Quantitative Postharvest Loss Assessment of Tomato Along the Postharvest Supply Chain in Northwestern Ethiopia

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Abstract. The aim of this study was to determine postharvest loss of tomatoes along the postharvest supply chain in Northwest Ethiopia. The study was conducted on tomato fruits produced in three productive kebeles (Chimba, Gumara, and Kudmi) of Northwest Ethiopia following the FAO load tracking and sampling assessment method. Postharvest losses of tomatoes ranged from 6.17 to 8.62%, 1.23 to 8.24%, 3.35 to 4.30%, and 9.38 to 12.58% at the farm, transportation, wholesale, and retail levels, respectively. The mean total postharvest loss of tomatoes was 25.91 ± 1.04% along the supply chain in the study area with in a period of 5 days. Storage and handling of tomatoes at ambient temperature and low relative humidity for a relatively long period of time were the main causes of postharvest losses of tomatoes along the supply chain. Besides, inappropriate postharvest handling practices, lack of storage facilities at wholesale and retail levels, and lack of reliable market system and market information were also identified as contributors for the high postharvest losses of tomatoes observed in our study.

Keywords: Load tracking method · Tomato · Postharvest loss · Supply chain

1 Introduction

Tomato (Lycopersicon esculentum Mill.) is one of major horticultural crops with an estimated total world production of 182.30 million tones [1]. Tomato is also one of the most commonly grown vegetable crops in Ethiopia and has a significant contribution to food and nutrition security [2]. Its production is dominated by small scale farmers with annual production of 23,583.75 tones, which are produced on more than 4000 hectares of land [3]. It is consumed in Ethiopian in various modes [4].

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The quality and quantity of harvested fruit and vegetables is reduced rapidly, which is associated with inherent biological nature and very high water loss after harvesting. Since tomato fruit is perishable and poorly managed in developing countries such as Ethiopia, it may suffer significant postharvest losses along the supply chain [5]. Postharvest losses of fruits and vegetables in developing countries can occur at all stages throughout the marketing and distribution chain and it varies between 20 to 50% [6], and even up to 62.5% for tomato [7].

Few reports are available in Ethiopia regarding the cause and extent of postharvest losses of tomato along the supply chain; 45.32% in the Dire Dawa region [8] and losses ranging from 18 to 22% in South Wollo [9]. However, there are no reports regarding the extent as well as cause of tomato quantitative postharvest loss in Northwest Ethiopia specifically along the supply chain. Therefore, the aim of this study was to assess effects of growing location and postharvest supply chain on quantitative postharvest losses of tomato in Northwest Ethiopia.

2 Materials and Methods

2.1 Description of the Study Areas

The study was conducted in three tomato producing kebeles, Chimba, Gumara, and Kudmi which are found in North Achefer, Fogera, and Mecha woredas, respectively as well as Bahir Dar city in Amhara region, Northwest Ethiopia. North Achefer is one of the woredas in the West Gojam zone of the Amhara region, Ethiopia with the capital of Liben, which is found about 100 km away from Bahir Dar. Liben is located at 11°41’53.9"N latitude and 36°56’31.6"E longitude. It has an altitude of 2033 m above sea level. Chimba is one of the kebeles in North Achefer which is found in about 30 km away from Bahir Dar. Fogera is one of the woredas in the South Gondar zone of the Amhara region, Ethiopia with the capital of Wereta, which is found about 61 km away from the regional capital, Bahir Dar. Wereta is located at 11°55’27.2"N latitude and 37°41’46.3"E longitude. It has an altitude of 1819 m above sea level and receives an average annual rainfall of 1321 mm. Gumara is one of the kebeles in Fogera woreda which is found in about 40 km away from Bahir Dar. Mecha is one of the woredas in the West Gojam zone of the Amhara region, Ethiopia with the capital of Merawi, which is found about 35 km away from Bahir Dar. Merawi is located at 11°24’49.4"N latitude and 37°09’10.7"E longitude. It has an average elevation of 2010 m above sea level and receives an average annual rainfall of 1487 mm. Kudmi is one of the kebeles in Merawi which is found in about 42 km away from Bahir Dar. Bahir Dar is the capital of Amhara regional sate, Ethiopia. Bahir Dar is located at 11°35’33.5"N latitude and 37°20’45.9"E longitude. It has an altitude of 1800 m above sea level and receives an average annual rainfall of 1419 mm. The three kebeles used different growing practices of tomato. In Chimba and Kudmi kebeles, tomato plants are supported (staked) (Fig. 1A), whereas in Gumara kebeles they are not supported (Fig. 1B).

2.2 Treatments and Experimental Design

The treatments consisted of three growing locations (Chimba, Gumara, and Kudmi) and four postharvest supply chains (Farm, Transportation, Wholesale, and Retail) which

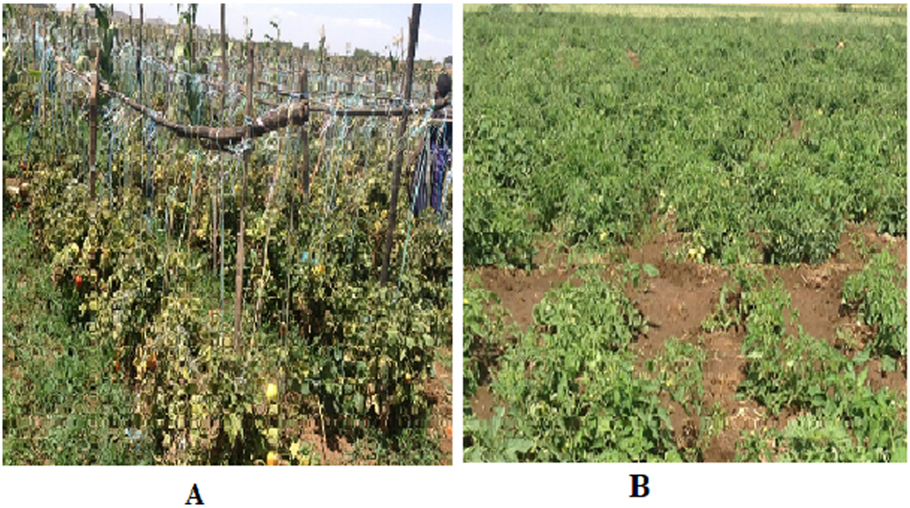

Fig. 1. Tomato cultivation practice in Chimba and Kudmi (A) and Gumara (B) kebele, Northwest Ethiopia

were arranged in Randomized Complete Block Design (RCBD) with four replications (Table 1). The major tomato postharvest supply chain activities consisted of harvesting, sorting and loading, transportation, storage, wholesale and retail as illustrated in Fig. 2.

Table 1. Treatment combination used to assess quantitative postharvest losses of tomato

Location	Supply chain	Treatment Combination
Chimba (C)	Farm	CF
	Transportation	CT
	Wholesale	CW
	Retail	CR
Gumara (G)	Farm	GF
	Transportation	GT
	Wholesale	GW
	Retail	GR
Kudmi (K)	Farm	KF
	Transportation	KT
	Wholesale	KW
	Retail	KR

Note: C = Chimba, G = Gumara, K = Kudmi, F = Farm, T = Transportation, W = Wholesale, R = Retail

2.3 Data Collection

Key Informant Interview. Key informant interviews were performed to collect a comprehensive set of information and data related to postharvest management practices and causes of postharvest losses of tomatoes in the study kebeles along the supply chain. Key informants (15 in number) were selected from Woreda Agricultural Offices, Agricultural Extension at Kebele level, producers, wholesalers and retailers.

Observation. An observation of all the activities and processes along the supply chain was also made during data collection.

Load Tracking. Load tracking and sampling method was used to quantify quantitative postharvest losses of tomato along the supply chain as described by FAO [10]. Representative samples of tomato cultivar (Galilea) were collected from farmers in each kebele, which were produced during the dry season of March to May 2019 using irrigation.

Tomato producing kebeles were selected purposively. From each kebele, one potential producer who has a relatively large farm and major supplier to wholesalers in Bahir Dar fruit and vegetable market was selected. From the producer, six wooden boxes that were filled with tomato fruits were collected from Gumara and Kudmi kebeles which were transported with Toyota Minibus Hiace and animal cart (farm to main asphalt road in Kudmi kebele). Moreover, eighty-four wooden boxes that were filled with tomato fruits were collected from Chimba kebele and transported with ISUZU NPR track. From this load at the first sampling stage, five boxes were randomly selected and labeled. Out of the selected five boxes, four boxes (approximately 65 kg each) were randomly selected and their initial quantitative data were collected. While following the samples in the supply chain, the necessary quantitative postharvest losses of tomato were estimated at each point of the supply chain.

2.4 Estimation of Quantitative Postharvest Losses of Tomato

Postharvest losses of tomatoes were estimated by percentage in weight basis at each of the following stages of the different supply chains: farm (harvesting, sorting and field packing), transportation (during transport and arrival at market), wholesale (after two days of handling and storage of tomatoes before selling to retail), and retail (selling and handling of tomatoes to customers with maximum of three days storage). Any tomato fruits that had visible decay or severe injury were regarded as a loss. Quantitative postharvest losses were estimated the equation described below (1):

$$Quantitaive\ \ Postharvest\ \ Loss\ (\%) = \frac{Q_{unmarkatable}}{Q_T} \times 100 \quad (1)$$

Where, $Q_{unmarkatable}$ = Quantity of unmarketable tomato due to physical damage, damage by diseases and insect pests, bruising and wilting (kg).

Q_T = Total tomato quantity (net quantity + discarded quantity) (kg).

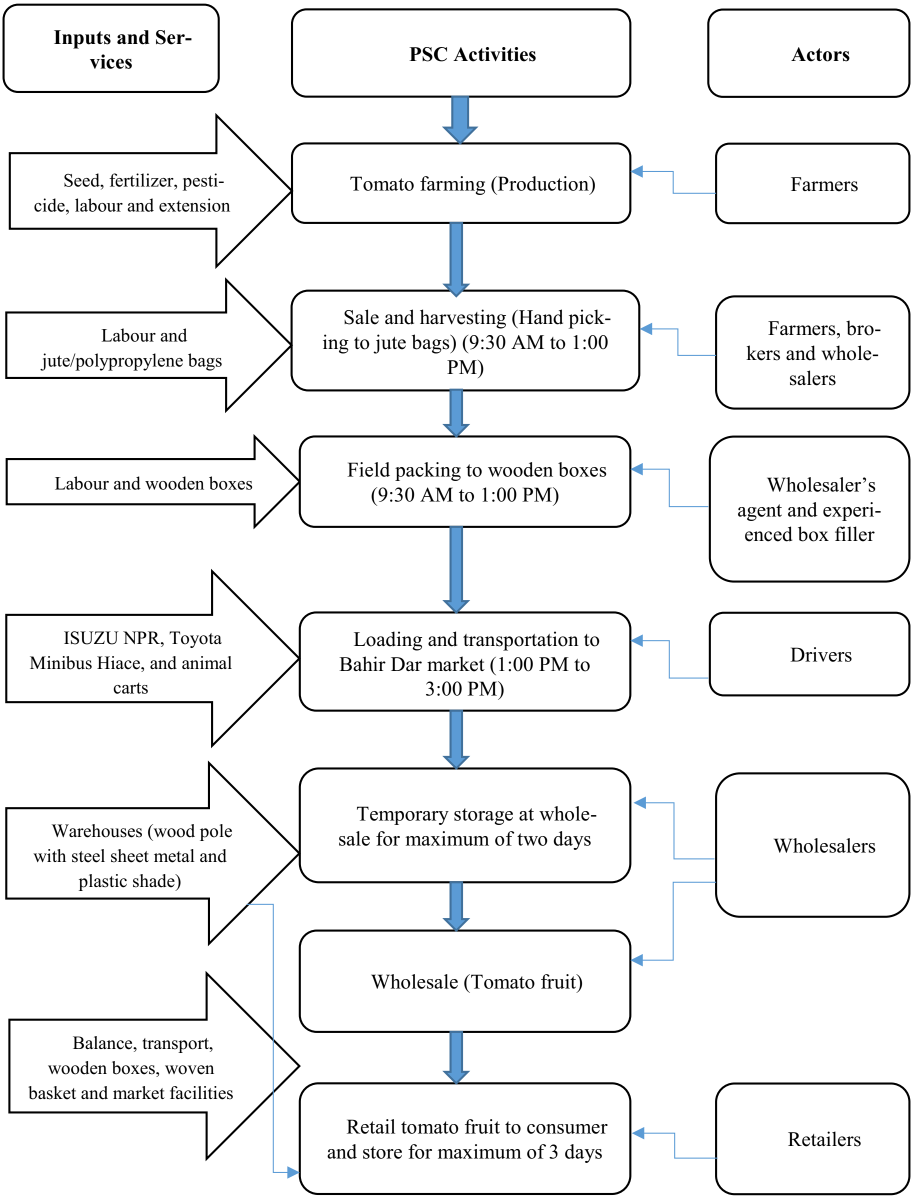

Fig. 2. Tomato postharvest supply chain (PSC) activities and waiting periods in the study kebeles, Northwest Ethiopia

2.5 Weather Conditions (Temperature and Relative Humidity)

Weather conditions such as temperature and relative humidity were measured along the supply chain where temperature were measured using HOBO Temp Data Logger (UX100-001, Range: −20 °C to 70°C, Accuracy: ±0.21 °C from 0° to 50 °C) while relative humidity using HOBO Temp/RH 2.5% Data Logger (UX100-011, Range: 1% to 95%, Accuracy: ±2.5% from 10% to 90%).

2.6 Data Analysis

All data recorded were subjected to statistical analysis. Two way analysis of variance (ANOVA) was carried out using SAS software version 9.2 (Cary, NC, USA) to detect significant effects of growing locations and postharvest supply chain on quantitative postharvest losses of tomato. Treatments were considered as significantly different at $p < 0.05$. Tukey HSD test was used to compare significance differences between means. Graphs were plotted using SigmaPlot software Version 14.0.

3 Results and Discussion

3.1 Weather Condition

The temperature recorded at the farm, transportation, wholesale, and retail levels ranged from 23.94 to 25.19 °C, 22.94 to 24.39 °C, 22.49 to 24.10 °C, and 22.90 to 25.51 °C, respectively (Fig. 3). The relative humidity recorded at the farm, transportation, wholesale, and retail in our study ranged from 33.40 to 57.24%, 30.46 to 37.82%, 38.45 to 46.54%, and 34.88 to 54.90%, respectively (Fig. 4). The temperature and relative humidity conditions recorded in this study throughout the supply chain were suboptimal as such high handling temperature and low relative humidity accelerates the processes that lead to the quality and quantity deterioration of tomatoes.

3.2 Growing Locations and Harvesting Practices

Quantitative postharvest losses (QPHL) of tomato at different stages of the supply chain and growing location are shown in Fig. 5. The study revealed that the interaction effect among growing locations and supply chain significantly ($P < 0.0001$) altered the percentage of postharvest losses of tomatoes. Quantitative postharvest loss at the farm level soon after harvesting of tomato was in the range of 6.17 to 8.62% with an average loss of 7.31%. The mean postharvest loss of tomatoes at the farm were 8.62%, 7.15%, and 6.17% in Gumara, Kudmi, and Chimba kebele, respectively (Fig. 5). Lack of harvesting skills and inappropriate packaging like use of wooden crates with hard and sharp surfaces which causes mechanical injuries on harvested fruits, diseases, and insect pests were the prominent factors causing losses at the farm level in the study kebeles.

The highest postharvest loss (8.62%) of tomatoes at the farm level was recorded in Gumara kebele may be associated with the growing practices employed in this kebeles. In this growing location, tomato plants were not staked and thus most of the tomatoes were in direct contact with the soil (Fig. 2B), which predisposes the fruits for disease infection and decay and mechanical damages as indicated in Fig. 6A. Findings of present study are comparable with the findings reported by Genova II, et al. [11] in Vietnam where postharvest losses of tomato at farm level is about 8%. On the other hand, postharvest losses of tomatoes recorded in the present study were relatively lower than those reported by Robert, et al. [12] where it was about 15 to 19%.

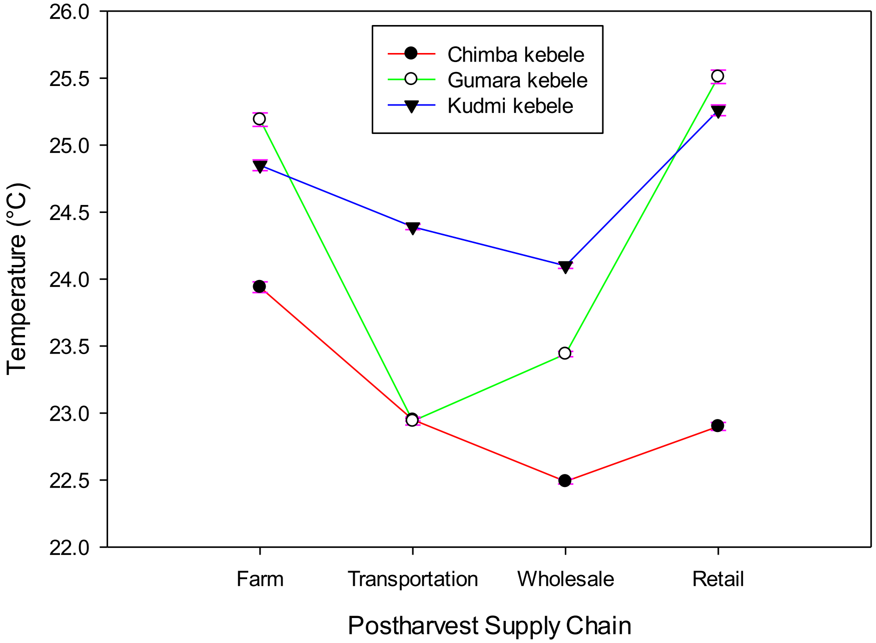

Fig. 3. Temperature in °C (Mean ± standard error) along the postharvest supply chain, Northwest Ethiopia

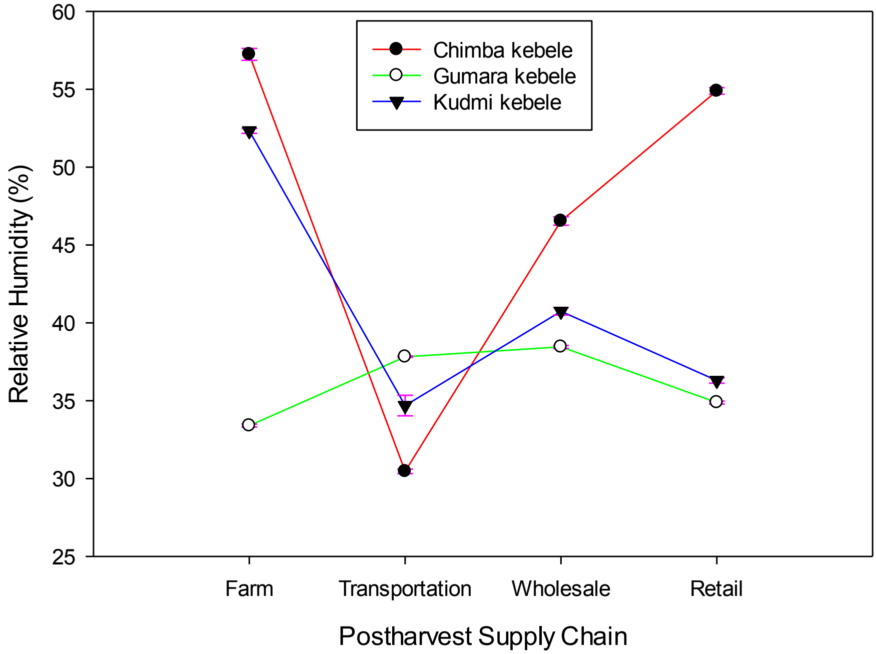

Fig. 4. Relative humidity in % (mean ± standard error) along the postharvest supply chain, Northwest Ethiopia

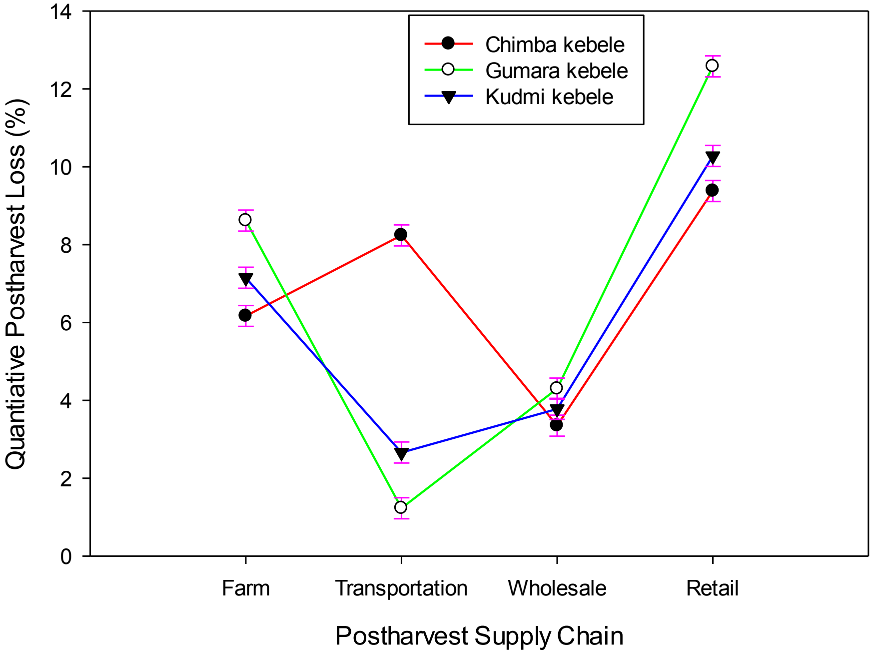

Fig. 5. Quantitative postharvest losses in % (mean ± standard error) of tomatoes along the postharvest supply chain, Northwest Ethiopia

Tomatoes were harvested in the study kebeles at different harvesting stages including turning, pink and light red stages, which was depending on the intended use or mar-ket. Harvesting was almost done by hand without using any special equipment where daily laborers (young male and females) mostly employed. Harvester moved through the planting rows and handpicked the fruits that were ready for harvesting and throw it into the jute/polypropylene bags. Such type of harvesting and handling causes bruising and mechanical damages. Therefore, postharvest losses of tomato fruits begins in the field and continues in the supply chain due to the high possibility of compression stresses during postharvest handling practices such as harvesting, sort-ing, field packing, transportation, and subsequent handling [13, 14]. The harvesting time of tomato was from morning to afternoon (9:30 AM to 1:00 PM) in the study area. Harvesting during the warmer part of the day results in faster senescence, shriv-eling and wilting of fruit through high transpiration rate and losses of water [15, 16].

3.3 Transportation

Quantitative losses of tomatoes during transportation were ranged from 1.23 to 8.24%. The mean losses of tomatoes during transportation were 1.23%, 2.66%, and 8.24% in Gumara, Kudmi, and Chimba kebeles, respectively (Fig. 5). Loading and transportation was done immediately after harvesting and completed from 1:00 PM to 3:00 PM where Bahir Dar city fruit and vegetable market was the destination. Toyota Minibus Hiace

C D

Fig. 6. Damaged tomatoes at the farm (A), during transportation (B), at wholesale (C), and retail (D) level in Northwest Ethiopia

was used to transport tomatoes from Gumara and Kudmi kebeles while ISUZU NPR for tomatoes from Chimba kebele. About 1:35, 1:50, and 2:00 h were required to transport tomatoes from Gumara, Kudmi, and Chimba kebeles, respectively, to Bahir Dar fruit and vegetables market.

The results of the present study showed that postharvest loss during transportation of tomatoes in Chimba kebele (8.24%) was higher than those in Kudmi and Gumara kebeles. This is due to the relatively poor packaging (wooden box), poor road access, and use of poor means of transportation methods like donkeys, public transport and rented trucks which leads to high mechanical damage and high postharvest losses (Fig. 6B). Chimba kebele is 30 km away from the market place (Bahir Dar fruit and vegetable market) and of which about 25 km of the road was bumpy. On the other hand, Kudmi kebele 42 km away from the market place and of which 7 km was bumpy. Gumara kebele was 40 km away from the market place where the road was relatively good. In addition, 84 wooden boxes of tomatoes were loaded in one ISUZU NPR truck in Chimba kebele while in Kudmi and Gumara kebeles only 6 wooden boxes of tomatoes were loaded in one Toyota Minibus Hiace. Similar tomato transportation practices for local market were also reported in Nigeria and Tanzania in line with present study [7, 17]. Vibration during transport because of road bumpiness is one of the major causes of postharvest losses of fruits and vegetables, especially tomatoes [18].

3.4 Wholesaler and Retailer

Immediately after arrival at the market place, tomato fruits in wooden boxes were unloaded by daily laborers (young males) and stored in the warehouses of wholesalers. The warehouses of wholesaler and retailer were constructed from wooden pole covered with stainless steel sheet metal and thick polythene. The warehouses did not have essential storage facilities like cooling. Moreover, the stores are too small and not clean (Fig. 7). Tomatoes in wooden boxes and woven cane baskets were stored for two and three days by wholesaler and retailer, respectively.

A B

Fig. 7. Handling and storage conditions of tomatoes at wholesale (A) and retail (B) levels in Bahir Dar city fruit and vegetable market

Quantitative postharvest losses of tomato at wholesale, and retail levels ranged from 3.35 to 4.30%, and 9.38 to 12.58%, respectively (Fig. 5). The mean postharvest losses of tomatoes at wholesale level sourced from Gumara, Kudmi, and Chimba kebeles were 4.30%, 3.78%, and 3.35% for tomatoes, respectively with an average loss of 3.81%. The mean postharvest losses at retail level were 12.58%, 10.28%, and 9.38% for tomatoes from Gumara, Kudmi, and Chimba kebele, respectively with an average loss of 10.75% (Fig. 5).

The study showed that postharvest losses of tomatoes sourced from Gumara kebele at wholesale and retail levels from were higher compared to those from Kudmi and Chimba kebeles which may be associated with production practices, and suboptimal handling practices (high temperature and low relative humidity storage) which accelerate physiological deterioration of tomatoes than tomatoes from Kudmi and Chimba kebeles. In the present study, tomatoes at the wholesale and retail levels were stored at temperatures ranging from 22.49 to 24.10 °C and 22.90 to 25.51 °C, respectively and with relative humidity ranging from 30.46 to 57.24% (Fig. 3 and 4). However, the recommended transport and storage temperatures for tomatoes are 10 to 18°C depending on the maturity stages of fruits. Temperature below these ranges will cause chilling injuries, while too warm conditions promote transpiration and ripening and thus hastened deterioration and reduces postharvest lives [6, 19, 20].

According to the results of the present study the main causes of postharvest losses of tomatoes at wholesale and retail levels were perhaps associated with inappropriate handling and packaging, inadequate storage facilities, and poor sanitary conditions at local open-air markets (Fig. 6C and D). Such condition lead to the damages of tomatoes by rodents and accelerates physiological and microbial damages, which is in line with the findings of other authors [21–23]. Similar with the present study, postharvest loss of tomato at wholesale level in Vietnam was about 4% as reported by Genova II, et al. [11]. The losses of tomatoes at retail level observed in this study were also comparable with the results reported by Kitinoja and Cantwell [24] in Rwanda which was about 14.7%.

4 Conclusion

The production practices of tomatoes in Northwest Ethiopia varies from location to location, where some farmers used staking (Chimba and Kudmi Kebeles), while others produced tomatoes without staking (Gumara kebele), which increases postharvest losses.

High temperatures and low relative humidity during handling and storage had a significant effect on the quantitative postharvest losses of tomatoes. Tomatoes sourced from Gumara kebele exhibited the highest amount of postharvest losses (12.58%), followed by those from Kudmi (10.28%), and Chimba kebeles (9.38%) at retail level which is associated with high temperatures and suboptimal handling practices. On the other hand, tomatoes sourced from Gumara kebele exhibited the lowest amount of postharvest loss during transportation (1.23%) because of relatively good asphalt-concrete road. The total postharvest losses of tomatoes produced in Chimba, Gumara, and Kudmi kebeles were 27.21%, 26.72%, and 23.88%, respectively, with an average total loss of 25.91% along the postharvest supply chain. These losses were only for the first five days from harvesting up to selling to customers at Bahir Dar fruit and vegetable market. The retail practice was one of the highest and serious postharvest loss points of tomato along the postharvest supply chain next to harvesting, which is associated with the cumulative effects of all pressures exerted on tomatoes from time of harvesting, box filling, loading, transporting, unloading and storage conditions.

Generally, the high postharvest losses of tomatoes in the study were associated with lack of knowledge and skills in postharvest management and handling practices along the supply chain, which includes improper harvesting stage, inappropriate harvesting methods and time, inappropriate harvesting containers and packaging materials, unsuitable transportation system including methods of transport and bumpy roads, inappropriate loading and unloading practices, lack of cold storage facilities at farm, wholesale and retail levels. The information from this study could be used as a basis to minimize the postharvest losses of tomato by policymakers to emplace appropriate policies that minimize postharvest losses of perishable crops along the supply chain. It can be used as base for provision of extension services given by postharvest experts for different actors in the supply chain of tomato.

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