

## Full Length Research Paper

# Assessment of post-harvest losses of *Warqe* food products along the supply chain in Central Ethiopia

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Post-harvest food loss is a global problem but it is more critical in the food-insecure countries. Food waste occurs at different levels in the food supply chain from production through post-harvest handling to consumption. The presented paper aims at an assessment of post-harvest food loss of *warqe* foods along the supply chain and identified hot spots of the losses in the chain. *Warqe* (*Ensete ventricosum* (Welw) Cheesman) is banana like plant and it used as a food and non-food applications. *Kocho* and *bulla* are two main food products of the *warqe* plant. A total of 522 responders were randomly selected across the supply chain started from the two major *warqe* growing areas. *Kocho* and *bulla* reach final consumers through various channels. About 45.3% of *kocho* and 45.6% of *bulla* were lost from the total marketed product along the supply chain. The highest *kocho* (24.0%) and *bulla* (28.8%) losses were observed at retailer and processor levels, respectively. Practicing poor processing method, using perishable packaging material, poor transportation and inappropriate storage and market conditions were the main reasons for the losses. It is, therefore, important to work on value addition in *warqe* foods, improve processing storage and packaging technologies to reduce post-harvest losses.

**Key words:** *Bulla*, Ethiopia, *Ensete ventricosum*, *kocho*, post-harvest loss.

## INTRODUCTION

Post-harvest food loss is a global problem but it is more critical in food-insecure countries. The Food and Agriculture Organization of the United Nations (FAO) estimated that one-third of food produced for human consumption is wasted globally, which is equivalent to about 1.3 billion tons per year. This loss leads to significant losses of resource used for food production (FAO, 2011). Post-harvest loss exists throughout the supply chain, from initial agricultural production down to

final household consumption (Parfitt et al., 2010). Losses of food from farm to table through storage, transport, processing, and retail and in consumption are huge and associated water loss is significant, and therefore, reducing food loss and wastage reduces water needs in agriculture (Lundqvist et al., 2008).

In order to assess the magnitude of the food waste problem, it is first essential to define what food waste means. Losses of food are described using many

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different terms and there is no clear definition or demarcation between the terms *food losses*, *food waste*, and *post-harvest losses*. These terms are used in inconsistent ways in the literature and sometimes overlap. It is not easy to find one definition that combines all kinds of food waste. According to Grolleaud (2002), food loss is the loss in a quantity which leads the food to become unfit for human consumption. Food loss and waste is defined by Lipinski et al. (2013) in depth as “*the edible parts of plants and animals produced or harvested for human consumption but not ultimately consumed by people. It represents a decrease in the mass, caloric, and/or nutritional value of edible food intended for human consumption at any stage in the food value chain.*” According to (FAO, 2013), food loss implies the decrease in the quantity or quality of food which was originally intended for human consumption. However, food waste is defined as food appropriate for human consumption being a waste, whether or not it is kept beyond its expiry or left to spoil. The word food wastage includes both food loss and food waste together and it refers to any food lost by deterioration or waste. Food waste can occur at different points of food supply chain (Parfitt et al., 2010) and this wastage has a significant influence on the sub-Saharan African situation of food shortage (Affognon et al., 2015). It is believed that reducing of wastage of food by improving post-harvest management is more crucial than the production of more food by extensive agriculture horizontal expansion. Hodges et al. (2011) have also pointed out reducing food losses can increase food availability without requiring additional production resources and it can contribute to rural development and poverty reduction in less developed countries.

The main causes of post-harvest loss in low-income countries may include improper methods of harvesting, insufficient cooling, and unhygienic handling, lack of infrastructure, poor technical and managerial skill in food production and post-harvest (FAO, 2011). Bio-deterioration by microorganisms, insects, rodents or birds are also the main causes of postharvest loss in low-income countries (Hodges et al., 2011). Post-harvest loss ranges from about 21% for cereals up to 66% for fruits and vegetables in Sub-Sahara-African food value chains. Studies conducted in Ethiopia on seven fruit and vegetable crops (tomato, cabbage, onion, potato, mango, banana and avocado) revealed that the total average post-harvest losses range from 14 to 60%. Highest losses observed on cabbage were 58.9% and lowest loss (14.1%) recorded on onion crop (Gebresenbet et al., 2016). Developed world (North America, Oceania, and Europe) and the industrialized Asian nations such as China, Japan, and South Korea share about 56% of food loss and waste occurs from total loss whereas the developing world accounts for 44% of the loss (FAO, 2011). When looking at the distribution of the loss and waste, there is significant variation between developed and developing regions. In the developed countries loss

occurs more at the consumption level, however, in developing countries, it occurs more during production and handling and storage (Lipinski et al., 2013). For instance, in Tanzania, maize losses that occur in the field are more economically significance than those which occur during any other single activity from harvesting to marketing (Abass et al., 2014). Main causes of significant post-harvest losses in the early stage of the supply chain in developing countries are financial and structural limitations in harvest techniques, storage, and transport infrastructures, combined with climatic conditions favourable to food spoilage (FAO, 2013).

Relatively there are high food losses of fresh root and tubers in developing countries early in the supply chain (FAO, 2011). As a result wastage of starchy roots appears in the top 10 because of high wastage volumes in the agricultural and post-harvest phases (FAO, 2013). One reason for this high loss in these countries is the perishable nature of the crops which make them easily damaged during harvesting and post-harvest activities especially in the warm and humid climates (FAO, 2011). However, many of the developing countries peoples are highly dependent on root and tuber crops as a source of food, nutrition and cash income (Scott et al., 2000). In Ethiopian root and tuber crops are the third national food commodity next to maize and wheat in the quantity of production (CountrySTAT Ethiopia, 2016). Cassava, potato, sweet potato, and yam are the major root and tuber crops in worldwide and reported that about 50 millions of hectares occupied by these crop in 1995-95 worldwide (Scott et al., 2000). Some other root and tuber crops are very specific to a certain country, for instance, *warqe* is a staple food in Ethiopia.

*Warqe* (*Ensete ventricosum* (Welw.) Cheesman) is banana like plant and sometimes it calls “*enset*”. *Warqe*-based farming plays a significant role in food security of Ethiopia (Brandt et al., 1997). According to Gebremariam (1996), *warqe* grows in Sub-Saharan countries and Asia mainly as a wild plant and only domesticated in Ethiopia. The complex *warqe* farming system is the most sustainable indigenous farming activity in Southern and South-western Ethiopia and supports the densely populated highlands of these regions in terms of food sources (Tsegaye and Struik, 2002). Ethiopian economy as a whole strongly depends on agriculture. In 2016, Ethiopian population estimated about 92.2 million (ECSA, 2016) and over 84% of the population lives in rural areas, where crop production and animal husbandry are their main livelihoods (CountrySTAT Ethiopia, 2016b). Agriculture accounts for 42.9% of gross domestic product (GDP) of the country (MoFED, 2014) and it contributes to nearly 80% of export earnings. Moreover, it provides employment opportunity to 73% of the population (EATA, 2014). The exact number of people that depend on *warqe* food is not known. Thus, based on the 2014 Central Statistical Agency of Ethiopia agricultural sample survey report (ECSA, 2014) and 2012 population projection

(ECSA, 2013), it could be estimated that about 35% of Ethiopians, living in the *warqe* production areas, use *warqe* as their staple food. In addition, *warqe* is commonly used as food in big cities like Addis Ababa, Awassa, Dilla, Adama, Jimma, Sodo, Hosaena, Wolkite, Woliso, Bonga, Arba Minch, and other cities, which makes that more than 35% of the Ethiopian population consuming *warqe* as food.

Production of *warqe* foods is processed by traditional knowledge, using locally made traditional tools (Hunduma and Ashenafi, 2011). The major food products of the *warqe* plant are *kocho*, *bulla* and *amicho*. *Kocho* is the dough which is the bulk of the fermented starch obtained from the mixture of the decorticated leaf sheaths and pulverized corm. *Kocho* processing involved a two-stage fermentation process and fermentation takes place in earth pit. After two or three months, fully fermented *kocho* can be produced (Tuffa, 2016). The bread that is prepared from fermented *warqe* is also called *kocho*-bread. It is common to serve in the restaurant's menu *kocho*-bread with *kitfo* (*kitfo* is traditional Ethiopian food which is prepared from chopped red meat mixed with spiced butter). *Bulla* is white dry powder or semi-liquid which is produced by squeezing the decorticated leaf sheaths and pulverized corm and decanting the liquid. It is eaten as porridge and dumpling. *Amicho* is non-fermented the corm of *warqe*, which is consumed after boiling just like other root and tuber crops (Brandt et al., 1997).

Mogessie and Yewelsew (1996) reported that about 33% of *kocho* spoilage happens during storage. Traditional *kocho* fermentation and extended period of storage in the pit has shown spoilage problem and it creates bad smell (Brandt et al., 1997; Hunduma, 2012). Hunduma (2012) indicated that works done on the post-fermentation loss of *warqe* primary food products are very minimal and no scientific attempts have been made to improve storage facilities for products. Even though *warqe* has multiple uses, the production, and processing of this "valuable" crop is poorly investigated. Unlike many other crops, *warqe* has had very little research conducted on it. Very limited information about the post-harvest loss of *warqe* primary food products is available. Moreover, the cause of spoilage is not clearly known so far and the extent of loss in the supply chain of *warqe* has also not been studied and documented. Thus, the main objective of the present study was to assess the post-harvest losses of *warqe* food products along the supply chain and to identify hot spots of the losses in the chain. The specific objectives were to quantify post-harvest losses of *warqe* food products at different chain levels and to identify the factors responsible for the losses.

## MATERIALS AND METHODS

### Selection of study area

The study was conducted during 2014 across the major *warqe*

growing areas of West Shoa and Southwest Shoa Zones of Oromia Region, Ethiopia. Two major *warqe* growing areas namely Haro Wanchi and Maruf were purposely selected for this study. These study sites were selected with the consultation of relevant agricultural officials and based on preliminary survey result made in 2013. The result of preliminary indicated that Haro Wanchi and Maruf areas are main sources of *kocho* and *bulla* supplier to the central market (Addis Ababa, the capital city of Ethiopia) (Tuffa, 2016). Haro *kocho* market, Haro open market, Haroj and Woliso *kocho* main market were selected by following *kocho* and *bulla* supply in Haro Wanchi area. Guder Odo-Bari *kocho* open market and Guder *bulla* market were selected by following supply from Maruf area. All these markets are feeders to Addis Ababa Merkato *kocho* market, which was also included in the study. To collect data regarding *bulla* processing in Addis Ababa and Woliso cities were selected. Consumer related information was collected from Haro Wanchi, Guder, Ambo and Addis Ababa.

### Sample size and sampling technique

Multistage sampling procedures were used to select representative respondents from the study areas. In the first stage, *warqe* grower households from Haro Wanchi and Maruf areas were selected. Then traders, transport operators, small-scale food processing enterprises and consumers were selected by following *warqe* products supplied from the two growing areas. Appropriate sample sizes were determined using Equation 1, assuming that there is no significant difference in population of *warqe* grower farmers (Yamane, 1967):

$$n = \frac{N}{1 + N(e^2)} \quad (1)$$

Where  $n$  is designated as the sample size the researcher uses,  $N$  is designated as total number of households in Haro Wanchi (680) and Maruf (525) areas;  $N = 1205$  *warqe* growing household in total,  $e$  is designated as maximum variability or margin of error 0.063 and 1 designates the probability of the event occurring. Thus samples of *warqe* grower households were determined as 209.

For transport operators, small-scale *bulla* processing enterprises, and cultural restaurants, we considered all the aforementioned in the area because of their small population. Generally, in analysing the supply chain and post-harvest loss of *warqe* foods a total of 522 respondents were selected by using simple random sampling method for collecting primary data and information at production, processing, distribution and consumption levels. Among the total respondents interviewed, 209 were *warqe* growing households, of which 91 households from Maruf area and 118 households from Haro Wanchi were selected.

A total of 56 *kocho* and *bulla* traders were interviewed in all marketplaces. About 15 respondents were selected from *kocho* and *bulla* transport operators. Eight traditional food processing enterprises were included in this survey. Interviews were also held with *warqe* consumers both at household and restaurant levels for assessing post-harvest losses of *warqe*. A total of 223 *warqe* foods consumers at household level were randomly selected and interviewed. Again, 11 cultural restaurants were purposely selected from Addis Ababa city and included in the study.

### Method of data collection

Five sets of pre-tested semi-structured interview questionnaires translated to the local language were used for collecting data and information from all respondents. Data collections were done by eight data collectors out of them two were researchers and six were data enumerators. Trained enumerators were used with close supervision and involvement in data collection by the researchers to

avoid variation between data collectors. These respondents comprised of *warqe* growers, processors, traders (intermediaries), transporters and consumers. The data collected were reviewed and the information required to address the specific aspects of the study was extracted and utilised. Secondary data were gathered from the agricultural offices of the respective districts, journal articles, and other research reports. Market information was received from tax offices and market owners of respective *kocho* and *bullaa* markets.

Socio-economic characteristics of the farmer such as family size, the age of the farmer, education level, land ownership, total farm size and *warqe* farm size were considered and recorded.

### Method of estimation of different post-harvest food losses

Post-harvest food losses in this study refer to measuring quantitative and qualitative losses that occurred at each level in the supply chain. Quantitative loss implies the loss of physical substance of these products which are reflected in weight loss. The quality losses in this study is expressed in a change of colour, taste, and odour in *kocho*, *bullaa*, and their food products. However, the qualitative loss is more difficult to measure because of the lack of quality criteria that are easily measurable.

The post-harvest loss was assessed by adopting LaGra (1990) Commodity System Assessment Methodology (CSAM). CSAM is made up of 26 components in four subsections that together account for all the steps associated with the pre-production, production, post-harvest handling and marketing of any given commodity. CSAM helps to quantify the losses and identify the causes of losses at different points of the food supply chain. Field data from different respondents (farmers, transporters, traders, food processors, and consumers) were collected on quantity basis and post-harvest losses obtained at different operations and different levels. *Warqe* growers were asked through questionnaire-based interview what quantity of *kocho* and/or *bullaa* they produced during 2014. To assess post-harvest losses, farmers were asked how much quantity of *kocho* and/or *bullaa* products was lost during each operation (harvesting, sorting, processing, fermentation, storage, and transporting to market).

Traders' level losses were estimated as the quantity of the *warqe* product lost during trading in the same period. During interviewing, the traders were asked what quantity of *kocho* and/or *bullaa* was bought and sold. Then the losses at different levels of traders (transportation, handling etc.) were estimated in terms of the quantity bought.

Losses at consumers' level were estimated on the basis of the quantity lost at households and restaurants. Post-harvest losses were also estimated for different types of losses such as weight loss, rotten or spoilage, and physical losses, etc. The characteristics and symptoms of different types of losses were explained to the respondents and it helped to identify and quantifying the losses they experienced. Then, the individual losses were calculated in reference to the total quantity of the *warqe* product and expressed in percentage. For the calculation of total losses in terms of percentage, it should be noted that the total cannot be taken as the sum of the percentages at each loss stage. Thus, if the producer losses, wholesaler losses, food processing losses, retailer losses and consumer losses were  $x_1$ ,  $x_2$ , and  $x_3$ , ...,  $x_n$ , then total losses were calculated as:

$$x_1 + (100 - x_1) \times x_2 / 100 + [100 - (100 - x_1) \times x_2 / 100] \times x_3 / 100 + \dots$$

### Data analysis

Data analysis was made using MS Excel and IBM SPSS Statistics software version 22. Using the pivot table and figure, depending on

the type of data, means, standard deviation and/or frequencies were computed. T-test, least significant difference (LSD) test was used to identify significant differences between *warqe* growing areas and value chain stage ( $P < 0.05$ ) at 95% confidence interval level.

## RESULTS

### *Warqe* production

*Warqe* production is one of the main farming activities in the areas of Maruf and Haro Wanchi. As shown in Table 1, the size of farmland and a number of *warqe* stand in the farm significantly differed between Maruf and Haro Wanchi areas. Average farm land size per household in Maruf (1.93 ha) was larger than the Haro Wanchi (1.01 ha) area. The size of farm land covered by *warqe* in Maruf area was larger (3,413.19 m<sup>2</sup>) as compared to Haro Wanchi (1,955.35 m<sup>2</sup>). However, land covered by *warqe* was not significantly different between the two areas. On the other hand, the number of *warqe* plants per household in Haro Wanchi area (688 plants) was higher as compared to Maruf area (226 plants).

The maturity stage of *warqe* plant differs from plant to plant and it depends on the *warqe* cultivar planted and climatic conditions of the area. The present study has shown that *warqe* plant in Haro Wanchi matures (6.07 years) earlier than that of Maruf area (4.57 years). However, *kocho* yield per plant in Maruf was higher (64.82 kg/plant) as compared to Haro Wanchi (29.08 kg/plant) and this yield positively correlates with a number of plant per unit area (Table 1). Under the condition where the number of *warqe* plant per unit area is small there is a higher yield of *kocho* per plant. With regards to *bullaa* and *amicho* yield per plant, there is no significant difference between the two study areas. A highly significant difference in the length of *kocho*, *bullaa*, and *amicho* storage period is observed between Haro Wanchi and Maruf. *Kocho* and *bullaa* on average stores for 302.74 and 262.68 days in Maruf, respectively; but in Haro Wanchi *kocho* can be stored on average for 90.75 days and *bullaa* for 35.11 days. *Kocho* and *bullaa* can store for a longer period of time compared to *amicho*. It was observed that in Maruf the maximum storage time for *kocho* was 730 days while it was for 540 days for *bullaa* whereas in Haro Wanchi *kocho* stores for 365 days and *bullaa* for 180 days.

*Warqe* production is the main source of household income in the study areas (Table 1). There was a highly significant difference in income generated from *warqe* in the two areas. On average, a household can get up to 3,106 Ethiopian Birr per year (1 US dollar  $\approx$  21 Ethiopian Birr) in Haro Wanchi, whereas in Maruf a household can get about 1,336 Ethiopian Birr per year from *warqe* sale. The study also has revealed that Maruf farmers travel more distance (8.5 km) to sell their *warqe* products as compared to Haro Wanchi area (3.86 km).

**Table 1.** Farm size, land cover by *Warqe*, maturity time, yield and storage time, contribution of *Warqe* to income in year and distance to market in the study areas (mean  $\pm$  SE).

Parameter	Area		Mean
	Maruf	Haro Wanchi	
Size of farm land (hectares)**	1.9 ( $\pm$ 0.2)	1.0 ( $\pm$ 0.4)	1.5 ( $\pm$ 0.1)
Land covered by <i>warqe</i> plant (m <sup>2</sup> ) <sup>ns</sup>	3413.2 ( $\pm$ 739.2)	1955.3 ( $\pm$ 685.4)	2900 ( $\pm$ 538.7)
Numbers of <i>warqe</i> plants in a farm**	225.9 ( $\pm$ 13.3)	687.7( $\pm$ 33.3)	408.5 ( $\pm$ 24.9)
<i>Warqe</i> plant mature (year) **	4.6 ( $\pm$ 0.1)	6.1 ( $\pm$ 0.1)	5.4 ( $\pm$ 0.1)
<i>Kocho</i> yield (kg/plant) **	64.8 ( $\pm$ 3.7)	29.1 ( $\pm$ 0.8)	43.8 ( $\pm$ 2.0)
<i>Bulla</i> yield (kg/plant) <sup>ns</sup>	4.4 ( $\pm$ 0.5)	3.7 ( $\pm$ 0.2)	3.9 ( $\pm$ 0.2)
<i>Amicho</i> produce (kg/plant) <sup>ns</sup>	14.1 ( $\pm$ 5.2)	17.1 ( $\pm$ 1.3)	17.1 ( $\pm$ 1.3)
<i>Kocho</i> stored (in days) **	302.7 ( $\pm$ 15.4)	90.8 ( $\pm$ 7.5)	185.7 ( $\pm$ 10.9)
<i>Bulla</i> stored (in days) **	262.7 ( $\pm$ 18.2)	35.1 ( $\pm$ 19.9)	112.4 ( $\pm$ 16.8)
<i>Amicho</i> stored (in day) **	1.0 ( $\pm$ 0.0)	1.9 ( $\pm$ 0.1)	1.9 ( $\pm$ 0.1)
Revenue from <i>warqe</i> (Birr/year) **	1335.9 ( $\pm$ 207.7)	3105.6 ( $\pm$ 207.7)	2754.0 ( $\pm$ 180.9)
Distance to marketplace (km) **	8.5 ( $\pm$ 0.9)	3.9 ( $\pm$ 0.1)	4.90 ( $\pm$ 0.3)

\*\*Highly significant difference ( $P < 0.01$ ) between *Warqe* growing areas (Maruf and Haro Wanchi) at 95% confidence interval of the difference; <sup>ns</sup> non-significant difference between *Warqe* growing areas at 95% confidence interval of the difference.

### Purpose and uses of *warqe* growing

The survey result indicates that *warqe* plant is the major food and non-food crop in the study areas. Almost all respondents (94%) of *warqe* growing farmers noted that *warqe* makes an integral part of their livelihood and 6% of them consider as less important for their livelihood. All respondent farmers mentioned that they mainly grow *warqe* for multipurpose. The purpose of *warqe* crop production in the study areas is presented in Figure 1. *Warqe* growers were putting in the order of importance *warqe* crop production for family livelihood as food, construction purpose, leaves used for bread making, a plant used as soil conservation, to make household utilities, for income generating, medicinal value for human and animal, feeding the animal, compost, and fuel.

### Supply chain of *warqe* foods

The supply chain of *warqe* food products is illustrated in Figure 2. Producers, collectors, wholesalers, retailers, processors, transporters, open market dealers and consumers (households and restaurants) were the main actors in *kocho* and *bulla* supply chain. As described, Chaka et al. (2016) producers are referred to *warqe* growing farmers. Collectors are non-licensed traders who operate in the primary market (local market). They are one of the basic key players in the local market. The collectors generally run their business with wholesalers. They buy *warqe* products directly from producers in the vicinity of growers and sometimes at the local market and transport to the marketplace and then sell all the collected products in a large amount to wholesalers at the

local market.

Wholesalers are big traders and generally operate between rural market and urban market. They have fixed establishment in the marketplace with a short time storage facility. They purchase a lot of *warqe* products from producers or through collectors and sell a large amount of *warqe* products to retailers and large consumers like restaurants. The retailers have permanent shops or places in the market. In the shops, they have a storage place. They purchase products in a bulk amount from their suppliers and sell in a small amount to their clients. *Bulla* processors are those who are involved in the processing of *bulla*. They purchase fresh *bulla* in a large amount and then process it into dried products and sell in bulk or in a small quantity to their customers. Transporters are those who participate in the transporting of *warqe* products by using vehicles from local market to central market or somewhere from market to processing place and from processing place to market. Open market dealers are retailers and have a permanent place in the urban market. They purchase a few products from retailers or processors. They run their business with other commodities and sell their products to the consumer at urban market. Consumers are final consumers and those who make food from *kocho* and *bulla* for direct use by themselves or to sell the foods which are prepared from *warqe* products to their customers in the restaurants.

It was observed that the supply chain is long and often overlapping. The relationship of *warqe* supply chain actors is complex. Producers sell their products either to wholesalers, collectors and/or to consumers. The proportion of the amount sold depends on the availability of buyers and nearness of market. Collectors purchase a

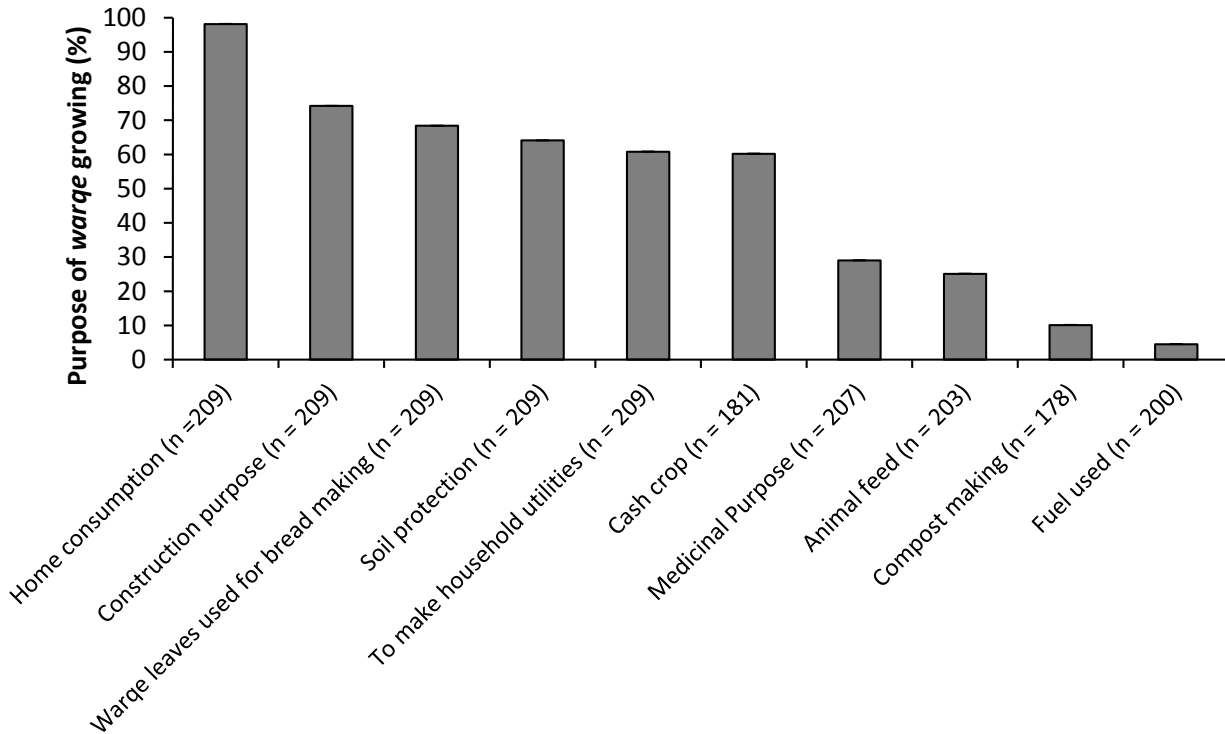


Figure 1. The multiple purposes of warqe crop production in the study areas (n is the number of respondents).

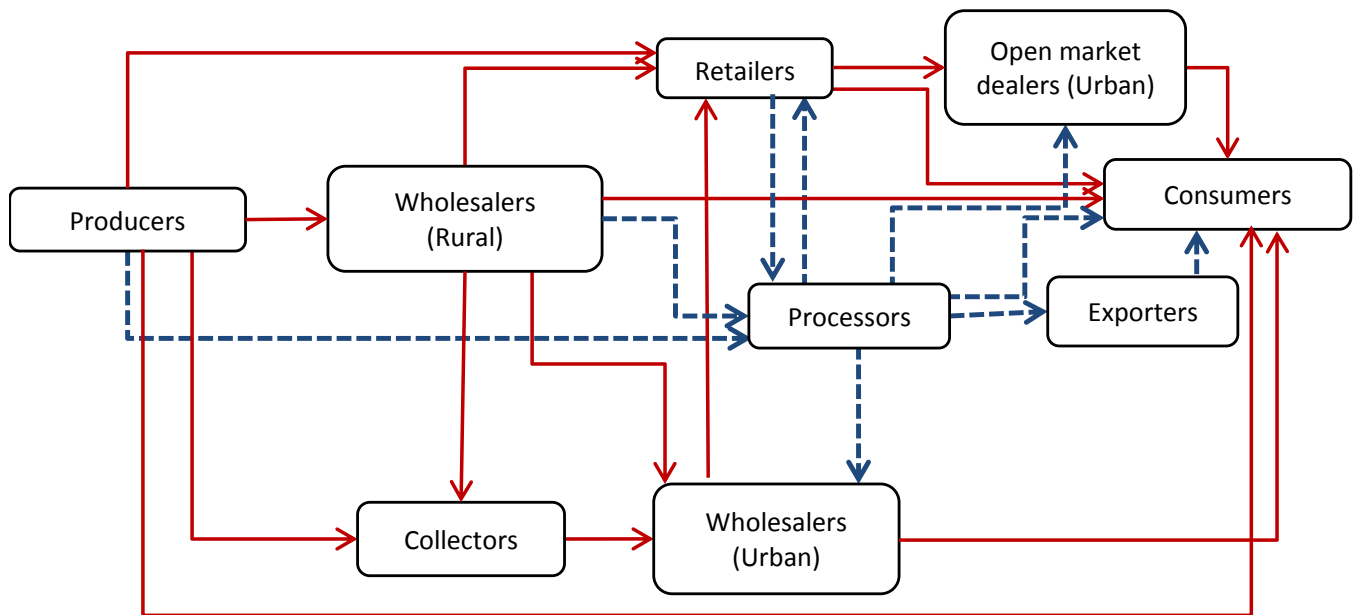
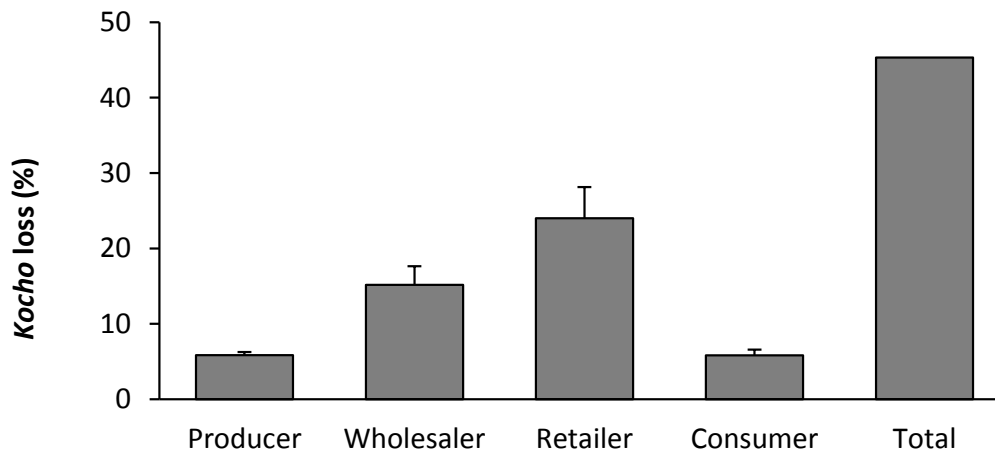


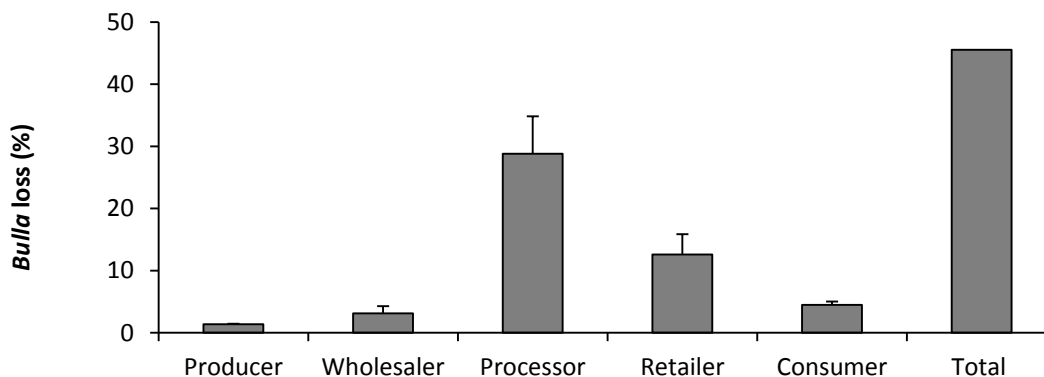
Figure 2. Schematic mapping of the *kocho* and *bulla* supply chain in the central part of Ethiopia. Red solid arrows indicate that physical flow of *kocho* and fresh *bulla*. Blue dash arrows indicate the physical flow of processed *bulla*.

large amount of *kocho* and fresh *bulla* from producers and wholesaler in the vicinity of farmers and at the local market. They sell directly to urban wholesalers.

Wholesalers buy *kocho* and fresh *bulla* from producers and then sell to urban wholesalers, retailers, and consumers. Urban wholesalers sell their *kocho* and fresh



**Figure 3.** Kocho loss (%) at different stages of warqe supply chain in Central part of Ethiopia (mean  $\pm$  S.E).



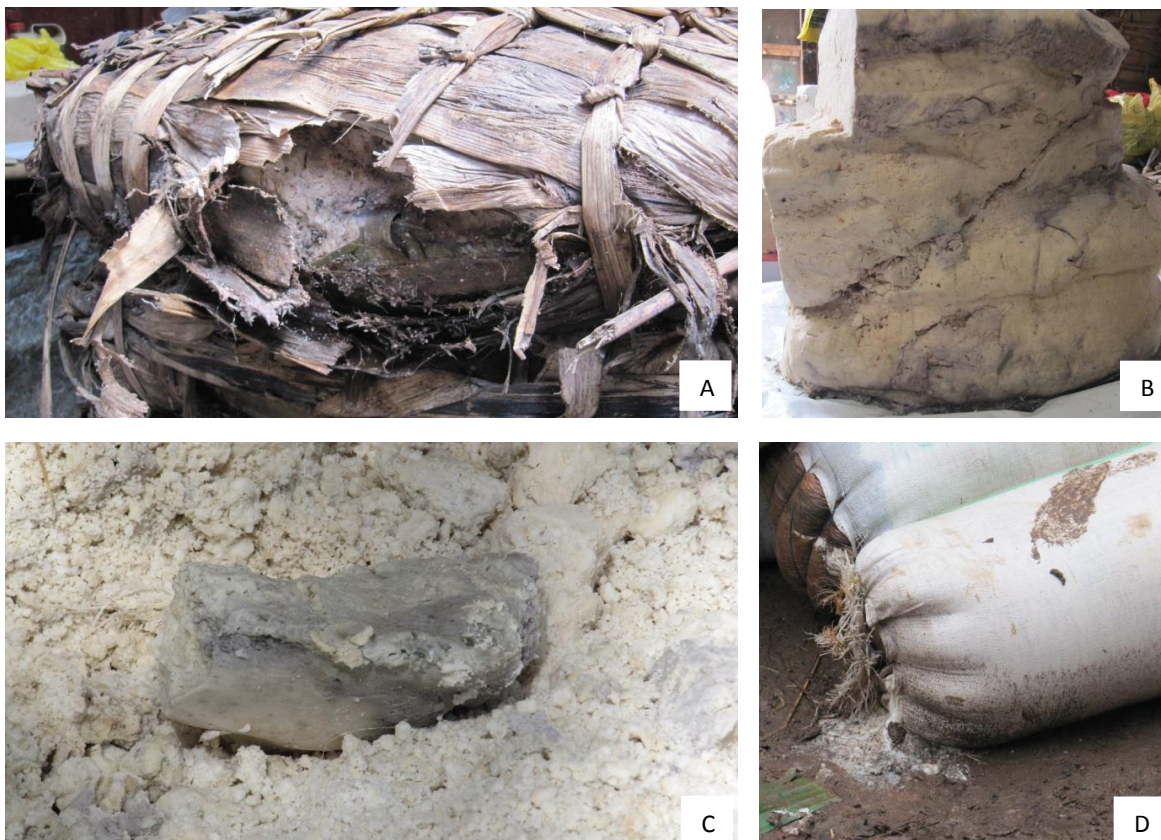
**Figure 4.** Bulla loss (%) at different stages of warqe supply chain in Central part of Ethiopia (mean  $\pm$  S.E).

*bulla* to retailers and directly to consumers. Retailers buy from wholesalers and sell larger portions, to consumers and the rest to open market dealers in urban areas. Open market dealers buy from retailers and directly sell to consumers.

It observed that the supply chain of *bulla* is different than that of *kocho*. In *bulla* supply chain, both fresh and processed *bulla* products are involved. The supply chain of fresh *bulla* is similar to that of *kocho* as described above. For the purpose of processing, fresh *bulla* is purchased by processors from three different suppliers which include: Producers, wholesalers, and retailers. Processed *bulla* is mostly sold to wholesalers, retailers and open market dealers and some amount directly to the final consumers. Very small amount of processed *bulla* is sold to exporters. Exporters export the products to different countries mainly to Ethiopian traditional restaurants and shops which are found abroad. Thus, final consumers can get *kocho*, fresh and processed *bulla* from different suppliers through a number of chains.

### Post-harvest food losses in the supply chain

Substantial losses were observed in the whole supply chain of *warqe* food products. There was a highly significant ( $P < 0.01$ ) difference in the extent of loss between the chain actors for both *kocho* and *bulla* (Figures 3 and 4). It was calculated that about 45.3% of *kocho* and 45.6% of *bulla* are lost from the total marketed product of *kocho* and *bulla* in the supply chain respectively. In *kocho* supply chain, the highest loss is estimated at retailer levels. For *kocho*, the loss at retailer levels is 24.0% of the total loss of the same product at all supply chain levels. Figure 5 shows the spoiled *kocho* at marketplace due to damage by rodents (A) and poor display and exposure to the air (B). The lowest *kocho* losses were estimated at producer and consumer levels to have been about 5.8%. Similarly, in the *bulla* supply chain, the highest loss (28.8%) is reported at processor level (Figure 4). The lowest loss is observed in *bulla* at producer level which is about 1.4% of the total *bulla*



**Figure 5.** Spoiled *kocho* at marketplace due to damage by rodents (A) and poor display and exposure to the air (B). *Bulla* spoilage at processing place due to mould development (C) and physical loss due to poor packaging (D).

produced. In general, the losses of *bulla* and *kocho* are similar in the chains.

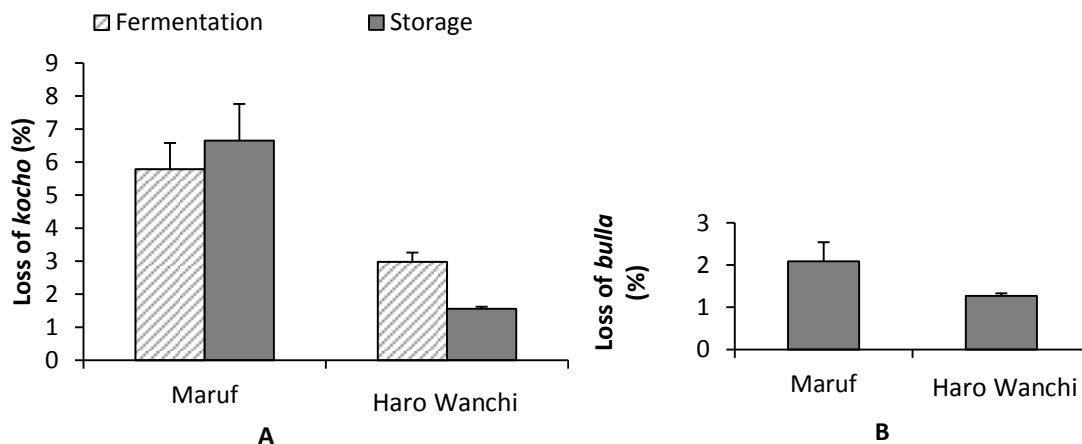
Loss of *kocho* and *bulla* at producer level in the study areas is shown in Figure 6. Loss of *bulla* is reported to be found only during storage time at the producer level. No loss was reported for both *kocho* and *bulla* during harvesting and transportation. However, some physical losses of *warqe* are observed while harvesting, but it was difficult to quantify that losses. There was highly significant difference ( $P=0.000$ ) in the extent of loss reported of *kocho* in the storage at Maruf and Haro Wanchi areas. There was also a highly significant difference ( $P=0.002$ ) in the extent of loss reported of *kocho* during fermentation process between Maruf and Haro Wanchi areas. However, there was no significant difference in the extent of *bulla* losses between the two areas ( $P=0.106$ ). The highest loss of *kocho* has been reported at Maruf area both in the storage (6.7%) and during the fermentation process (5.8%). The lower losses have been reported at Haro Wanchi, which was about 3% loss during fermentation and 1.6% loss in the storage. Main causes of losses during the fermentation process of *kocho* were the entrance of flood water during the rainy season to the fermentation pit, exposure of products to air and sunlight, improper decorticating process, mould

development and soil contamination. Rodent attack (mainly mole rats), the insects (termites and ants) damage has been specifically reported in Maruf area, mould development and physical loss were causes of loss in the storage.

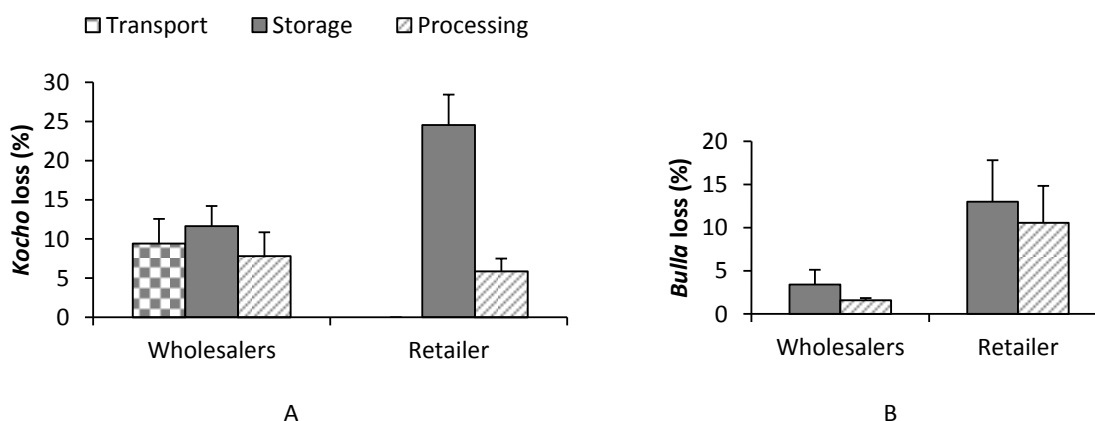
Fermentation and storage losses are higher in Maruf area as compared to Haro Wanchi area. The reason of higher loss observed in storage at Maruf area is due to the fact that *kocho* is usually stored for a long time of period at Maruf (303 days) whereas at Haro Wanchi *kocho* is stored on average for 91 days (Table 1). The main reason of higher loss occurs in fermentation period at Maruf is reported that there are higher termite and ant pests existing in the area. These insects live in the fermentation pit and cause spoilage of *kocho*.

There are the highest losses of *kocho* and *bulla* recorded at trader level. The losses recorded at wholesalers and retailer level is shown in Figure 7. There was a significantly different ( $P=0.016$ ) in storage loss of *kocho* observed between wholesaler and retailer levels. The loss during transportation to the marketplace is observed only at the wholesale level. However, the loss reported during *kocho* and *bulla* processing and that of *bulla* at storage is not significantly differed between wholesalers and retailer level. The loss at the storage





**Figure 6.** Loss of *kocho* (A) and *bulla* (B) in percentage at producer level (mean  $\pm$  SE) from the total produced.



**Figure 7.** Estimated loss of *Kocho* (A) and *bulla* (B) at wholesalers and retailer levels (mean value + SE) from total purchased.

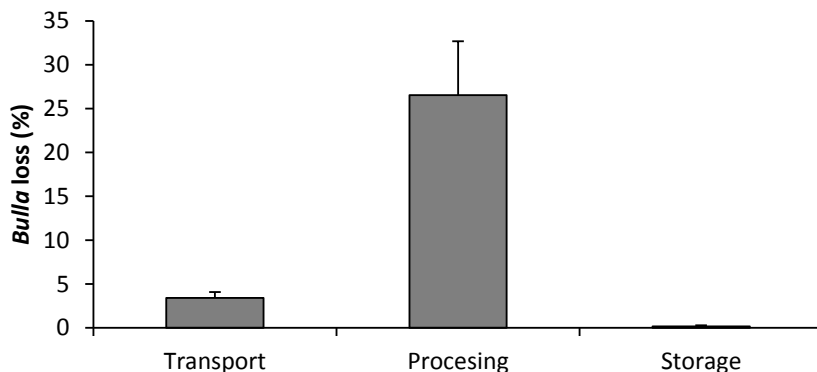
**Table 2.** *Kocho* and *bulla* storage duration and distances of suppliers to marketplace at trader level (mean value  $\pm$  S.E).

Parameter	Business group			Mean
	Wholesalers	Collectors	Retailer	
Distances of suppliers travel to market (Km) *	30.92 ( $\pm$ 3.87)	20.00 ( $\pm$ 2.89)	62.25 ( $\pm$ 13.55)	41.95 ( $\pm$ 5.32)
<i>Kocho</i> stored (days)**	8.26 ( $\pm$ 1.62)	7.00 ( $\pm$ 0.00)	29.35 ( $\pm$ 4.65)	16.12 ( $\pm$ 2.32)
<i>Bulla</i> stored (days) <sup>ns</sup>	113.53 ( $\pm$ 54.30)	7.00 ( $\pm$ 0.00)	98.67 ( $\pm$ 29.77)	97.79 ( $\pm$ 28.04)

\*\* Highly significant difference ( $P < 0.01$ ) between business groups at 95% confidence interval of the difference; \* Significant difference ( $P < 0.05$ ) between business groups at 95% confidence interval of the difference; <sup>ns</sup> non-significant difference between business groups at 95% confidence interval of the difference.

both for *kocho* and *bulla* shows the most remarkable loss at trader level. Storage losses in *kocho* (24.5%) and that of a *bulla* (13.0%) from total purchased products at the retailer are the highest losses recorded. The main factors responsible for losses during transport to the marketplace are poor packaging, leakage (physical loss) and poor

transporting methods. The main factors for the storage loss in both *bulla* and *kocho* are reported to be poor packaging, long period storage (Table 2) and mould development. The cause of *kocho* and *bulla* losses at market place processing is mainly due to lack of suitable processing place.



**Figure 8.** Loss of *bulla* experienced by the processor (mean value + SE) from the total purchased *bulla*.

**Table 3.** *Kocho* and *bulla* purchased annually (mean  $\pm$  S.E) and storage (day  $\pm$  S.E) at consumer level.

Parameter	Types of consumers			Mean
	Household in countryside	Restaurant	Household in city	
<i>Warqe</i> foods purchased in a year (Kg) **	759.7 ( $\pm$ 58.2)	22934.5 ( $\pm$ 10460.3)	21.9 ( $\pm$ 6.6)	1770.9 ( $\pm$ 571.6)
<i>Kocho</i> stored (days) **	195.20 ( $\pm$ 10.85)	31.91 ( $\pm$ 8.20)	130.50 ( $\pm$ 80.03)	185.46 ( $\pm$ 10.49)
Fresh <i>bulla</i> stored (days) <sup>ns</sup>	104.16 ( $\pm$ 11.15)		103.63 ( $\pm$ 41.99)	104.14 ( $\pm$ 10.78)
Dried <i>bulla</i> stored (days)			105.45 ( $\pm$ 29.50)	105.45 ( $\pm$ 29.50)

\*\*Highly significant difference ( $P < 0.01$ ) between types of consumers at 95% confidence interval of the difference; <sup>ns</sup> non-significant difference between types of consumers at 95% confidence interval of the difference.

### **Bulla loss at processor level**

There is high loss observed during *bulla* processing (Figure 8). Highly significant differences ( $P=0.001$ ) are observed between the losses that occur during its transportation to processing points, during processing operation and storage at processing points losses. The highest *bulla* loss is observed at processor level which is about 26.5% of the total fresh *bulla* purchased. The lowest *bulla* loss was the storage loss (0.2%). The main reasons for loss at transport and storage were poor package and poor transport handling which result in a physical loss. Poor quality products for processing and physical loss during cleaning, washing, and drying activities were the main reasons for losses at processing operation. The development of mould and deterioration in quality due to exposure to air was another cause of loss at the processor level.

### **Warqe foods loss and wastage at consumer level**

From *kocho* and *bulla*, different kinds of food are prepared. *Kocho*-bread, *Qummusi* (bread made from *kocho* mixed with cereals flour), *Honkuroo* (it is prepared from best quality of *kocho* mixed with spiced butter served for a highly respected guest); porridge and

soup are some of the food types prepared from *warqe* in the study areas. The amount of consumption varies depending on the types of consumers (Table 3). On average, about 760 kg of *warqe* food is consumed per year in the countryside at household level with an average family size of 6.3. However, in the city at a household level, about 22 kg of *warqe* foods per year is consumed. *Kocho* is mainly consumed both at household and restaurant levels whereas *bulla* is mainly consumed at the household level.

At the consumer level, there was a significant amount of food wastage observed (Figure 9). There were highly significant differences ( $P=0.000$ ) on loss observed between different kinds of losses at the consumer level. Highest food wastage was observed due to leftover food (3.7%) from total prepared food, however, no significant difference in the loss that occurs with *kocho* in storage (3.4%) from total purchased at the consumer level. The lowest loss was observed at storage of fresh *bulla* (1.2%). Food wastage due to the leftover was mainly because of the excess or over-preparation of food, improper preparation of food and excess provision of food. Major causes of loss of *kocho* in storage at consumer level were its exposure to the air and contamination of soil in the storage pit. Physical loss, sticky nature of *bulla* and inappropriate food preparation were the main reasons for the loss during food

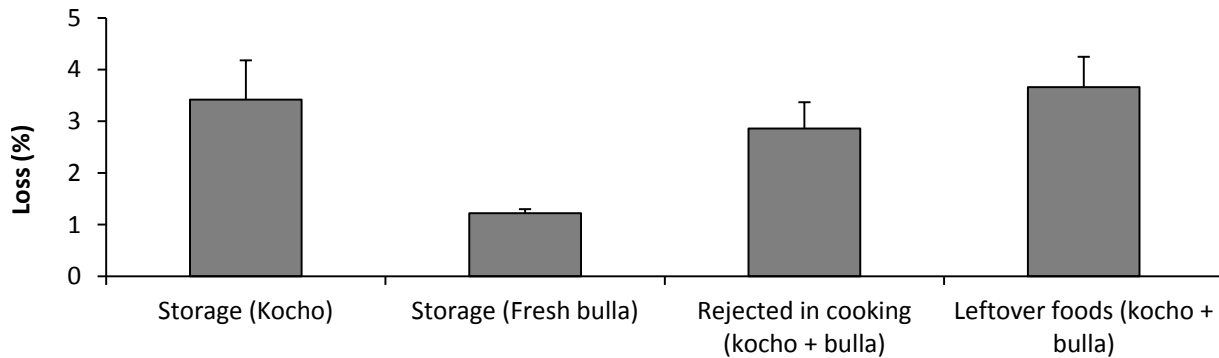


Figure 9. Warqe foods loss and wastage at the consumer level (mean  $\pm$  S.E.).

preparation of *bulla*.

## DISCUSSION

*Warqe* production is unique as compared to cereal crops and needs complex processing to produce *kocho* and *bulla*. The farmers describe that in the study areas at least one *warqe* seedling needs to be three times transplanted to the permanent site. One fully mature *warqe* plant needs on average six to seven years after final transplanting to permanent planting site to reach harvesting. To get fully fermented, *kocho* needs two to three months fermentation process in the pit. Farm and processing activities are gender-based labour division. It is observed that unlike other crops all post-harvest and trading activities of *warqe* is mainly done by women. Moreover, men are not involved in the marketing activities even in the central market in Addis Ababa; most of the *warqe* traders are women. In the study of Abass et al. (2014) indicated that in Tanzania maize processing activities mainly done by women. In line with our observation, Chiche (2012) and MacEntee et al. (2013) reported that women as a sole responsible body in decision making for processing; marketing and in *warqe* income controlling at the producer level. The role of men and women in *warqe* cultivation and processing are clearly distinguished. Women have the responsibility to secure household food by transforming the *warqe* plant into *warqe* food (Negash and Niehof, 2004). This indicates that tradition and cultural influence of *warqe* production and trading are very unique and it is considered as taboo if men are involved in the processing and trading activities. It makes the burden on women, as they are responsible for every post-harvest activity and this cultural tradition makes life very tough for women in the *warqe* growing areas throughout the country.

Growers use inputs like cattle manure as organic fertilizer and planting materials for *warqe* production from their own source. This indicates that in the *warqe* production system there are no external farm inputs suppliers. Brandt et al. (1997); indicate that *warqe*

farming mechanisms allow long-term high productivity with minimum external inputs. However, there are some research findings and experiences which indicate that there are improved *warqe* varieties and inorganic fertilizer application technologies developed by research centres. However, these technologies are not communicated to the farmers in the study areas. This implies that farmers do not have other options to use improved technologies like planting materials and fertilizer as a result of which they kept on using their own sources of farm inputs.

The results of the present study show that *warqe* is grown in the study areas for multipurpose uses (Figure 1). Farmers expressed that *warqe* is everything for their livelihood; it is food, it is feed to animals, medicine, packaging material, plates, beds, construction materials to build house and fence and even a source of water for cattle during the dry season. *Warqe* is also household's main income source and the majority of farmers (38%) responded that more than 75% of their household income comes from *warqe* production. This implies that *warqe* production is a very crucial farm activity for their family livelihood. In agreement with this study, previous study reports of the show that the livelihood of families in the *warqe* producing areas depends on *warqe* (Brandt et al., 1997; Negash and Niehof, 2004; Degu, 2012; Teamir and Tilahun, 2012). *Warqe* production is the basis of household food security (Negash and Niehof, 2004); it is insurance against hunger (Brandt et al., 1997) and more than just a food crop grown for multipurpose (Brandt et al., 1997; Degu, 2012; Teamir and Tilahun, 2012). It also has a potential of being used as industrial raw material to produced fibre-related goods and starch for paper and adhesives (Brandt et al., 1997; Bezuneh, 2012).

Most of the past studies were conducted in the southern parts of the country and reported about multiple uses of *warqe* focusing on family food security. However, the present study shows that *warqe* is used as a cash crop in addition to other benefits of this crop. This could be due to two main reasons: The first reason could be that the study areas have very suitable climate to grow *warqe* plant and this gives the best quality product with higher yields. *Warqe* product of the study areas is known

for its quality and it is known by a brand name “Yechebo *kocho*” in the market. The second reason is that the areas are located very close to the central market (Addis Ababa Merkato market) and thus the *warqe* products of these areas highly demanded in the market. These all indicate that *warqe* grown in the areas is not only for food but also enables farmers to get motivated by non-food products and multiple uses for their livelihood, including its use as a source of income.

It has been observed that *warqe* foods supply chain is long and complex (Figure 2). *Kocho* and *bulla* reach to final consumers through different suppliers in complex chains. According to Khatami et al. (2015), a supply chain defines networks among suppliers, manufacturers, transporters, warehouses, retailers and customers, which are systematized to transform raw materials into finished products and allocate the final products among customer through retailers. However, in the present study, supply chain refers to the sequential arrangement of different chain actors involved in the movement of *warqe* food products from producers to ultimate consumers. In the chain of *warqe* food products, mainly *kocho* and *bulla* follow from producers to final consumers through numbers of chain actors.

Generally, *kocho* and *bulla* reach the consumers in various ways. Rural consumers directly get from producers and wholesalers in local marketplaces. However, urban consumers in cities access through retailers, processors and open market dealers. The supply chain of processed *bulla* is different from the supply chain of the fresh *bulla*. In line with our study report, Degu (2012) also reports that similar ways of the supply chain are reported for fresh *bulla* in the Southern part of Ethiopia. There are multiple causes for the complexity of *warqe* food product supply chain including the producers and wholesalers in rural areas do not have the information about central markets, the transportation and market facilities are poor, there is an absence of links between producers and retailers, processors and consumers, and a lack of cooperation among producers. This is compounded by the nature of products like bulkiness and easy perishability. In addition, there is a lack of support from government to *warqe* markets, dominance of central market suppliers by a few people and difficulty for new players to enter central markets.

A significant amount of *warqe* foods is wasted throughout the supply chain, from initial *warqe* growing down to final household and restaurant consumption (Figures 3 and 4). The results show that highest loss occurs with *kocho* at retailer and *bulla* at processor levels while the lowest loss is recorded at the producer and consumer levels in both food types. In a report of FAO (2011) it is indicated that generally, food loss mainly occur at early and middle levels of food supply chain and less food is wasted at the consumer level in the low-income countries. Similar to the current study result FAO (2011) report shows that highest losses occur in post-

harvest handling and storage and processing and packaging, and the lowest losses are observed at consumption for roots and tubers in sub-Saharan Africa. This indicates that *warqe* food loss has the same trends of losses that occur in roots and tubers in the sub-Saharan Africa.

Highest *kocho* (24.0%) and *bulla* (12.6%) losses are observed at retailer levels particularly market storage. These highest losses reflect that the *warqe* food products are traded in poor hygienic conditions in the market. Traders sell the products by displaying at open air. There is no proper storage place for products and traders use the same place for selling and storage. This condition is not suitable for selling and storage. The markets are very crowded and not have a good ventilation system. It is observed that *kocho* and *bulla* are handled roughly during loading and unloading and even stacking in the stored place. Packaging material for *kocho*, which is a wrapping by *warqe* leaves at local markets, is not replaced until it reaches final consumers. The leaves become dry and deteriorate when they reach the central market because of rough handling during transport and due to delicate nature of leaves. Moreover, to check the quality of the products, there is a practice by traders piercing the packaging leaves to take out samples in the marketing chain. This opened hole gives a chance of exposing the product to air and, even flies have access to lay their eggs and eventual larvae can develop in storage time. All these stresses have their contributions to the deterioration of *kocho* at the retailer level. These may be causes for highest *kocho* and *bulla* losses in retailer levels. In *bulla* supply chain the highest loss is observed at processing levels (28.8%). One of the causes of high food loss in developing countries is a lack of processing facilities (FAO, 2011). The traditional method of processing, using inappropriate equipment, lack of quality products and a poor method of drying are the most probable reason for this highest processing loss of *bulla*.

At the producers level, the highest loss of *kocho* is found in storage as compared to the loss which occurs in fermentation. This may be due to the reason that *kocho* could be stored for long period of time in the pit. This long storage in the pit may cause higher loss of *kocho* due to contamination with soil, exposure to air and flood water. In both study areas, the loss of *bulla* is small as compared to a loss of *kocho*. This may be due to the following main reasons: unlike *kocho*, the nature of *bulla* is not easily spoiled, usually, *bulla* is not stored in the pit; the amount of production of *bulla* is very small in one harvesting time and producers gives much care to *bulla* because of its highest value in the market. In the work of Mogessie and Yewelsew (1996), it is reported that *kocho* loss reaches about 33% in storage. Hunduma (2012) points out *warqe* primary food products at producer level are serious and liable to loss. The loss of *warqe* food means the loss of investment which expends on the plant for long years through cultivation and processing

practices. In our study also, it is clearly indicated that *warqe* food loss is observed at the producer level. Therefore, *warqe* food loss in producer level is important and the loss is more pronounced in the storage and during formation processes.

The loss at trader level is a most significant source of loss in the *warqe* supply chain. Our result has clearly shown that there is the highest loss of *kocho* and *bulla* recorded in storage at retailer level (Figure 7). This highest loss of *kocho* at retailer occurs due to the long travel distance from suppliers and stored for long times (Table 2) as compared to wholesalers. In this long distance transportation, the products are exposed to stress like overloading, exposure to strong sunlight, air, and dust. Moreover, *kocho* is stored in the market in poor storage with poor handling practices. The method of *kocho* displaying in retailer marketplace are very poor and result in the exposure of products to air and light. One of the natures of *kocho* is its changing colour when exposed to air. The blackish colour is an indication of poor quality *kocho*. Inappropriate handling in the storage exposes the products to rodents (mainly rats) attack. Package material is damaged by rats, the result which leads to exposure to air and contamination with fungus and also contaminates the food directly with urine, faeces, and pathogens from rat feet and fur. As a result of this, colour changes and mould development are observed.

The loss during *bulla* processing, as has been revealed by this study is the most significant source of loss in the *bulla* supply chain. This highest loss happens during the main processing operation. Using of the poor and traditional method of processing may be the main cause of *bulla* wastage. Processors use inappropriate tools for processing like large barrels and sieves. Using of this kind of equipment may be increasing the loss. The way of drying *bulla* on open plastic sheet on the ground may cause to expose it to dust contamination and wind blowing. As a result, of these poor ways of drying method *bulla* physical loss and the discard of fresh *bulla* due to quality problems are observed. Lack of quality products for processing, a poor package of the fresh and processed *bulla*, poor transportation and handling are additional causes for this high loss. Similar to this study in cassava processing discarding due to small and woody tubers are reported to be the main causes of cassava processing loss (Oguntade, 2013). This indicates that one of the main causes of loss at processor level in the root and tuber including *warqe* is a lack of quality and suitable raw materials for processing.

Foods prepared from *kocho* are commonly consumed both at household and restaurant levels. However, foods prepared from *bulla* are commonly restricted to only household level. This may be the foods prepared from *bulla* are traditionally labelled as 'female food'. At the consumer level, a remarkable amount of *warqe* foods is lost in the course of food preparation and home storage

(Figure 9). Unlike other chain levels, the loss in consumer level is observed to be low in *bulla* supply chain (Figure 4). This might be due to a small amount of *bulla* purchased and given much care to the product in consumer level as compared to other levels of supply chain actors. Similar kind of result is obtained in potato post-harvest loss study in Bangladesh (Hossain and Miah, 2009). Losses which are estimated due to leftover and *kocho* storage show high losses when compared to another kind of losses at the consumer level. These may be due to the reason that foods prepared from *warqe* have short shelf-life and inappropriate handling food in the home. Traditionally, in the study areas food is served to people over the limits of the consumer. Thus, due to this custom, excess foods are prepared and leftover foods are common phenomena. This tradition may be main causes for food wastage at the consumer level.

## Conclusion

This paper assessed post-harvest losses of *warqe* food products along the supply chain and identified hot spots of the losses in the chain. The result showed that there are eight supply chain actors involved in the *warqe* foods supply chains. *Warqe* growers, collectors, wholesalers, retailers, processors, transporters, open market dealers and consumers were identified as the main actors in the very complex supply chain of *warqe*. *Kocho* and *bulla* reach to consumers through various channels. Significant amounts of *warqe* foods were found to be wasted throughout the supply chain, from initial *warqe* growing down to the final consumer stage. The overall losses of marketed *kocho* and *bulla* were 45.3 and 45.6%, respectively, in the supply chain. The highest losses of *kocho* (24.0%) were observed at the retailer level and the highest losses of a *bulla* (28.8%) at the processor level. Lack of appropriate processing technology at producer and processor level, use of poor storage facilities, packaging materials and transport methods, poor handling in the market and air exposure during market display, insect pests at the producer level and rodent problems at farm and market level are the main causes of *kocho* and *bulla* losses. Therefore, it is important to work on value addition to *warqe* foods, improvement of processing technology, transportation, storage, packaging and handling, and improvement of market conditions to reduce post-harvest food losses of *warqe*.

## Conflict of Interests

The authors have not declared any conflict of interests.

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