

A Comprehensive Review of Tomato Post-Harvest Losses: Understanding Impacts and Contributing Factors in Ethiopia

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ABSTRACT

This review explored the underlying causes and factors that contribute to postharvest losses in tomato production by analyzing their economic and environmental impacts. Tomatoes, a popular crop worldwide, especially in tropical regions such as Ethiopia, are highly valued for their rich vitamin and mineral contents, including lycopene. It is an affordable and nutritious vegetable and is known for its high content of antioxidants, including carotenoids such as β -carotene, polyphenols and ascorbic acid, making it a top choice for those seeking a healthy diet. Despite their nutritional significance, tomatoes, which are climacteric and perishable fruits, have a short shelf life of 2 to 3 weeks, which renders them susceptible to postharvest losses throughout the food supply chain from farm to table. These losses, experienced in both quantity and quality, occur during the harvesting, storage, transportation, processing, marketing and preparation phases. In Ethiopia, postharvest losses affect various regions differently, including North Wollo, South Wollo, East Wollega, West Shewa and South Tigray, with loss rates fluctuating during harvesting, packing, transport and storage. The causes of these losses include inadequate harvesting equipment, improper packaging and storage methods, deficient infrastructure such as roads and transportation systems and a lack of technological advancements in the production and distribution processes. Addressing these challenges is vital for enhancing the efficiency and sustainability of tomato production, minimizing economic losses and mitigating the environmental impact of food waste.

KEYWORDS

Postharvest loss of tomato, economic impact, environmental impact, Ethiopia

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a widely cultivated crop worldwide, including in tropical countries such as Ethiopia. Tomatoes rank fourth in terms of acreage among vegetables, with 182 million tons produced globally in 2017, including 21 million tons in Africa^{1,2}. Tomato is believed to have originated from the wild in Peru, Ecuador and other parts of tropical America³ and is now cultivated in different major growing areas of Ethiopia, including the eastern and central parts of the country's mid-to low-land regions⁴. Climatic and soil conditions in Ethiopia are favorable for tomato cultivation and the crop has



become the most profitable for small-scale farmers, providing a higher income than other crops. During the 2016-2017 cropping season, the total annual tomato production in Ethiopia was estimated to be 283,648.27 quintals, with 41.51% coming from the Oromia region and 49.83% from the Amhara and Tigray regions⁵. Tomatoes and tomato-based dishes provide a variety of nutrients and many health benefits. They are rich in phytonutrients such as lycopene, β -carotene, phenolic compounds and ascorbic acid, as well as essential nutrients, which aid in preventing oxidative damage in the body⁶. It is rich source of vitamins and minerals, particularly as a rich source of lycopene (60-90 mg/kg)⁷. Lycopene serves as a potent antioxidant linked to lowering the risk of prostate cancer⁸. It holds the top position among vegetables in terms of nutritional value, offering significant biological activity in human diets⁹. The nutritional and health advantages of tomatoes encourage widespread cultivation and consumption in various forms, including fresh in salads, cooked and as snacks. Presently, tomatoes are highly prized as an industrial crop globally due to their substantial economic returns and versatility for processing into various products¹⁰. However, fruits and vegetables such as tomatoes are highly perishable product particularly once they have been harvested¹¹.

Postharvest losses pose a major challenge in tomato supply chains, particularly in tropical agriculture, where losses of fresh fruits like tomatoes can be significant. These losses stem from various factors such as inadequate pre-harvest techniques, improper handling, transportation issues, lack of information, poor infrastructure, limited technology, skills and management capacity among supply chain actors¹². Tomatoes are particularly susceptible to postharvest losses because of their perishable nature, which is exacerbated by the humid conditions found in tropical climates, leading to increased quality deterioration once tomatoes are harvested¹³. As climacteric fruits, tomatoes undergo a respiratory peak during their ripening process, contributing to their short shelf life, typically lasting only 2-3 weeks¹⁴. This ripening process is complex and results in dramatic changes in the color, texture, flavor and chemical composition of tomatoes¹².

Globally, postharvest losses in tomatoes can be alarming, ranging from 25 to 42%¹⁵. Sub-Saharan Africa (SSA) encounters significant challenges in tomato postharvest management, with fresh market tomato losses averaging around 9.5% in East Africa, 9.8% in Central and Southern Africa and 10.04% in West Africa¹⁶. Tropical countries face even higher losses, with rates varying from 20 to 50% between harvesting, transportation and consumption¹⁷. In Ethiopia, postharvest losses along the tomato value chain are estimated to be between 20 and 35%¹⁸. This review aims to investigate the root causes of postharvest losses in tomatoes, identify the key contributing factors and evaluate their implications for both the economy and the environment, with a particular focus on Ethiopia.

Overview of tomato production in ethiopia and worldwide: Tomato production worldwide has surpassed 182.2 million tons, grown on more than 4.7 million hectares of land. Tomatoes flourish in tropical, subtropical and temperate regions. The leading ten tomato-producing nations comprise China, India, Turkey, the USA, Egypt, Iran, Italy, Spain, Mexico and Brazil¹⁹. In 2012, the FAO estimated a global tomato cultivation area of 4.7 million hectares, yielding 161 million metric tons. China led the production, accounting for 29.8% of the total, followed by India with 17.5 million tons⁶. Despite its importance, African agriculture lags behind other regions in terms of productivity²⁰.

In Ethiopia, tomato holds significant importance as a widely grown vegetable crop, cultivated by smallholder farmers, commercial state and private farms during both rainy and dry seasons. The crop thrives in elevations ranging from 700 to 2000 m above sea level, receiving annual rainfall between 700 to over 1400 mm. Large-scale tomato production occurs in the upper valley under irrigated and rain-fed conditions, while small-scale production for the fresh market is common in various regions such as Koka, Batu, Wondo-Genet, Guder and Bako²¹. Commercial tomato cultivation in Ethiopia traces back to the 1980s, with the first recorded production in the upper Awash region covering 80 hectares by Merti Agro-industry for domestic and export markets²².

Despite its significance, tomato production in Ethiopia faces challenges with low productivity. In 2016, the total cultivated area spanned approximately 9700 hectares, yielding 91300 tons of fresh tomatoes, averaging 9.4 tons/ha. This is notably lower than the global average productivity of 38.3 tons/ha and the averages in Africa, America, Europe and Asia²³. Between 2011 and 2016, FAO data showed an average rain-fed tomato area of 7,100 ha in Ethiopia, yielding 50,150 tons of fruits²⁴. Despite the country's potential, the average tomato productivity remains low at 6.18 tons per hectare compared to other regions such as Africa, America, Europe and Asia¹⁹.

The Ethiopian National Agricultural Research System has introduced approximately 25 tomato varieties, including open-pollinated types like Melkashola, Marglobe, Melkasalsa, Heinz 1350, Fetane, Bishola, Eshet and Metadel from the Melkassa Agricultural Research Center²¹. Tomato production in Ethiopia is distributed across various regions, showcasing varying yields. Leading the pack is Oromia, contributing 68% of the total production, with Meki alone accounting for 9% of that output. Following closely, Tigray and the Somalia region contribute 5 and 4%, respectively, to the country's tomato production²⁵.

Nutritional benefit of tomato: In Ethiopia, tomatoes are a staple ingredient in many local dishes, often used to prepare sauces and salads. Additionally, processed tomato products such as tomato paste, juice, soups, stews and ketchup are consumed in large quantities compared to other vegetables²³. Tomatoes offer significant health benefits due to their high content of phytonutrients like lycopene, β -carotene, phenolic compounds and ascorbic acid²⁶. These compounds have been associated with a reduced risk of cancer, prostate and heart diseases⁶, with tomato intake linked to decreased risks of various cancer sites, including lung and stomach malignancies²⁷. Moreover, tomatoes are rich in essential amino acids, sugars, dietary fibers, vitamin B and C, iron and phosphorus, contributing to their nutritional value²⁸. Furthermore, tomatoes contain phenolic compounds that exhibit strong antioxidant activity²⁹. They are utilized in various forms, including fresh consumption, processing into products like tomato paste, juice, ketchup and cherry tomatoes, serving as income-generating crops for small-scale farmers and providing employment opportunities in production and processing industries³⁰. The rich nutritional profile of tomatoes, including their high vitamin C and vitamin A content, is essential for promoting eye health and preventing muscular degeneration³¹.

Tomato postharvest losses: Tropical fruits, by nature, are prone to high and rapid postharvest losses due to their inherent biological characteristics. Estimates suggest that postharvest losses of fruits and vegetables range from 5 to 20% in developed countries and 20 to 50% in developing nations³². Among those vegetables, tomatoes are particularly susceptible to significant postharvest losses, attributed to their highly dynamic metabolic changes during development. Tomato damage assessment at wholesale markets often surpasses that of other vegetables, highlighting the severity of the issue. Factors contributing to postharvest losses in horticultural crops, including tomatoes, encompass storage conditions, transportation facilities, diseases and insect pests¹².

Tomatoes exhibit some of the highest postharvest losses within the fruit and vegetable supply chains of Sub-Saharan Africa¹⁶. In Ethiopia, out of the total crop production of 39.7 million tons, a significant amount of about 6.6 million tons consists of highly perishable fruits, such as tomatoes³³. Despite their nutritional value and economic importance, tomatoes have a short shelf life due to factors such as inadequate technology and insufficient awareness among producers and market actors, leading to suboptimal handling and storage practices⁹. The perishable nature of tomatoes is exacerbated by their high-water content, often exceeding 90%, which renders them highly susceptible to spoilage¹⁰. This high moisture content poses challenges in handling, transportation and marketing of tomatoes³⁴. Postharvest losses vary significantly among commodities, production areas and seasons, with tomatoes being a widely grown vegetable crop in Ethiopia, where high postharvest losses pose a major constraint in the vegetable supply chain³⁵.

Table 1: PHL of fruits and vegetables selected country in SSA

Sub-region	Country	Estimated postharvest loss (%)	References
East Africa	Ethiopia	50	Sipho and Tilahun ⁴²
Central Africa	Rwanda	30-80 depending on product	
West Africa	Ghana	30-80 depending on product	
South Africa	Swaziland	20-50	

Postharvest losses of horticultural produce, particularly tomatoes, are a pervasive issue throughout the post-harvest value chain, primarily due to high rates of bruising, water loss and subsequent decay during handling³⁶. These losses occur at various stages, including harvest, preparation for market, transportation and consumption of fruits and vegetables³⁷. Ethiopia, like many other countries, experiences a significant proportion of postharvest losses in perishable horticultural commodities due to limited cold storage facilities, poor packaging and transport infrastructures, lack of processing facilities and inadequate handling practices³⁸.

Additionally, postharvest losses and reduced yields in Ethiopian agriculture are attributed to factors such as diseases, pests and suboptimal fertilization practices⁷. Pests, microbial infections, natural ripening processes and environmental conditions like heat and drought also contribute to postharvest losses and quality deterioration of horticultural crops³⁹. Various studies conducted across Ethiopia have revealed significant postharvest losses of tomatoes, ranging from 2.5 to 45.3%, with causes including pre-harvest infection, injury and physical damage during handling and transportation (Table 1)^{32,39-42}.

Key factors contributing to postharvest losses in tomato production

On-farm causes

Inappropriate harvesting periods and containers: Tomatoes are considered climacteric fruits, meaning they can be harvested when mature but still green and then allowed to ripen naturally during the postharvest period. However, allowing tomatoes to become overripe is not recommended, especially for long-distance markets. Fully ripened fruits are prone to bruising during harvest, leading to a shortened shelf life. This susceptibility to damage contributes significantly to the high postharvest losses observed in developing countries¹⁰. Tomato is a soft fleshy fruit that is quickly loses its firm texture during over-ripening and particularly vulnerable to post-harvest losses⁴³. Most of the fresh tomato losses in Africa take place at the stage before they are sold to consumers. Research by Goka *et al.*² highlights this, indicating that post-harvest losses for tomatoes are particularly severe, reaching up to 20% within five days of harvesting. Improper harvesting and post-harvest practices result in losses due to spoiling of the product before reaching the market, as well as quality losses such as deterioration in appearance, taste and nutritional value⁴⁴. There is also tomato loss during harvesting due to mismanagement of the time, criteria to harvest the tomato⁹. Improper harvesting method and equipment can also cause losses⁴⁵. Due to lack of properly designed harvesting equipment and poor labor incentive harvesting F&V is not done with a maximum care to avoid mechanical damage⁴⁶. Moreover, a higher temperature at the harvest leads to a time of harvest leads to an increased respiration rate, consequently reducing shelf life and contributing to losses. This is because fresh produce continues to respire and ripen after harvesting, leading to physiological deterioration⁴². The fruit's physiological maturity during harvesting significantly impacts its quality. In many developing countries, tomatoes are manually picked rather than mechanically harvested. In Ethiopia, for example, farmers commonly use wooden crates and woven baskets with hard surfaces and sharp edges, which can cause mechanical damage to the harvested fruits. Additionally, overloading during harvesting can result in excessive compressive stresses, leading to the crushing of fruits located at the bottom of the containers⁴⁷.

Lack of cooling and storage facilities: Tomatoes are living organic organisms and very perishable food items with relatively short postharvest storage lives⁴⁸. In storage, without control of cleanliness, temperature and humidity these are significant problems for loss of products both quality and quantity.



Fig. 1: Handling and storage conditions of tomatoes⁵¹



Fig. 2: Field sorting and packing of tomatoes before loading⁴¹

Standard, round tomatoes are sensitive below 12.5°C, specialty tomato quality may also be affected when held at lower temperatures⁴⁹. The heat from the field causes a swift rise in metabolic activity. The ideal temperature for harvesting tomatoes, near 20°C, is usually reached early in the morning or late in the evening³¹. Some studies are conducted in different parts of Ethiopia, such as in Sodo Market of Wolaita Zone, results showed that, loss due to traditional storage materials as shown in Fig. 1 (22% banana and 21% tomato) were physical damaged⁵⁰. Postharvest loss of tomato in Asella Town, Ethiopia, due to use of unsuitable storage (6.91, 2.81 and 0.5%) was recorded in wholesalers, retailers and consumers, respectively¹².

Inappropriate packaging materials: The use of inappropriate packaging material is a basic factor most regularly related to the maximum level of losses after harvest⁵². Some of the most common packaging materials used in Ethiopia, include large green leaves, clay pots, woven cane baskets, wooden crates, cardboard crates, cardboard boxes, plastic buckets, nylon sacks and jute sacks mainly used by small-scale farmers. The reason for the use of sacks and baskets as major packaging material was their accessibility and low cost⁵³. These, packaging material are used to pack and transport in which there is no palletizing and large mass of commodity is tightly packed³². Packaging problem is not only lack of ventilation, but physical damage due to rough surface and excessive pressure due to large depth of fruit leading to excessive weight on bottom layer and lack of strength in the carton one of the causes of spoilage at destination³¹. The main reasons for post-harvest losses in fruits and vegetables such as tomatoes are improper packaging and the use of unsuitable packaging materials (Fig. 2). Inadequate packaging materials do not offer enough protection for fresh produce, making them susceptible to damage and speeding up their spoilage⁴⁶. Mechanical damage to FV may result from inappropriate packaging and over or under packaging of containers⁴².



Fig. 3: Tomato fruit loading and modes of transportation⁴¹

Off-farm causes

Lack of transport and handling practices of tomatoes: Transportation is a major issue for numerous farmers in developing areas, especially when dealing with highly perishable fruits and vegetables. Most farms are located in remote regions with insufficient farm-to-market roads, impeding the prompt transportation of produce to markets. As a result, significant postharvest losses occur, particularly for tomatoes. Consequently, smallholder farmers face more than 20% postharvest losses due to transportation delays¹⁰. Lack of access roads to production fields in many African countries is a major challenge hampering the success of the tomato industry. Losses can still occur in transit due to bad road conditions and delays at checkpoints, increasing physical damage and exposure to high temperatures. Vibration and impact during transportation as a result of undulations on roads is one of the major causes of post-harvest losses to most fruits and vegetables especially tomatoes³¹. Postharvest losses occur due to transports of fruits and vegetables without temperature-controlled environmental conditions resulting in further deterioration⁴². Compared with several temperate fruits and vegetables, tropical and subtropical vegetables such as tomatoes present greater transportation problems because of their perishable nature³⁸. The absence of appropriate means of transport, poor roads and inefficient logistics management prevent perishable foods from being properly preserve⁴⁶. Likewise, the transportation system in postharvest handling of horticultural products frequently involves loading items on top of one another, which can result in injury, damage and a shorter shelf life (Fig. 3). Furthermore, the practice of carrying mixed cargoes of bulk goods creates significant issues. Different products in these loads react differently to temperature, transpiration, dehydration and ethylene. When carried combined, these elements lead to increased physiological, mechanical, biological and chemical losses, reducing the commodities' durability⁵². In most developing countries like Ethiopia, roads are not adequate for proper transport of horticultural crop such as tomatoes¹¹. The kind of transportation system in Ethiopia is the use of pack animals and on the back of man and woman which leads to bruising during loading and unloading³³. According to the report of Yeshiwas and Tadele,⁵³ study in Debre Markos Ethiopia, the maximum percentage of total loss of tomato (10%) was recorded during transportation. In addition, in Asella Zone, Ethiopia, loss due to transportation of tomato during loading and unloading were 0.85, 0.75 and 0.5% recorded during wholesaler, retailer and consumer, respectively¹². Similar, study also conducted in Sodo, Wolaita Zone, Ethiopia, postharvest loss of tomato due to long distance transport to market place (18.8%) tomato was damaged⁵⁰.

Lack of knowledge of post-harvest technologies: Unlike dry grains, fresh fruits and vegetables are difficult to handle post-harvest due to their perishable nature and size, making their production challenging⁵⁴. One reason for the underdeveloped horticulture industry in sub-Saharan Africa, particularly in Ethiopia, is the perishable nature of the produce, coupled with a lack of knowledge and limited financial resources among small-scale farmers⁵⁵. In Ethiopia, farmers do not have any formal knowledge on



Fig. 4: Tomato postharvest losses due to rodents, decay and bruise⁴¹

handling methods of harvested products and they do not receive any training on postharvest handling practices of fruits and vegetables, except for their traditional knowledge⁵³.

Disease and pest problem: The impact of diseases and pests at the production level significantly contributes to postharvest losses and quality deterioration in fruit crops such as tomatoes⁵². In particular, reports have indicated common occurrences of cutworms affecting crops at the field level. Among the primary insect and mite pests infesting tomatoes are the African bollworm, potato tuber moth, tomato leaf miner/fruit borer, whiteflies and spider mites⁵². Fungal activity is one of the most prevalent causes of fungal deterioration. Post-harvest diseases alone can lead to losses ranging from 10 to 30% of the total crop yield, a particularly acute issue in perishable crops, such as tomatoes, notably in developing countries¹. Research by Emana *et al.*¹¹ revealed that at the farm level, a significant proportion of tomato damage occurs owing to insect attacks (26%) and diseases (25%), with wholesalers experiencing disease affecting over 40% of their tomato stock. A study conducted in the Fogera District of the Amhara region highlighted postharvest losses primarily caused by pests (borers), diseases and physiological disorders, accounting for 18.25, 3.28 and 2.62%, respectively³¹ as shown in Fig. 4. These findings underscore the critical need for effective pest and disease management strategies to mitigate losses and ensure the quality and longevity of tomato crops from the field to market.

Postharvest losses: Economic, market and environmental impact

Impacts on economic and marketability: Tomatoes provide better economic returns to many farmers in Ethiopia, particularly when cultivated during the wet season. Production methods range from home gardening and smallholder farming to commercial farms owned by both public and private entities⁵⁶. Loss of fruits and vegetables has significant negative impacts on the economy, reflecting poor functioning and inefficient value chains and food systems, leading to a loss of economic value in the food produced⁵⁵. In small-scale production, most fresh produce is stored at relative humidity levels below the recommended range, resulting in excessive moisture loss. Consequently, fruits and vegetables experience wilting, shriveling and dryness due to minor moisture losses of 3-6%, affecting the marketability and economic value of produce¹⁶. Regarding market conditions, the majority of farmers sell their products in nearby markets, with a few selling directly on farms. Marketing conditions are unsatisfactory and discouraging, primarily because of the oversupply of the product and the perishable nature of the crop³³. Temperature plays a crucial role in marketing, directly affecting the quality of tomatoes by influencing color, firmness and flavor⁴⁵. Post-harvest operations for fresh fruits and vegetables, especially during marketing, are sub-standard in developing countries. Approximately 20-30% of fresh fruit and vegetable produce is wasted before reaching the consumer, as seen in tomato post-harvest losses ranging from 6.70 to 33.50% in

India⁴⁴. Studies estimating economic losses for fruits and vegetables in sub-Saharan Africa reveal that 16-40% of production is lost along the entire value chain. In addition to revenue loss, a significant consequence of quality deterioration is nutrient degradation⁵⁷. In Debre Markos, Ethiopia, the highest postharvest tomato loss (18%) occurs during marketing/selling, resulting in reduced economic value and farmer income⁵³.

Impact on the environment and climate: In a study conducted in Chimba, Gumara and Kudmi Kebeles in Bahir Dar, Amhara, Ethiopia, temperatures were recorded at various stages: Farm, transportation, wholesale and retail levels, ranging from 22.49 to 25.51°C. These temperature fluctuations, along with relative humidity, significantly contribute to the deterioration of fruits and vegetables, accelerating the ripening process of tomatoes and reducing their shelf life⁴¹. Postharvest losses of fruits and vegetables pose environmental concerns due to the resources invested in their production, such as energy, water and soil. Uneaten food results in unnecessary CO₂ emissions, contributing to environmental degradation⁵⁸. When fruits and vegetables, including tomatoes, are wasted and end up in landfills or rivers after markets, they emit methane, a potent greenhouse gas^{59,60}. Improper disposal of damaged or overripe tomatoes in Ethiopian cities like Addis Ababa leads to environmental degradation, emitting odors that negatively impact the climate⁶¹. Globally, food loss and waste are significant contributors to greenhouse gas emissions, exacerbating climate change and biodiversity loss⁶². Implementing sustainable waste management strategies, such as the 5 R system and circular economy models, can help mitigate food waste and its environmental impact⁶³.

CONCLUSION

Tomatoes serve as both a vital nutrient source and a significant economic asset for those engaged in their cultivation and trade. In Ethiopia's diverse agricultural landscape, where fruits and vegetables are integral to the economy, tomatoes stand out as a key commodity. However, the journey of these perishable goods from farm to market is fraught with challenges that lead to substantial postharvest losses. Factors such as inadequate packaging, storage facilities, transportation infrastructure and market connections, along with issues like poor handling practices and hygiene standards, all contribute to these losses. Despite efforts to quantify postharvest losses in Ethiopia, estimates vary, highlighting the need for more comprehensive data collection methods. Current estimates suggested that postharvest losses of tomatoes in Ethiopia may reach up to 40-45%, emphasizing the urgency of addressing underlying issues across the supply chain. Improving harvest practices, investing in modern storage technologies, enhancing market information systems and strengthening value chain development are critical steps toward mitigating these losses and ensuring the sustainability of tomato production. By adopting a multidisciplinary approach and embracing innovations in storage and marketing, Ethiopia can not only reduce postharvest losses of tomatoes but also create greater economic opportunities for smallholder farmers and contribute to food security and economic growth in the country.

SIGNIFICANCE STATEMENT

This study investigates the factors causing postharvest losses in tomato production, focusing on their economic and environmental effects. By analyzing challenges throughout the supply chain, it aims to pinpoint opportunities for intervention to enhance sustainability. Findings reveal multiple causes of losses, including inadequate equipment and infrastructure, with variations noted among regions in Ethiopia. These findings underscore the need for customized strategies to minimize losses, bolstering food security, economic growth and environmental sustainability.

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