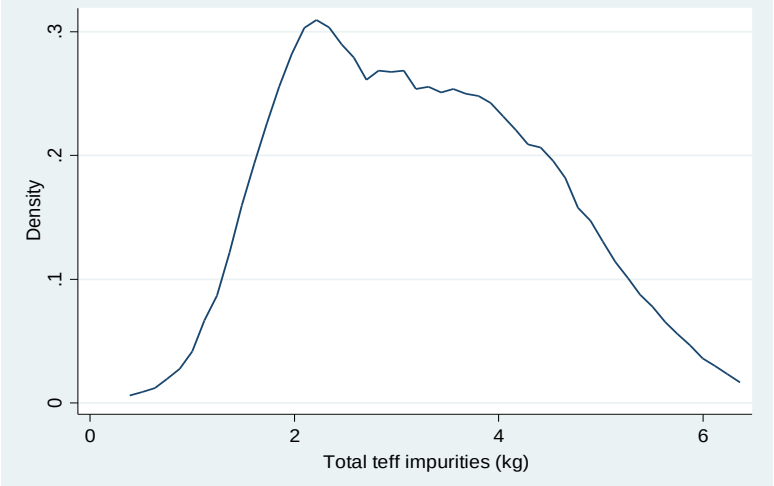
Table 5.5: Losses during transportation by wholesalers and retailers

	Unit	Mean	Median	Standard deviation
Wholesalers/brokers				
Share of wholesalers reporting losses during transportation	%	6.7		
For those reporting losses				
- average quantity lost	quintal	0.12	0.10	0.08
- size transaction	quintal	84.60	75.00	36.61
- share lost	%	0.2	0.1	0.1
Share of wholesalers that transported	%	9.5		
For those that transported				
- average quantity lost	quintal	0.09	0.10	0.09
- size transaction	quintal	109.71	109.00	61.93
- share lost	%	0.1	0.1	0.1
Retailers				
Share of retailers reporting losses during transportation	%	32.6		
For those reporting losses				
- average quantity lost	quintal	0.07	0.03	0.11
- size transaction	quintal	22.71	19.50	21.84
- share lost	%	0.4	0.2	0.6
Aggregated over all retailers				
- average quantity lost	quintal	0.02	0.00	0.07
- size transaction	quintal	21.11	15.00	20.87
- share lost	%	0.1	0.0	0.4

Source: Authors' calculations based on teff value chain surveys.

Finally, we also asked retailers about cleaning the teff. Traditional threshing methods often result in foreign material being included in the marketed bags of teff. The teff is therefore cleaned at the household by consumers, or more commonly at the mill by cleaners, who are usually paid separately for that cleaning. We asked the mill owners how much foreign material (impurity) was obtained from a quintal of raw teff. The results are presented in Figure 5.2. This chart shows that the average level of impurities of teff varies mostly between 2 and 4 kg per quintal of raw teff. It is to be noted that these impurities are not considered losses in the value chain, as they are usually stones, hay, or remains of faeces of the animals that did the threshing. These results will therefore not be used in further analysis.

Figure 5.2: Impurities in marketed teff, kg per quintal of raw teff



Source: Teff retail survey.

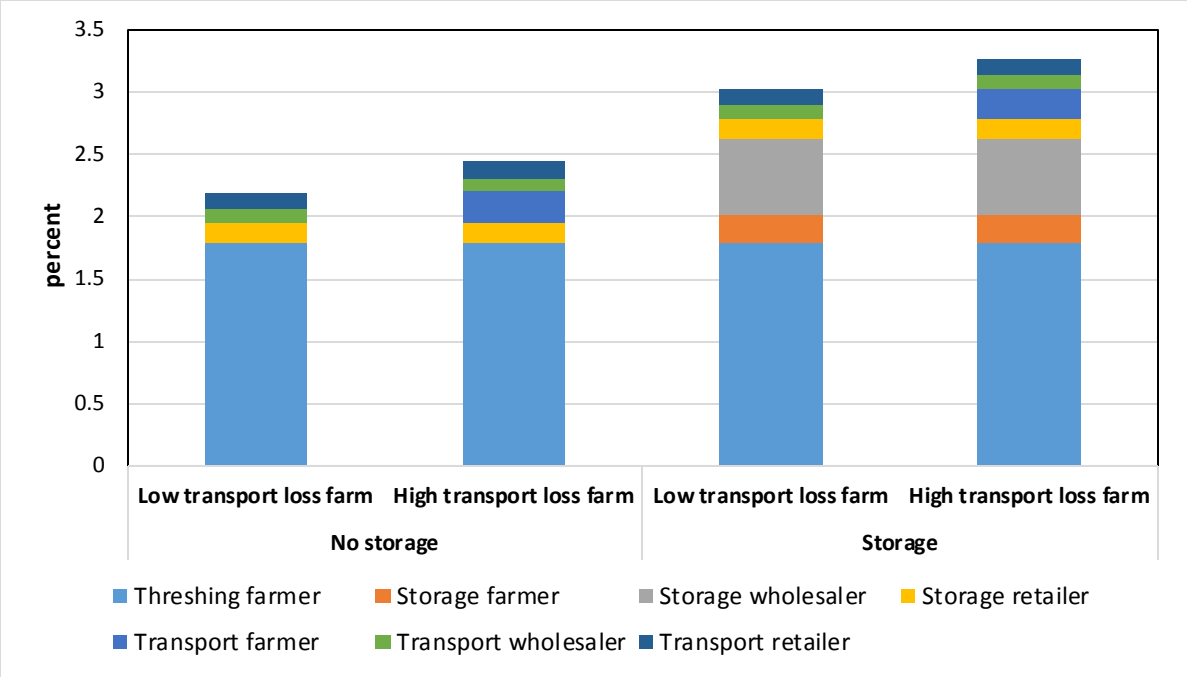
d) Post-harvest losses in the value chain

Having evaluated the structure of the value chain between rural producers and urban consumers and having obtained estimates of the losses for most of the processes that occur between the production by farmers and the purchase of consumers, we aim to create a comprehensive assessment of total losses in the rural-urban value chain of teff. As these are self-reported losses, caution is required. However, we believe that these numbers likely paint a more reliable picture of losses compared to other methods for estimating post-harvest losses in food value chains in vogue until now. Moreover, these losses were reported by stakeholders that are heavily involved in these crops and are impartial to the under- or over-reporting of losses. The most significant unknowns in our assessment of overall losses are the losses incurred in transportation from field to house and from house to market. As stated earlier, we evaluate two scenarios in Figure 5.3 with arbitrary imputed losses at that level of the value chain of zero and 0.25 percent of total production.

Figure 4.1 showed that there is a multitude of possible structures of value chains to ship teff to Addis Ababa, from very short to long value chains. We evaluate the losses in the teff value chain using the most common value chain structure where teff is shipped from the farmer to the rural wholesaler to an urban wholesaler/broker and then to an urban retailer. We evaluate two extreme cases where no storage is undertaken by any of the value chain agents, which means that teff is sold immediately after harvest and is not stored by traders and retailers. In a second scenario, we include storage at all levels. This estimate therefore reflects a lower- and upper-bound on losses incurred during storage activities. The results are presented in Figure 5.3.

We present four scenarios, moving from less to more conservative estimates of loss. On the left side of Figure 5.3, we evaluate a case where there was no loss during transportation from the field to the house and from the house to the market, and that there was no storage by farmers and wholesalers. However, we do assume that storage was done by urban retailers, as they usually take time to sell their produce. In this least conservative scenario, we find that losses in the value chain amount to 2.2 percent. If we move to the far right of Figure 5.3, we evaluate total losses by assuming that there were losses of 0.25 percent of total harvest during transport by the farmers from their field to their house and from their house to the market. We further assume that farmers stored and incurred losses during storage. We also assume that wholesalers were engaged in storage activities. In this conservative case, we note that post-harvest losses amounted to 3.3 percent of the total value chain. Between these two extremes, the evaluated losses in two alternative scenarios – high transport losses at the farm and no storage by wholesalers and farmers; and low transport losses at the farm and storage by wholesalers and farmers – give us overall losses in the value chains of teff of 2.4 and 2.7 percent, respectively (Figure 5.3).

Figure 5.3: Losses in the teff value chain in Ethiopia, results from four scenarios



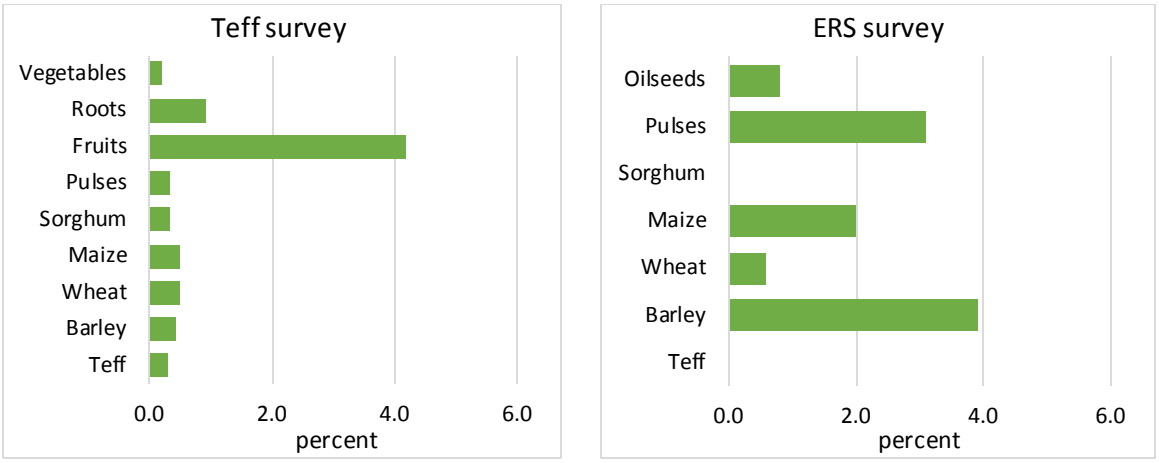
Source: Authors' calculations based on teff value chain surveys.

6. IS TEFF ANY DIFFERENT TO OTHER CROPS WITH REGARDS TO POST-HARVEST LOSSES?

Teff is different to other crops, as storage losses are presumed to be less important due to its lower moisture content, which is an important factor for storability. We therefore present information on other crops in this section. In the teff survey we collected information from farmers on post-harvest losses for crops other than teff. We also collected information on losses from a large survey of retailers in Addis Ababa that was conducted in 2012. The results of the self-reported losses for these other crops are shown in Figures 6.1 and 6.2.

In the case of teff farmers, they were asked to indicate if the harvested quantity was used for own consumption, sales, and seeds. They were also asked to indicate how much was lost. When we examine the left chart in Figure 6.1 for the reported post-harvest losses at farm level, we note that teff has the lowest reported losses. Losses for other cereals are slightly higher than for teff, but only by small amounts. None of the reported losses for any of the cereals nor the pulses is reported to be higher than 1 percent. The highest losses are reported for fruits, which are more perishable and obviously more prone to losses. The right chart in Figure 6.1 shows reported post-harvest losses based on the nationally representative Ethiopian Rural Survey (ERS). In this case, no losses were reported for teff. Reported losses, however, are higher compared to the teff survey for maize and barley, at 2 percent and almost 4 percent, respectively. Wheat shows similar low levels of post-harvest loss in both surveys.

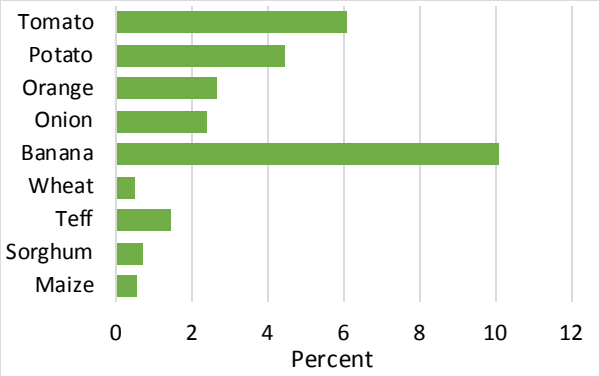
Figure 6.1: Self-reported post-harvest losses for a range of crops produced by farmers from teff survey (left) and ERS survey (right)



Source: Authors' calculations. Note: ERS – Ethiopian Rural Survey.

In Figure 6.2, we further report the results of large-scale surveys from urban retailers in Addis (Assefa et al. 2016). Based on a stratified sampling scheme representative for the city as a whole, 1,226 urban food retail outlets were interviewed in March and April 2012. In this survey, data were gathered for four main cereals (teff, wheat, maize, and sorghum) and five fruits and vegetables (tomato, potato, onion, banana, and orange). These products are of considerable importance in the diet of urban consumers. Again, we note relatively low losses for cereals, with teff exhibiting the highest losses. The picture is however significantly different for vegetables where losses are now becoming more substantial. In the case of tomato, losses amounted to 6 percent and in the case of bananas, losses were reported to be 10 percent.

Figure 6.2: Self-reported post-harvest losses for a range of unprocessed food products handled by urban retailers



Source: Authors' calculations.

7. DISCUSSION AND CONCLUSIONS

We rely on a unique dataset to assess post-harvest losses in the teff value chain in Ethiopia from rural producers to consumers in Addis Ababa. The results from these surveys challenge the conventional wisdom that traditional supply chains for staples are mired in high rates of post-harvest losses (FAO 2011). In contrast with these studies, which mostly rely on key informant information rather than on primary surveys, we find that post-harvest losses in teff are significantly lower than previously assumed. We find that these self-reported losses vary between 2.2 and 3.3 percent depending on assumptions on storage facilities and losses during transportation on the farm. Very few studies have previously looked at losses in the way that we have done using representative surveys at each level of the value chain. We therefore believe that these results are more reliable than alternative estimates. The results further are in line with more recent studies that also rely on such large-scale surveys (Kaminsky and Christiaensen 2004; Affognon et al. 2015).

The lower than expected post-harvest losses might be due to bad measurements in previous studies of total post-harvest losses.[8] However, it is also possible that due to the diffusion of mobile phones, wastages in traditional value chains have been reduced, e.g., Jensen (2007) shows this to be the case for fish markets in Kerala, India. This is not to belittle the importance of post-harvest handling. It appears that many of the needed practices and investments have been already put in place to minimize post-harvest losses in the teff value chain in Ethiopia. Moreover, it is likely that post-harvest performance in Ethiopia might be better than in developed countries, where quality and cosmetic criteria are more severe, and where foods of lower quality are usually completely discarded from human consumption (Kader 2005; Parfitt et al. 2010).

The findings from this study have important public policy implications. While it is important that post-harvest losses are low, it should also be kept in mind that achieving such reduction in post-harvest losses entail costs. It is therefore important to look at the rate of returns to investments in facilities that might reduce post-harvest losses, and the potential benefits of such facilities (e.g., Greeley and Boxall 2001; Greeley et al. 1978), and then compare these with alternative options for investment. For example, it has recently been shown that the development of a new teff variety, *quncho*, has contributed to increased productivity in the teff sector by 10 percent, i.e., almost five times as much as could be gained by the elimination of all post-harvest losses in teff (Minten et al. 2016).

While we believe that our research has generated novel insights on post-harvest losses, however, there are two important caveats to this analysis that should be tackled in future research. First, we had to limit our producer surveys to an important and well-connected production area supplying teff to the capital. We therefore miss out on estimates from non-commercial areas. Second, no surveys were fielded at the consumer level, and our post-harvest loss estimates therefore only reach the points of sale by the urban retailer. Hence, we have no estimates on wastage at the consumer level. Better estimates of wastage by consumers should therefore be tackled in future surveys in order to extend this data.

[8] Mattoo et al. (2007) mention that "According to one study, India wastes more fruits and vegetables than those consumed in the UK" (ibid, p. 43). Others put wastage of horticulture crops between 20 percent and 40 percent (CII/McKinsey, 1997; Mittal 2007). In Bihar, the World Bank (2007) estimates the wastage in the potato value chain at 24 percent.

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About the Authors

Bart Minten is the Program Leader for the Ethiopia Strategy Support Program (ESSP) and a Senior Research Fellow in the Development Strategy and Governance Division of IFPRI, based in Addis Ababa. **Ermias Engida** is an ESSP Research Officer at the Ethiopian Development Research Institute. **Seneshaw Tamru** is a PhD candidate in the LICOS Centre for Institutions and Economic Performance at the University of Leuven (KU Leuven) in Belgium.

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
2033 K Street, NW | Washington, DC 20006-1002 USA
T: +1.202.862.5600 | F: +1.202.457.4439
Skype: ifprihomeoffice | ifpri@cgiar.org | www.ifpri.org

IFPRI–ESSP ADDIS ABABA
P.O. Box 5689, Addis Ababa, Ethiopia
T: +251.11.617.2000 | F: +251.11.646.2318
mahlet.mekuria@cgiar.org | http://essp.ifpri.info

ETHIOPIAN DEVELOPMENT RESEARCH INSTITUTE
P.O. Box 2479, Addis Ababa, Ethiopia
T: +251.11.550.6066; +251.11.553.8633 | F: +251.11.550.5588
info@edri-eth.org | www.edri-eth.org

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