Quantitative and qualitative post-harvest loss of emmer wheat in selected value chain in Bale zone, Ethiopia

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Abstract: An assessment of post-harvest losses and handling practices of emmer wheat was carried out in 2019 Bale zone, southeastern Ethiopia. A semi-structured survey questionnaire was used to collect primary data from farmers, and traders, whereas FAO’s 4s (screening of relevant data, surveying, sampling, and synthesis) method was used to determine losses in selected value chain of emmer wheat at farmers’ level. The assessment study was conducted in three purposively selected districts and three kebele’s from each district. In this study total of 370 emmer wheat producing farmers were interviewed. Laboratory analysis was carried out to determine the proximate composition losses during storage. A multiple regression analysis was used for post-harvest loss determinants analysis whereas one-way ANOVA for quality loss analysis. The results from the load tracking indicated that harvesting (3.75%), transportation to threshing field (0.17%), and threshing (2.96 %) were identified as the major loss points. Around 58.6% of the respondents mentioned that shattering as the major cause for losses during harvesting. In addition, during threshing, incomplete threshing, seeds eaten by oxen and cleaning (separation of seeds from the straw) are mentioned as the major factors for losses. In the result of this survey study, about 71.10% of farmers have mentioned that the most important causes of the post-harvest losses in storage were occurred due to rodents. The area coverage, yield per hectare, method of harvesting, and harvesting time significantly influenced emmer wheat post-harvest losses at farmers’ level. Hence, it can be concluded that due to poor post-harvest handling practices a significant amount of emmer wheat qualitative and quantitative losses was occurred in supply chains.

Subjects: Agriculture and Food; Food Chemistry; Food Laws & Regulations

Keywords: emmer wheat; post-harvest losses; value chains and determinants

1. Introduction

Teff (Eragrostis tef), maize (Zea mays), sorghum (Sorghum bicolor), wheat (Triticum aestivum), and emmer wheat (Triticum dicoccum) are the main major food crops of Ethiopia (CSA, 2020). In particular, in the Bale zone, emmer wheat is one of the key cereal crops in the country. It was produced by around 206000 small-scale farmers and accounted for about 7% of Ethiopia’s wheat crop (Melese et al., 2019; CSA, 2020). Emmer wheat’s versatility makes it ideal for growing on highlands and on infertile soils. It is also more tolerant of climatic changes, easy to store, and resistant to different pest (Giuliani et al., 2009 & Yaman et al., 2019). Emmer wheat is essential to the life of poor populations as a source of money, nourishment, and traditional medicine (Giuliani et al., 2009). Emmer wheat is a nutrient-dense grain that is high in carbohydrates, proteins,
minerals, fibre, and antioxidant components yet low in fat. In locations where it is grown, emmer wheat is regarded as a highly healthy cereal. Additionally, emmer wheat is praised for its superb flavour and encouraged in the diet of people with allergies (Bartošová et al., 2015; Shewry, 2017). Recently, there has been an increase in the demand for nutritious cereals like emmer wheat, and hulled wheat cultivars show some promise.

Agricultural commodities undergo unit operations harvesting, drying, threshing, winnowing, bagging and storage. The primary role of effective post-harvest practice is to ensure the delivery of harvested crop reaches the consumer, with minimum loss and maximum efficiency. Post-harvest losses in agriculture commodities can occur at any stage between harvest and consumption. The losses can be categorized as weight loss due to spoilage, quality loss, nutritional loss, and seed viability loss (Deepak & Prasanta, 2017). In developing countries, these losses have been estimated to range between 20 to 40% (Deepak & Prasanta, 2017) as compared to developed countries. The low post-harvest losses in developed countries are due to more efficient and advanced agricultural practices, better transportation facilities and infrastructure, and effective storage and processing facilities (FAO, 2017).

Ineffective harvesting and a lack of technological efficiency in post-harvest activities including threshing, cleaning, drying, and storing are the main causes of post-harvest losses (Abrehet F., 2018 and Satheesh & Fanta, 2018). In developing nations like Ethiopia, traditional postharvest treatment of cereal grains is leading to severe postharvest loss, which directly affects food security and results in nutritional and financial losses (Hodges & Bernard, 2014). According to Befikadu (2018), typical postharvest losses in the value chains of specific cereal crops in Ethiopia have been estimated to range from 10 to 50 percent. The Food and Agricultural Organization estimated that in Ethiopia’s post-harvest losses of wheat were 9.9% (FAO, 2018). While a survey research by Dessalegn et al. (2017) found that the average loss of wheat in 2017 was 17.1% across four areas of Ethiopia (Amhara, Tigray, Oromia, and Southern Nations Nationalities and Peoples region). Due to the higher losses in underdeveloped nations like Ethiopia, which still relies on food imports and help to feed its population, reducing postharvest losses is crucial to enhancing food security.

By 2025, 125 million people are expected to live in Ethiopia. Ethiopia’s economy is based on agriculture, which employs roughly 80% of the population (Befikadu, 2018). However, due to unregulated food production and supply in recent decades, several million people needed emergency food assistance, making the nation the largest beneficiary of food aid in Sub-Saharan Africa (Godebo, 2020). For the future security of the world’s food supply, it is thought that postharvest loss must be reduced (Hengsdijk & de Boer, 2017). To offer alternative solutions for the reduction of loss, it is therefore required to determine the main sources and magnitude of losses.

The postharvest grain losses in Ethiopia were found in the range of 30 to 50% (Befikadu, 2018). According to Amentae et al. (2016), and Dessalegn et al. (2017) the postharvest loss of teff, sorghum, barley, wheat and maize were estimated to be 3.3 to 16.3%, 12.5 %, 10%, 17.1% and 17.8 to 22.6 %, respectively. Yet, fewer studies have addressed the gaps in agronomic and breeding of emmer wheat in Ethiopia (Ebso et al., 2017), but studies on determination of qualitative and quantitative postharvest losses among the value chains of emmer wheat are not available. Therefore, this study is important in the present context with the objective of assessing the postharvest loss and quality of emmer wheat and identifying the major causes for the postharvest losses.

Several loss assessment methods (Load Tracking Method, Commodity Assessment System and Rapid Loss Assessment) have been developed to measure postharvest losses in the value chains of the agricultural commodities. Among the postharvest loss assessment approaches, Load tracking method has been developed by FAO. This method is used to identify the critical loss points (where maximum losses are occurring), determine the main causes for the losses and to analyze the
impact and draw the solution to reduce the losses on their technical and economic feasibility. In this assessment method both qualitative and quantitative approach are considered (FAO, 2015).

In this study, load tracking methodology was used to determine the quantitative and qualitative postharvest losses and the critical loss points of emmer wheat value chains in Bale zone, Oromia Regional State. Therefore, the objective of this study was to assess the postharvest loss and quality of emmer wheat and identifying the major causes for the losses.

2. Materials and methods

2.1. Description of the study area

The study was conducted in purposively selected three districts (Ginir, Goba and Sinana) of Bale zone of Oromia region, Ethiopia (Table 1). Bale zone is located 430 km from Addis Ababa in southeastern part of Ethiopia. The bale zone geographically distributed between 6° 44' 59.99"N and 40° 14' 60.00"E (Figure 1) and its elevation ranged from 300 to 4377 meters above sea level. The study location is characterized by bimodal rainfall, with a short rainy season from March to April and a long rainy season from June to mid-October. Bale zone has different climatic conditions which in turn results in different vegetation types. The landscape and the soil type create a favorable condition for the production of different crops. The human force engaged in different economic activities and have diverse cultural values. The highlanders are mostly farmers and the lowlanders are predominantly pastoralists (Olana & Kanna, 2016). Wheat, emmer wheat, teff, barley, maize and sorghum are the major cereal crops produced in this zone. Bale zone is one of the major emmer wheat producing zones in the Oromia region, contributing 66.8% of the total regional production (CSA, 2020). Bale zone comprises 18 rural and 2 urban districts and its capital city is Robe. According to the Ethiopian national census of 2007 E.C, the population of Bale zone is 1.5 million (Olana & Kanna, 2016).

2.2. Sampling procedure and data collection

2.2.1. Determination of Sample size

The FAO (2015), 4S (screening, surveying, sampling (load tracking) and synthesis) methodology was used to conduct this study. The screening of the literature was carried out from secondary data sources including published and unpublished reports and documents from different local agricultural offices. The secondary data was used as input for the assessment survey and field sampling work. As specified early the survey was conducted in purposively selected three districts, on information about emmer wheat production and postharvest handling practices (Abass et al., 2014). From each district, three kebeles were purposively selected based on their potential for production of emmer wheat and out of 8050 farmers 370 emmer wheat producing farmers were selected using the method of Cochran (1977) as described in equation-1.

\[
n_0 = \left( \frac{1}{t} \right)^2 \frac{p(q)}{(d)^2}
\]  

(1)

Where: \(n_0\) is the sample size, \(t\) is the value for the selected alpha level, \(p\) is the estimated proportion of an attribute that is present in the population, \(q\) is 1-\(p\). \((p)(q)\) are the estimate of

| S.no | Location | Latitude | Longitude | Altitude (masl) | Mean rainfall (mm) |
|------|----------|----------|-----------|-----------------|---------------------|
| 1    | Ginir    | 7°08'N   | 40°42'E   | 1750            | 1081.6              |
| 2    | Goba     | 7°0' N   | 39°59'E   | 2,743           | 736.3               |
| 3    | Sinana   | 07°06'12"N | 40°12'40"E | 2400            | 812                 |
variance and \( d \) is the acceptable margin of error for proportion being estimated at 95% confidence level and 5% margin of error.

Further, samples were collected according to the population probability in different kebeles. The data was collected with the help of trained and experienced data collectors and enumerators with supervision of the researchers. Data were collected by using pre-tested questionnaire which was first prepared in English and translated to local language (“Affan Oromo”). The information on socio-demographic characteristics of respondents, farming practices (seed source, seed selection management practices, area and varieties grown), harvesting techniques, postharvest management of emmer wheat, farmers’ awareness, perception on loss and information on improved storage technologies (Abass et al., 2014).

Representative respondents of traders were selected by purposive sampling where total of 20 traders (10 wholesalers and 10 retailers) were interviewed from Robe city main market. Robe is the capital city of Bale zone and it is found 430 km away from Addis Ababa, the capital city of Ethiopia.
Information was collected on socio-demographic characteristics, procurement of emmer wheat, and postharvest handling practices of emmer wheat at traders. The data quality was maintained through closer supervision and checking each questionnaire immediately by the enumerators and supervisors.

A Focus Group Discussion (FGD) was conducted with selected producers to cross-check the information obtained (Kueper et al., 2013). Eight producers participated for the FGD from Sinana woreda. Sinana woreda was selected for FGD because of its potential emmer wheat production than Goba and Ginir. The FGD was made in local language (Affan Oromo) and discussion were made on the findings of post-harvest handling (threshing, winnowing, cleaning and bagging), causes of post-harvest losses, consumption and marketing of emmer wheat. Information was also obtained from key informant interviews (KII) from eight participants of agricultural officers from Sinana woreda.

2.3. Load tracking method to determine cause and extent of losses
Load tracking (LT) is a method used to determine specific loss at a value chain (FAO, 2015). Three farmers were randomly selected from one of the study district. The 5 m x 5 m quadrats were randomly marked from each selected farm. Losses during harvesting, transportation of harvest to threshing field, threshing, winnowing and storage were measured from the quadrat and calculated in percentage loss from the total harvest. In the sampled area the average yield of emmer wheat was 2.1 tons ha⁻¹, used to calculate the losses (CSA, 2020). Procedures used to determine losses during the supply chains are given below.

2.3.1. Loss determination at Harvesting
Losses occurred at harvesting stage due to the shattering were determined by using quadrant from the selected farmer field. Emmer wheat plants were harvested manually by sickles as commonly used in the study area. To estimate the extent of loss during harvesting a 1 m x 1 m quadrant with replication were selected from the 5 m x 5 m quadrats. To quantify the extent of loss during harvesting seeds shattered during harvesting stage in the quadrant were collected and weighed. Finally, the measured harvesting loss was added in the calculation of total harvest (FAO, 2015).

2.3.2. Loss determination during transportation of harvest to threshing field
The harvested hillas were wrapped by polypropylene sheets. Seeds shattered and fall in the sheet were collected and used to measure loss during transportation of hillas to threshing field.

2.3.3. Loss determination at threshing and winnowing
Harvested emmer wheat was threshed in a traditional method by animal tramping and the threshed emmer and straw were retained. The emmer seed retain on the straw and scattered were carefully hand stripped and collected and weighed to estimate the losses occurred during threshing and winnowing. Then all the postharvest losses occur during (harvesting, transportation to threshing fields, threshing and winnowing) were added and converted to losses to per hectare basis.

Once, losses at each actor in considered value chain are observed, the total losses reported in the country calculated. For this calculation, the data on the amount of the land used for the emmer wheat cultivation was acquired from central statistical agency and the relative total losses were calculated by multiplying with the loss amount observed in the study. In addition, the economic loss happened due to the postharvest loss also calculated by considering the price of the emmer wheat in retail market at the study duration.

2.4. Determination of storage loss
To determine the loss of emmer wheat during storage, the percent bored grain method described by Harris and Lindblad (1978) were used. A random sample of 100–1000 grains were taken and the number of bored grains were counted within a few days after storage. Then the percentage damaged grains was calculated by the equation 2.
% Bored grain in sample = \frac{\text{Number of bored grain}}{\text{Total number of grain counted}} \times 100 \quad (2)

Finally, the percentage weight loss was determined by the count and weigh method and the average weight were determined by

\% \text{ Weight loss} = \frac{(UNd - DNu)}{U(Nd + Du)} \times 100 \quad (3)

Where; U = \text{weight of undamaged grains (gram)},

Nu = \text{number of undamaged grains},

D = \text{weight of damaged grains (gram)},

Nd = \text{number of damaged grains}

2.5. Determination of qualitative losses

After harvesting, emmer wheat from one of a surveyed farmer's field was procured for storage loss determination analysis. Samples were packed in polypropylene sack as representing the farmer's practice. To determine the qualitative losses (proximate composition) during storage, the sample were analyzed every three month intervals stored for six months.

2.5.1. Proximate composition

The moisture content was determined by the hot air oven method gravimetrically (AOAC, 2011, method number: 925.10). Protein content was determined by Kjeldhal method and conversion factor of 5.7 was used (AOAC, 2000, method number: 979.09), fiber content was determined by non-enzymatic gravimetric method (AOAC, 2000, method number: 920.168). The fat content was determined by soxhelet extraction method using the hexane as the solvent. In addition, total ash content was determined by using the incineration method by muffle furnace (AOAC, 2011, method number: 923.03).

2.6. Data analysis

Descriptive statistics was used to analyze the survey data by using Statistical Package for Social science (SPSS) software version 25 and a multiple regression analysis was done to identify the determinants of postharvest losses at farmers' level. Equation 4 was used to determine the losses (Aidoo et al., 2014).

\ln \text{PHL} = b_0 + b_1 \ln x_1 + b_2 \ln x_2 + b_3 \ln x_3 + b_4 \ln x_4 + b_5 \ln x_5 + \mu \quad (4)

Where: \ln: \text{denotes natural logarithm; PHL: Post-harvest losses (kg), } x_1; \text{time of harvest after maturity (days), } x_2; \text{variety of emmer wheat grown, } x_3; \text{farm size, } x_4; \text{Method of harvesting, } x_5; \text{quantity of emmer wheat harvested (kg) } \mu; \text{error term.}

Analysis of variance (One-way ANOVA) was used to explore the effect of storage period on proximate of emmer wheat by using SAS version 9.3. Mean comparison was computed at P- value of < 0.05 using least significant different (LSD) test.

3. Results and discussions

3.1. Postharvest handling practice assessment of emmer wheat

3.1.1. Socio-demographic characteristics of respondents and their relation to post-harvest loss

About 89.5 % of the respondents were male with an overall average family size of 8 for Bale zone (6 in Ginir, and 8 each in Goba and Sinana district; Table 2). The proportion of female respondents in the present study of 10.5 % was higher than the report of Dessalegn et al. (2017), who reported...
8% female. Around 42.4% of the respondents had completed primary school education, 9.7% of respondent's completed secondary education. In the study area about 37.6% of the respondents were above 49 years of age and involved in the cultivation of emmer wheat. The sociodemographic characteristics of respondents may lead to different role in management to the agricultural practices. From the observed field and survey study, the result showed that gender played a significant role in the loss of emmer wheat. Male respondents are better involved in the farming practices then female management/handle their products to reduce losses. According to the result of this study, there was a positive relation between the age of the respondents and the loss of emmer wheat. As the age of the respondent increases the loss at each point of chain increases. The possible reasons for the increase of the loss might be the young farmers give better care and use of technologies than the older respondents for postharvest loss reduction.

3.1.2. Postharvest value chain and actors of emmer wheat

The actors are individuals who are directly involved in the value chain activities, whereas the crop value chain is the system of interconnected activities and procedures, where the phases may vary greatly by crops (Gibbon and Ponte 2005). A postharvest agricultural system is a series of connected operations that span the period from harvest to market distribution to consumer consumption. The main players in the value chain are farmers, wholesalers, and retailers. All of these players have one thing in common: at some point along the value chain, they claim ownership of the raw, partially processed, or finished product. Agricultural products undergo a number of processes after harvesting, including drying, storage, processing, transporting, marketing, and consumption.

Figure 2 depicts the key emmer wheat postharvest value chain activity phases and players in our investigation. The survey found that farmers, wholesalers, and retailers were the three main value chain actors. A farmer is a person in charge of agricultural production, harvesting, and tasks connected to processing of emmer wheat after harvest. Retailers, who provide the last link in the supply chain and sell to customers, get enormous quantities of emmer wheat from farmers through wholesalers.

The processes in the value chains of emmer wheat were identified during both the survey and load tracking phases. These steps include harvesting, moving to the threshing fields, threshing, winnowing, and storing. When emmer reach maturity, they are harvested, then threshed, winnowed, and often delivered home by animal cart and small rented cars. In the study region, threshing is done mechanically and tramping is done by oxen. All farmers winnow the grain after threshing to get rid of the chaff and other debris by exposing it to the wind. The grain is then frequently placed in polypropylene bags, kept in a living room, and eventually sold.

3.2. Harvesting practice, estimated losses and reasons for losses

According to the survey results given in Table 3, emmer wheat harvesting starts from early December and completes by end of January. Due to sowing time and weather condition there is some variation in harvesting time among districts. Majority of the respondents (57%) accomplish harvesting during the month of January (Table 3). The respondents from both Ginir (1%) and Sinana (22.3%) start harvesting in early December and Goba (13.4%) at mid of December. Majority of respondents from Goba (70.7%) and Sinana (58%) accomplish harvesting in early January and Ginir (58.4%) in mid-January. Taherzadeh and Saeid (2013) reported that time of harvesting and varietal characteristics are the major factors affecting harvest loss of wheat. Determination of best harvesting time is very important to reduce the post-harvest losses (Kassie et al., 2018). Color change of the stalk and texture of seeds are considered as a major harvesting index by the 65.9% of the respondents. The rest of the respondents (34.1%) count days after sowing to start harvesting (Table 3). Accordingly, the majority of respondents from Ginir (69.9%) counts days after sowing to start harvesting whereas, in Goba (57.3%) and Sinana (67.5%) majority of the farmers consider the color change of stalk and seed texture as main harvesting indices.
| Variables          | Category          | Overall sample | Ginir     | Sinana    | Goba     |
|--------------------|-------------------|---------------|-----------|-----------|----------|
|                    |                   | N = 370 (%)   | N = 113 (%) | N = 175 (%) | N = 82 (%) |
| Gender             | Male              | 331 (85.9)    | 102 (90.3) | 150 (85.7) | 79 (96.3) |
|                    | Female            | 39 (10.5)     | 11 (9.7)   | 25 (14.3)  | 3 (3.7)   |
| Education          | No formal education | 87 (23.5)    | 24 (21.2)  | 45 (25.7)  | 18 (22.0) |
|                    | Can read and write | 79 (21.4)    | 22 (19.5)  | 31 (17.7)  | 26 (31.7) |
|                    | Completed primary education | 157 (42.4) | 46 (40.7)  | 84 (48.0)  | 27 (32.9) |
|                    | Completed secondary education | 36 (9.7) | 17 (15.0)  | 10 (5.7)   | 9 (11.0)  |
|                    | Post-secondary education | 11 (3.0) | 4 (3.5)    | 5 (2.9)    | 2 (2.4)   |
| Age                | 20-24             | 29 (7.8)      | 15 (13.3)  | 7 (4.0)    | 7 (8.5)   |
|                    | 25-29             | 38 (10.3)     | 21 (18.6)  | 10 (5.7)   | 7 (8.5)   |
|                    | 30-34             | 41 (11.1)     | 16 (14.2)  | 18 (10.3)  | 7 (8.5)   |
|                    | 35-39             | 65 (17.6)     | 12 (10.6)  | 35 (20.0)  | 18 (22.0) |
|                    | 40-44             | 58 (15.7)     | 11 (9.7)   | 39 (22.3)  | 8 (9.8)   |
|                    | Above 45          | 139 (37.6)    | 38 (33.6)  | 66 (37.7)  | 35 (42.7) |
| Family size        | 1-3               | 56 (15.1)     | 25 (22.1)  | 12 (6.9)   | 19 (23.2) |
|                    | 4-6               | 110 (29.7)    | 38 (33.6)  | 52 (29.7)  | 20 (24.4) |
|                    | 7-9               | 115 (31.1)    | 27 (23.9)  | 63 (36.0)  | 25 (30.5) |
|                    | Above 10          | 87 (24)       | 22 (20.4)  | 48 (27.4)  | 18 (22.0) |
In Ethiopia, wheat is harvested both manually (commonly by sickle) and by mechanical harvester. According to this study, 47.6 % of the respondents harvest emmer wheat manually, whereas, 52.4 % harvested by mechanical methods. Majority of respondents from Sinana (69.7 %) use mechanical harvester whereas 64.6 % and 61.9 % of respondents harvest manually (Figure 3) in Goba and Ginir, respectively. The possible reason that, Sinana farmers use more mechanical harvesters than the two districts, as they cultivate large emmer wheat area. Manual harvesting by sickles is still used in wheat harvesting in many areas, it is time consuming, laborious and the major cause for losses (Rohman et al., 2016; Sattar et al., 2015). As indicated in Table 3, during harvesting time the participation of both genders is higher (81.7 %) in Goba district followed by Sinana (67.4 %) and Ginir (51.3 %). This finding is in line with the study conducted by FAO (2017) in South Achefer district of Ethiopia, where both men and women participate in cereal harvesting.

About 60.5% of those surveyed were aware of harvest-related losses, the majority of which (58.6%) are caused by shattering in all areas (Table 3). This occurs as a result of farmers leaving the crop in the field in the mistaken belief that doing so will allow them to have sufficient time during overlapping operations at a time when labour is in high demand. More than 73% of those surveyed believe that up to 17% of seeds are lost during harvest. Dessolegn et al. (2017) also reported about 16.3% of losses in wheat during harvesting in Ethiopia. Relatively lower harvesting loss of about 9.10% was reported for wheat in Jordan (Khader & Yigezu, 2019), 8.0 % in India (Jha et al., 2015) and 4.88 % in Nepal (Arun, 2019). The probability of loss from shattering increases as the crop stands on the field longer, both before and during wheat harvest (Mohammed & Tadesse, 2018). Around 90.1 percent of respondents claimed that timely harvesting is the key element in reducing loss during harvest (Table 3). To minimise shattering losses, wheat must be harvested as soon as it reaches maturity (Sattar et al., 2015).

3.2.1. Drying, transport to threshing field, threshing and estimated losses

None of the respondents from the study districts said they dried emmer wheat after harvesting because they only harvested the grain when it was ready to be harvested (Table 4). Similar to this,
| Variables                      | Category                              | Overall sample |                          | Districts                                      |                          |                          |                          |
|-------------------------------|---------------------------------------|----------------|--------------------------|-----------------------------------------------|--------------------------|--------------------------|
|                               |                                       | N = 370 (%)    | N = 113 (%)              | N = 175 (%)                                   | N = 82 (%)               |                          |                          |
| Harvesting mechanism (%)      | Manual                                | 176 (47.6)     | 70 (61.9)                | 53 (30.3)                                     | 53 (64.6)                |                          |                          |
|                               | Machine                               | 194 (52.4)     | 43 (38.1)                | 122 (69.7)                                    | 29 (35.4)                |                          |                          |
| Harvesting time               | Early December                        | 40 (10.8)      | 1 (0.9)                  | 39 (22.3)                                     | 0.00 (0.00)              |                          |                          |
|                               | Mid December                          | 35 (9.5)       | 2 (1.8)                  | 22 (12.6)                                     | 11 (13.4)                |                          |                          |
|                               | End of December                       | 76 (20.5)      | 13 (11.5)                | 51 (29.1)                                     | 12 (14.6)                |                          |                          |
|                               | Early January                         | 141 (38.1)     | 25 (22.1)                | 58 (33.1)                                     | 58 (70.7)                |                          |                          |
|                               | Mid-January                           | 70 (18.9)      | 66 (58.4)                | 3 (1.7)                                       | 1 (1.2)                  |                          |                          |
|                               | End of January                        | 8 (2.2)        | 2 (5.3)                  | 2 (1.1)                                       | 0.00 (0.00)              |                          |                          |
| Harvesting indices            | Counting month from sowing            | 126 (34.1)     | 79 (69.9)                | 57 (32.6)                                     | 35 (42.7)                |                          |                          |
|                               | Color change of stalks and texture of seeds | 244 (65.9) | 34 (30.1) | 118 (67.5) | 47 (57.3) |
| Who is involved in harvesting | Male family members only              | 4 (1.1)        | 2 (1.8)                  | 2 (1.1)                                       | 0.00 (0.00)              |                          |                          |
|                               | Female family members only            | 123 (33.2)     | 53 (46.9)                | 55 (31.4)                                     | 15 (18.3)                |                          |                          |
|                               | Both male & female                    | 243 (65.7)     | 58 (51.3)                | 118 (67.4)                                    | 67 (81.7)                |                          |                          |
| Expectation of harvesting loss| Yes                                   | 224 (60.5)     | 71 (62.8)                | 100 (57.1)                                    | 53 (64.6)                |                          |                          |
|                               | No                                    | 146 (39.5)     | 42 (37.2)                | 75 (42.9)                                     | 29 (35.4)                |                          |                          |

Table 3. Farmers harvesting practice, loss expectation and major causes for the loss during harvesting of emmer wheat in study districts (Ginir, Sinana, Goba) of Bale zone, Ethiopia

(Continued)
### Table 3. (Continued)

| Variables                        | Category                     | Districts                     |
|----------------------------------|------------------------------|-------------------------------|
|                                  | Overall sample               | Ginir                         | Sinana                        | Goba                          |
|                                  | N = 370  (%)                 | N = 113 ( %)                 | N = 175 ( %)                 | N = 82 ( %)                  |
| Main reasons of loss during harvesting (%) | Shattering                   | 217 58.6                      | 68 60.2                      | 96 54.9                      | 53 64.7                       |
|                                  | Insects                      | 1 0.3                         | 0.00 0.00                    | 1 0.6                        | 0.00 0.00                     |
|                                  | Birds                        | 2 0.5                         | 1 0.9                        | 1 0.6                        | 0.00 0.00                     |
|                                  | Rodents at field             | 4 1.1                         | 2 1.8                        | 2 1.1                        | 0.00 0.00                     |
|                                  | No loss                      | 146 39.5                      | 42 37.2                      | 75 42.9                      | 29 35.4                       |
| Farmers estimated loss during harvesting (%) | Half of the harvest (1/2)   | 48 13                         | 11 9.7                       | 9 5.1                        | 28 34.1                       |
|                                  | ¼                            | 40 10.8                       | 14 12.4                      | 7 4                          | 19 23.2                       |
|                                  | 1/6                          | 282 76.2                      | 88 77.9                      | 159 90.9                     | 35 42.4                       |
| Methods suggested by farmers to control loss during harvesting (%) | Harvesting timely            | 333 90.1                      | 92 81.5                      | 164 93.7                     | 78 95.1                       |
|                                  | Using harvesting machine     | 21 5.7                        | 15 13.3                      | 5 2.9                        | 1 1.2                         |
|                                  | Not control                  | 16 4.4                        | 6 5.3                        | 6 3.4                        | 3 3.7                         |
an FAO research published in 2017 demonstrates that farmers in northern Ethiopia’s Korem area do not use field drying for wheat after harvest.

Five primary forms of transportation were employed in the study area, depending on the distance to the threshing fields: donkey (17.8%), human workers (17.3%), animal cart (37.8%), hand cart (0.5%), and small leased cars (26.5%; Table 4). Around 98% of those surveyed concurred that there is no loss during transit to the threshing site. This may be the result of farmers transporting crops to threshing fields with the utmost caution (such as a close proximity between the producing farm and the field). According to FAO (2017), the study carried out in Ethiopia’s Gedebo Hassasa area found that the crop was transported to the threshing fields with a very minimal loss of around 200 g per 100 kg (0.02 percent).

The most common threshing method in Ethiopia is animal tramping (Befikadu, 2018), performed on the land covered (painted) with the cattle dung. When the floor gets dry, hills are spread over and threshing is done by walking of single or pair of oxen in circle. The stones are laid around the threshing floor to prevent the scattering of grain straw. When the crop scatters outside the threshing floor, it will be swept back to the floor using a threshing fork.

According to the present study, threshing of emmer wheat is done by combined harvester (80.8%) and manual (19.2%) methods. The combine harvester charges about 55 ETB/100 kg and perform both harvesting and threshing at the same time. Above 66% of the respondents reported that 17% of seed loss during threshing and winnowing activities. Incomplete threshing (14.9%), seeds eaten by oxen (50.6%) and the process of separating the seeds from the straw (34.6%) are the major factors mentioned by the respondents for losses occurred during the threshing and winnowing activities. In traditional winnowing, exposing the threshed crop to wind leads to higher losses as lighter grains are flown by wind and also as threshing is carried by cattle, the grain may not completely separate from the spike and discarded in to the chaff. During threshing and winnowing process, 13.43% of wheat loss was estimated by farmers in India (Basavaraja et al., 2007) and 3.5% in Ethiopia (Dessalegn et al., 2017). In Madagascar, 9% of rice losses were reported during winnowing and threshing activities (Hodges & Bernard, 2014).

3.3. Storage practices and loss factors in storage
Storage of grains is one of the major post-harvest activities of emmer wheat in the study area. About 98.4% of farmers’ use polypropylene bag for storing emmer wheat, while “gotera” which is made from sticks and mud were used by 0.8% of farmers and the remaining 0.8% farmers do not practice any storage (Table 5). In all the three districts farmers commonly use polypropylene bag for storage of emmer wheat (Table 5). Studies by FAO (2017), Hengsdijk and de Boer (2017), and Yaman et al. (2019) reported that polypropylene bag is widely used for grain storage in different parts of Ethiopia. Polypropylene bag is less effective in protection of grains infestation by insects than other hermetic storages as compared to PICS (Purdue Improved Crop Storage), grain pro super bag, grain safe bag and metal silos (Walker et al., 2018). About 92.4% of respondents in the study area have no awareness about improved storage bags or structures. Similarly, Hengsdijk and de Boer (2017) reported that traditional storage methods are commonly used in Ethiopia for storage of cereals. However, modern storage methods such as metal silos are used rarely in which farmers’ don’t have awareness. Common storage structures used by most of the Ethiopian farmers are traditional with poor protection, exposing the stored grains/seeds to different quality and quantity deteriorating agents (Befikadu, 2018).

About 48.4% of the respondents store emmer wheat bags in separate (without other grains), whereas the remaining respondents (50.8%) store with other crops in common storage places. Common storage is less effective to control seeds from insect infestation. Majority of respondents (74.3%) from Ginir districts are practicing separate storage for emmer wheat as compared to Sinana and Goba districts (Table 5). Most of the respondents (97%) clean storage area before storing emmer wheat (Table 5).
Table 4. Threshing practice, loss estimation and major factors for loss during threshing in study districts (Ginir, Sinana, Goba) of Bale zone, Ethiopia

| Variables                                      | Category                  | Total sample | Ginir     | Sinana     | Goba     |
|------------------------------------------------|---------------------------|--------------|-----------|------------|----------|
|                                                |                           | N = 370 (%)  | N = 113 (%)| N = 175 (%)| N = 82 (%)|
| Drying practice of emmer wheat                | Yes                       | 0.00         | 0.00      | 0.00       | 0.00     | 0.00     |
|                                                | No                        | 370          | 100       | 113        | 100      | 82       |
| Mode of transportation of hillas               | Animal cart               | 140          | 37.8      | 47         | 41.6     | 67       |
|                                                | Hand cart                 | 2            | 0.5       | 1          | 0.9      | 1        |
|                                                | Human labor               | 64           | 17.3      | 34         | 30.1     | 25       |
|                                                | Donkey                    | 66           | 17.8      | 11         | 9.7      | 22       |
|                                                | Small hired vehicles      | 98           | 26.5      | 20         | 17.7     | 60       |
| Perception of farmers about loss occurrence during transportation of hillas to threshing field | Yes                       | 6            | 1.6       | 1          | 0.9      | 5        |
|                                                | No                        | 364          | 98.4      | 112        | 99.9     | 170      |
| Method of threshing                            | Manual                    | 71           | 19.2      | 13         | 11.5     | 21       |
|                                                | Machine                   | 299          | 80.8      | 100        | 88.5     | 154      |
| Loss estimate by respondents during threshing  | Half of the yield (1/2)   | 41           | 11.1      | 15         | 13.3     | 15       |
|                                                | ¼                         | 84           | 22.7      | 29         | 25.7     | 30       |
|                                                | <1/6                      | 245          | 66.2      | 69         | 61.1     | 130      |

(Continued)
Table 4. (Continued)

| Variables                              | Category                                      | Total sample | Districts |
|----------------------------------------|-----------------------------------------------|--------------|-----------|
|                                        |                                               | N = 370      | N = 113   | N = 175   | N = 82   |
|                                        |                                               | (%)          | (%)       | (%)       | (%)       |
| Major factors for losses during threshing (%) | Incomplete threshing                          | 55           | 36        | 2         | 17        | 20.7     |
|                                        | Seeds eaten by oxen during threshing          | 187          | 49        | 95        | 43        | 52.5     |
|                                        | During the process of separating the seeds from the straw | 128          | 28        | 78        | 22        | 26.8     |
In the study area, farmers store emmer wheat for over a year (25.1%). Table 5 shows that there is a difference in storage durations among districts. About 30.9 % of the respondents from Sinana district store emmer wheat for over a year than Goba (24.4 %) and Ginir (16.8 %; Table 5). Many farmers reported that, due to the tough hulls emmer wheat can be stored for a long period. The hard shell structure provides excellent protection against insect infestation in storage (Yaman et al., 2019). More than 72% of the respondents reported about 17% of loss during the storage which is higher than storage loss reported by Bala et al. (2010) for wheat (3.62%) and maize (2.45%) in Bangladesh. Majority of the respondents (91%) mentioned that rodents are the major causes for the losses in all studied districts. In consistent with this result, FAO (2017), and Dessalegn et al. (2017) reported that rodents and storage insects are mentioned as the major factors for the losses of wheat seeds during storage in Ethiopia, which is probably due to poor storage structure and extended storage durations.

3.4. Response of FGD and KII
According to the results obtained through FGD and KII with farmers and agricultural experts from Sinana woreda, the major post-harvest losses of emmer wheat occur during harvesting, threshing and storage. Farmers mentioned that harvesting of emmer is done both by manual and combine harvester. From the discussions farmers revealed that relatively lower losses are observed by use of combine harvester. Farmers and agricultural experts had mentioned that the major reasons for losses during storage are rodents. Additionally, farmers have mentioned that they were not having any awareness on technologies available to control post-harvest losses of emmer wheat.

In case of gender roles in post-harvest management, women farmers in Sinana woreda play a key role in harvesting, cleaning storage facilities, processing and preparation of food for household use. Conversely, men are responsible for activities from harvesting to storage and, they are the decision makers in selling of the crop and deciding the use of income from sales. Both men and women equally participate in most of the postharvest activities. Similarly FAO (2017), also reported that both men and women plays equal role in postharvest management of wheat in Ofila district, Ethiopia.

3.5. Determinants of emmer wheat postharvest loss
A multiple regression analysis showed that area coverage, yield per hectare, method of harvesting, and harvesting time were statistically significant and positively affect emmer wheat loss. The variety grown is not significantly associated with dependent variable. The adjusted coefficient of determination ($R^2$) was 0.278, indicating that 27.8 % of variation in the quantity of emmer wheat lost during and after harvesting was explained by the specified variables in the model.

The regression results showed that yield of emmer wheat has a positive and significant relation with postharvest loss occurred at farmers’ level at less than 5 % probability level (Table 6). An increase of emmer wheat production by one quintal increases the amount of postharvest losses increase by 0.252 kg. This may be due to the challenges faced by farmers’ like harvesting of emmer wheat at the right time due to the lack of manpower and advanced technologies. Basavaraja et al. (2007), also reported that in India there is a positive relationship between the amount of post-harvest losses and the amount of wheat produced. Similarly, Amentae et al. (2016) reported that production of higher amounts of teff has a positive relation with its post-harvest losses in Ethiopia.

The area allocated for emmer wheat production was significant at < 5 % probability level and had a positive relationship with quantity of emmer wheat postharvest loss. When production area increases, total yield will increase and it also increases the emmer wheat postharvest losses. With respect to postharvest losses, larger area allocation for the cultivation implies for greater yields. In this case, there is the greater chance of losses due to poor handling and lack of proper storage facilities (Filli et al., 2019). According to the results, harvesting time was significant at 1 % probability level and has a positive association with emmer wheat postharvest losses (Table 6). Early and delayed harvesting of grains had a direct impact on postharvest losses. The time of
Table 5. Storage durations, loss estimation and major reasons for storage losses in study districts (Ginir, Sinana, Goba) of Bale zone, Ethiopia

| Variables                        | Category                                      | Total sample | Districts          |
|----------------------------------|-----------------------------------------------|--------------|--------------------|
|                                  |                                               | N = 370 (%)  | N = 113 (%)       | N = 175 (%)       | N = 82 (%)       |
| Storage methods used             | Polypropylene bag                             | 364 (98.4)   | 110 (97.3)        | 172 (98.2)        | 82 (100)         |
|                                  | Gotera                                        | 3 (0.8)      | 3 (2.7)           | 3 (2.7)           | 0.00 (0.00)      |
|                                  | Others                                        | 3 (0.8)      |                   |                   |                   |
| Storage room                     | Separate storage for emmer                    | 179 (48.4)   | 84 (74.3)         | 86 (49.1)         | 9 (11)           |
|                                  | Common storage with other crops               | 188 (50.8)   | 29 (25.7)         | 89 (50.9)         | 73 (89.0)        |
| Storage period                   | Yes                                           | 359 (97)     | 107 (94.7)        | 170 (97.1)        | 82 (100)         |
|                                  | No                                            | 11 (3)       | 6 (5.4)           | 5 (2.1)           | 0 (0.00)         |
|                                  | 3 months                                      | 102 (27.60)  | 39 (34.5)         | 22 (12.6)         | 38 (46.3)        |
|                                  | 6 months                                      | 137 (37)     | 46 (40.7)         | 76 (43.4)         | 15 (18.3)        |
|                                  | 9 months                                      | 38 (10.30)   | 6 (5.3)           | 23 (13.1)         | 9 (11)           |
|                                  | >12 months                                    | 93 (25.10)   | 19 (16.8)         | 54 (30.9)         | 20 (24.4)        |
| Reasons for loss during storage  | Rodents                                       | 263 (71.1)   | 91 (80.5)         | 113 (64.6)        | 59 (72.0)        |
|                                  | Insects                                       | 19 (5.1)     | 4 (3.5)           | 9 (5.1)           | 6 (7.3)          |
|                                  | No loss experience during storage             | 88 (23.8)    | 18 (16)           | 53 (30.3)         | 17 (20.7)        |
| Loss estimate by respondents     | Half of the yield (1/2)                       | 48 (13)      | 14 (12.4)         | 21 (12)           | 13 (15.9)        |
|                                  | ¼                                             | 54 (14.6)    | 14 (12.4)         | 21 (12)           | 19 (23.2)        |
|                                  | >1/6                                          | 268 (72.4)   | 85 (75.2)         | 133 (76)          | 50 (61)          |

(Continued)
| Variables | Category | Total sample |  |  |  |
|-----------|----------|--------------|---|---|---|
|           |          | **Total** | **Ginir** | **Sinana** | **Goba** |
|           | **N = 370** |  | **N = 113** | **N = 175** | **N = 82** |
| Awareness of respondents to improved storage structures (%) | Yes | 28 | 7.6 | 13 | 11.5 | 12 | 6.9 | 3 | 3.7 |
|                        | No | 342 | 92.4 | 100 | 88.5 | 163 | 93.1 | 79 | 96.3 |
harvesting is considered as one of the most important factor in determining post-harvest losses of crops (Filli et al., 2019). Early harvesting encourages insect pest activity due to high grain moisture content and easy access to grains, shuts off the translocation process and reduces the yield and quality (Paneru et al., 2018).

The post-harvest losses of emmer wheat were positively and significantly affected by the method used for the harvesting of emmer wheat. The result implies that the good scientific method of harvesting also reduces post-harvest loss of emmer wheat. Traditional harvesting activities can lead to increased harvesting losses and rapid quality deterioration as compared to combined harvester. The study conducted by Sattar et al. (2015) reported that harvesting techniques had considerable impact on grain losses of wheat in Pakistan.

3.6. Postharvest handling practices and losses of emmer wheat at wholesalers and retailers level
Wholesalers purchase the produce from farmers (90 %) and collectors (10%). Majority of the wholesalers (60%) have the tendency of storing their products and commonly they use polypropylene bags for storage (Table 7). Based on the survey result, respondents are aware of the cause of losses and how to control them. Majority of the wholesalers (60%) considered rodents as the major causes for the losses of emmer wheat in storage. Whereas, the remaining (40%) respondents mentioned there are no losses during storage. The majority of wholesalers responded that loss of emmer wheat is about 16.5 kg /q during storage which is significantly higher than losses reported by Basavoraja et al. (2007) for wheat (0.08 kg/q) in India. Similarly, Amentae et al. (2016) also mentioned rodents as the major factors for loss of teff during storage at wholesalers’ level in Ethiopia.

Around 70 % of the retailers were buying emmer wheat directly from farmers and only 30% from collectors (Table 7). In retailers level no storage facilities were available; they leave their produce at market place to sell on the next day (Table 7). Based on the response, at retail level handling methods during the selling process was mentioned as the major causes for emmer wheat losses. The price of emmer wheat in the study season (December, 2019) was 60 ETB /kg in Robe retail market.

3.7. Results of Load tracking method used to assess loss in emmer wheat in selected supply chain
The study revealed that most of the surveyed farmers experienced losses during postharvest handling operations at harvesting, transportation, threshing, winnowing and storage. Farmers expressed their inability to effectively reduces losses occurred during postharvest operations. To determine the amount of losses occurred in post-harvest handling of emmer wheat, load-tracking activities were done on manual harvesting, transport to threshing field and threshing and winnowing process.

The extent of harvesting losses determined as 3.75% (Figure 4). The loss is maximum during harvesting followed by threshing and transportation to threshing field. This result was in line with the finding of Dessalegn et al. (2017) which states that the maximum loss of wheat (6.8 %) was occurred during harvesting followed by threshing in Ethiopia. High amount of losses were reported during the harvesting operations. This may be due to the harvesting of the crop at wrong maturity (when the crop is not at optimum physiological maturity; Deepak & Prasanta, 2017). During the field observation, while using manual harvesting the core reason for losses was shattering of grains. Similarly, Amentae et al. (2016) reported about 1.87 % post-harvest losses during harvesting of teff.

Crop harvesting at optimum physiological maturity provides higher seed yield and better qualitative characteristics (Befikadu, 2018) and knowledge of optimum maturity and harvesting time is important to control shattering losses.

In this study, a relatively lower loss (0.17%) was measured due to transportation from farm to threshing field (Figure 4). Similarly, the study conducted by FAO (2017) showed that transportation
loss from harvesting field to threshing floor of wheat was below 1.0% and this minimum losses were due to utmost care that is taken by farmers in the transportation. In addition to wrapping hills, decreasing the distance between harvesting farm to threshing field is a better strategy to reduce the loss (Figure 5).

Losses occurred during the threshing and winnowing activities was 2.96%, which is the highest loss point next to harvesting. These losses were mainly due to grazing of animals (animals used for threshing) on threshing materials and sticking of the grains to the soil, this made grain inferior in quality and losses during exposing to wind while winnowing. Similarly, the study conducted by FAO (2017) on maize post-harvest loss reported that losses occur during shelling or threshing of maize was mainly due to poor practice. After threshing, farmers clean their grains by winnowing in the natural wind force using “menshe”. During this process, it was possible to observe that strong winds cause grain loss by flying the grains away. The survey result of this study also confirmed that the main causes for threshing losses was due to grazing of the oxen during threshing, incomplete threshing and trapping of seeds on the straw. Good management practices during threshing and winnowing are crucial to minimize loss. This finding is consistent with Dessalegn et al. (2017), reported that wheat losses in Ethiopia during winnowing is about 2%.

During the storage losses determination, no damaged grains were observed for six months of storage. Similarly, the result of this survey study showed that farmers have mentioned by its nature emmer wheat is not susceptible to storage insects. Remigiusz et al. (2019) also reported that ancient wheat species such as emmer wheat and spelt are more resistant to storage insect pests compared to common wheat due to the natural barrier such as tougher glume and glumelle that protects grains against pathogens and pests. The total weight loss was figured out as 1.5% during storage.

In identifying the critical loss points the results of load tracking agrees with the survey outputs. However, the extent of losses estimated in each point during the survey was more exaggerated than the result obtained during the load tracking method.

### 3.8. Nutritional quality deterioration of emmer wheat in storage

The analysis of variance indicated that the effect of storage period had significantly influenced the protein and moisture contents of emmer wheat sample. On the other hand, total fat, ash and crude fiber are not significantly affected by storage periods.

#### 3.8.1. Protein content

The protein content of the emmer wheat samples before the storage was 9.19% (Table 8). However, as storage durations prolonged, protein content was significantly decreased. Protein content was reduced by 2.39% when emmer wheat was stored for six months. Similarly, Guo et al. (2015) reported that with an extension of storage period from 3 to 12 months crude protein of wheat decreased by 12%. In addition, Idler et al. (2012) also reported that storage period had a significant influence on protein content of stored wheat. Research indicated that the decrease in protein content during

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**Table 6. Regression results on the determinants of emmer wheat loss at farm level**

| Variables             | Coefficients | Standard Error | P-value |
|-----------------------|--------------|----------------|---------|
| Intercept (a)         |              | 0.029*         | 0.00    |
| Yield per hectare     | 0.252        | 0.022*         | 0.00    |
| Method of harvesting  | 0.455        | 0.026*         | 0.00    |
| Harvesting time       | 1.47         | 0.019**        | 0.00    |
| Varieties grown       | 0.028        | 0.131          | 0.53    |
| Area coverage         | 0.109        | 0.029*         | 0.017   |

Adjusted $R^2 = 0.278$; *, **, *** = significant at 5%, 1% and 0.1%, respectively
prolonged storage time is because of the progressive increase in non-protein nitrogen content, which could be due to the protein degradation during storage (Guo et al., 2015).

3.8.2. Moisture content

Moisture content of emmer wheat samples was significantly affected by storage duration extension. The initial moisture content was observed as 11.33 % (Table 8), as storage period extended...
Figure 5. Transporting hillas wrapping in polypropylene sheet to threshing field and shattered seeds on the sheet.

| Storage period | Moisture (%) | Crude fat (%) | Protein (%) | Ash (%) | Crude fiber (%) |
|----------------|--------------|---------------|-------------|---------|-----------------|
| Initial day    | 11.33<sup>a</sup> | 3.6<sup>a</sup> | 9.19<sup>a</sup> | 3.83<sup>a</sup> | 12.19<sup>a</sup> |
| Three months   | 10.76<sup>b</sup> | 3.5<sup>b</sup> | 8.30<sup>b</sup> | 3.83<sup>b</sup> | 12.19<sup>b</sup> |
| Six months     | 8.13<sup>c</sup> | 3.00<sup>c</sup> | 6.84<sup>c</sup> | 3.82<sup>c</sup> | 11.63<sup>c</sup> |
| LSD (0.05)     | 0.12         | 0.608         | 0.79        | 0.18    | 0.77            |
| CV (%)         | 0.52         | 4.20          | 2.29        | 0.18    | 1.50            |
| Mean           | 10.07        | 3.36          | 8.11        | 3.83    | 12.00           |

The values are presented in observation of triplicates
Note: LSD = Least Significance Difference and CV = Coefficient of Variation
Means with the same letters are not significantly different at 0.05 level

Moisture content significantly decreased. Similarly, the study conducted by Saif and Ahmed (2015) reported that the storage period had significant effect on moisture content of wheat. The reduction in moisture content of grains could be due to the loss of moisture to the air in the storage through transpiration (evaporation).

### 3.8.3. Ash content

The analysis of variance in this study revealed that storage duration had no significant influence on emmer wheat ash content (Table 8). Similar to this result, a study conducted by Andoseh et al. (2018) reported that storage duration had no influence on ash content of wheat and maize.

### 3.8.4 Crude fat

Crude fat content of emmer wheat sample is not significantly influenced by storage period (Table 8). In opposite to this result, the study conducted by Khadra et al. (2013) reported that the fat content of rice is significantly influenced by storage period.

### 3.8.5. Crude fiber

Crude fiber content of emmer wheat is not influenced by storage periods (Table 8). Whereas, the study conducted by Khadra et al. (2013) reported that as storage period increases there is a significant increase in crude fiber content of rice grains.

### 3.9. Emmer wheat loss estimation in terms of economic value

According to the load tracking result of this study about 0.006 tons ha<sup>-1</sup> or 128 tons of emmer wheat per year is lost in the whole country. According to the central statistical agency production data the average land covered by emmer wheat for the last five years (2016 to 2020) in Ethiopia...
was 106,409 ha. Out of the total production about 639 tons of emmer is lost in the country. Based on survey results the average emmer wheat price of 1 kg was 100 ETB (2.5 USD) in the country. The total amounts monetary of losses are equivalent to 1,597,500 USD per year.

4. Conclusions
The study showed that, there was an agreement between loss assessment survey and load tracking methods in terms of identifying critical loss points in emmer wheat postharvest handling activities. The significant factors contributing to the emmer wheat losses were identified as shattering during harvesting, incomplete threshing, and rodents during storage and lack of awareness on postharvest handling practices. Based on the survey results, the postharvest losses mentioned by farmers are overstated than the losses estimated by the load tracking study. From the load tracking study an estimated total loss of 6.88 % was found, Among the total losses attributed to harvesting (3.75 %), transportation to threshing field (0.17 %), and threshing (2.96 %). Around 6.88% losses in the post-harvest losses due to on farm postharvest activities will have a significant economic impact. In addition, the study showed that further storage of emmer wheat after six month had significantly influenced protein and moisture content. Hence, from the study it is possible to recommend that:

(i) Improved postharvest-handling practices and suitable storing of emmer wheat may bring a significant impact on reducing the post-harvest loss of emmer wheat
(ii) Capacity building in post-harvest research and development is one way of reducing post-harvest losses of emmer wheat in Ethiopia
(iii) Involvement of different stakeholders like research and development organizations, agriculture trainers is crucial in considering the identified loss points to implement losses reduction strategies in emmer wheat handling.

Highlights
- The highest (3.75 %) seed loss was recorded during harvesting.
- Area coverage, yield per hectare, method of harvesting, and harvesting time were statistically significant and positively affect emmer wheat loss.
- Further extension of storage period beyond six months causes significant decrease of protein and moisture content
- The lowest (0.17 %) loss was reported during transportation to threshing field
- About 92.4 % of respondents in the study area have no awareness about improved storage bags

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