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Potential food safety risks in tomato value chains in urban settings of Eastern Ethiopia: a qualitative investigation

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Background: The value chains of tomatoes in Ethiopia are largely informal which may pose potential food safety risks. Value chains (VCs) mapping was carried out with emphasis on tomatoes in two major cities in eastern Ethiopia—Harar and Dire Dawa—which were assessed to identify practices likely to result in unsafe food, considering production, transportation, retail, preparation, and consumption.

Methods: Qualitative methods were used to map the VCs to understand the flows, actors, and practices. Group discussions and key informant interviews were performed to better understand the processes, practices, beliefs, and food safety risks in these VCs.

Results: The two cities are supplied by two vegetable VCs: the first and larger being from distant producers in central Ethiopia, and the second from surrounding rural and peri-urban producers. The long-distance VCs involve producers, brokers, transporters, wholesalers, retailers, and consumers. The local producers, however, bring their fresh products directly to the cities without the involvement of VC actors other than final retailers and consumers. The study suggests microbiological contamination risks along tomato VCs, potentially including soil contamination, use of sewerage-contaminated irrigation water, untreated manure, unhygienic handling and storage conditions, and dirty contact surfaces during transportation and retailing. Tomatoes are mostly harvested by hand picking, collected, and sorted on the ground exposing to sunlight and physical bruising with potential contamination. More importantly, tomatoes are widely consumed raw without "a kill-step" that certainly contributes to food-borne infections. Suggestions by study participants for improving food safety and hygiene include funding toward improved infrastructure and facilities in the sectors, supporting VC actors with improved technology for quality production, and increasing awareness of good and hygienic practices. Consumers were particularly concerned about contamination with agrochemicals without much emphasis on the potential microbial contaminants. Fresh tomatoes are prepared in a variety of ways and are often consumed raw or slightly cooked. Further

recommendations included using health extension workers to conduct awareness campaigns on improved food safety and hygienic practices.

Conclusion: The qualitative VC mapping generated useful information for designing intervention strategies, especially targeting developing food safety interventions and an awareness communication campaign.

KEYWORDS

food safety risk, hygienic practices, food market, vegetable value chain, tomato, food transport, Ethiopia

1 Introduction

In Ethiopia, tomato is one of the most widely cultivated vegetables with an annual production volume of about 41,948 tons (FAOSTAT, 2020). It is grown both under rain-fed and irrigation systems covering a total land area of about 6,298.63 hectares. In addition to being a source of food, it is becoming an important cash crop for a large proportion of rural farming households, particularly in the Rift Valley areas of the country, playing a vital role in household income generation, human nutrition and health (Wiersinga and de Jager, 2009). Generally, tomatoes have good nutritive value being rich in vitamins, minerals, dietary fibers, phytochemicals, and essential biochemical substances such as antioxidants (Ali et al., 2020). As a result, tomatoes and other vegetable consumption are generally encouraged as part of a healthy and balanced diet. Fresh tomatoes are prepared and consumed in a wide range of food recipes including salads, soups, sauces, baked dishes, and grilled or roasted food items either as uncooked or with slight cooking or frying. Most of the consumers in Ethiopia prefer to consume tomato as raw and undercooked (Degaga et al., 2022). However, vegetables that are commonly consumed raw, including tomatoes, are increasingly reported as vehicles of foodborne pathogens (Berger et al., 2010). Several foodborne outbreaks have been also traced back to fresh tomato consumption, globally (Valadez et al., 2013; Callejón et al., 2015; Müller et al., 2016).

Several studies have been carried out in different parts of Ethiopia, focusing on tomato value chain analysis (Wosene and Gobie, 2022), characterizing market outlets (Mohammed Kassaw et al., 2019), and production and characterization of pre-and post-harvest losses (Emana et al., 2017). Constraints related to vegetable VCs were low productivity, insufficient production and marketing skill, lack of capital, market information and market policy, problems related to road access and storage, poor quality seeds, and unfair terms of trade that disfavors producers. Tomato is such a perishable vegetable and characterized by high postharvest losses due to poor packaging, poor storage facilities, package material and poor means of transportation (Alemu et al., 2011; Emana et al., 2017). However, none of the studies linked tomato value chain to food safety issues and provide evidence for policy makers and to create awareness among the VC actors and consumers.

Ethiopia like many developing countries is experiencing a high rate of population growth and urbanization, with many moving to urban areas. This is putting pressure on food production and the provision of adequate and safe food for the population (Kearney, 2010). The effect of urbanization is especially significant in low-and-middle income countries (LMICs) due to the lack of proper city planning. Food safety, as one of the crucial components of food security, is a major problem, especially for urban consumers with foods commonly handled, transported, and consumed in bulk in an unhygienic way due to lack of basic infrastructure including food preservation facilities and inadequate water supply (Salamandane et al., 2020). Specifically, handling perishable foods such as animal-source foods (ASF), vegetables and fruits poses a challenge because of the greater complexity of their VCs and distances between production and consumption (Grace, 2015) coupled with limited knowledge of hygienic food handling of vendors (Salamandane et al., 2020). They are also inherently riskier as they offer better matrices for microbial survival and growth particularly if handled inappropriately without cold storage.

Studies conducted on the microbiological quality of fresh tomatoes have identified a wide range of potential foodborne pathogens such as *Staphylococcus*, *Salmonella* and *Escherichia coli*, *Klebsiella*, *Pseudomonas*, and *Shigella* at global or local levels (Ogundipe et al., 2012; Julien et al., 2017; Sahile and Teshome, 2019; Degaga et al., 2022). These pathogens have also been isolated from fresh tomatoes in Ethiopia (Dugassa et al., 2014; Alemu et al., 2018; Sahile and Teshome, 2019; Degaga et al., 2022), suggesting a public health risk of tomatoes in the absence of a risk mitigation strategies toward eliminating the pathogens before consumption. The dominance of informal actors in vegetable VCs in LMICs such as Ethiopia, with the absence of an overarching management structure or strong regulation, further complicates the control of food safety risks. This tomato VC mapping can be used to scope key food systems to inform efforts toward improving food handling practices and minimize associated health risks. This study aimed to understand the production, transport, retail, handling, marketing and consumption practices of tomatoes, with a focus on potential food safety risks using a VC approach in Harar and Dire Dawa. It also aimed to identify potential areas for more detailed assessment or for interventions to improve food safety in vegetable VCs.

2 Materials and methods

2.1 Study settings

The study took place along the tomato VC from production in the central Rift Valley of Ethiopia to marketing points at two major cities of eastern Ethiopia: Dire Dawa (9.6009°N, 41.8501°E)

and Harar (9.3126°N, 42.1227°E). Dire Dawa is a lowland area with an elevation of 1204m above sea level (masl) and Harar is midlevel to highland area with an elevation of 1,917 masl. As per the unpublished data, the city administration of Dire Dawa has nine urban and 38 rural kebeles (the smallest administrative unit in Ethiopia) with an estimated human population of 466,000. Harar is an administrative seat for Harari Regional State and the East Hararghe Zone of Oromia Regional State. Harari Regional State is demarcated administratively into six urban and three rural administrative districts. Harari Regional State administrative districts are further divided into 19 urban and 17 rural kebeles with an estimated human population of 246,000. Culturally, fruits and vegetables constitute major components of diets in the two cities. Vegetable and fruit wholesale markets are in the neighborhoods of Kefira in Dire Dawa and Deker in Harar.

2.2 Data collection

The qualitative data collection was carried out in the third and fourth quarters of 2019 using various tools: key informant interviews (KIIs), focus group discussions (FGDs) and in-depth interviews (IDIs). Semi-structured question guides were prepared based on the framework of the previous work used for qualitative data collection following participatory approaches (Carron et al., 2017). A total of 16 IDIs were held with different VC actors including retailers and producers of vegetables as well as a total of 8 KIIs with people working in different local government offices such as health, agriculture, trade, industry and tourism conducted. The selection of professionals for KIIs was based on knowledge of agriculture and food VCs, specifically vegetables, focusing on food safety and the consequences associated with food-borne diseases. The key informants on vegetable (tomato) consumption were selected from those people working in the field of food safety, health regulation, home economics and health bureaus.

Moreover, we conducted six FGDs (three each in Harar and Dire Dawa targeting low-, middle- and high-income groups of women, 1 FGD per stratum) with 8–12 female participants in each discussion as food practices and risks to consumers likely differ with socio-economic status. Stratifying urban residents into three income groups was achieved by obtaining the income status of the households from health offices in the study sites and participants of discussions with health extension workers. Health extension workers in Ethiopia are responsible for giving basic health advice and services to households in the form of packages (Tilahun et al., 2017). Typically, each FGD lasted 2–3 h and was facilitated by an experienced agricultural extension and development professional in the local languages (Amharic or Afan Oromo). Another person assisted the facilitator by taking notes and carrying out the audio recording of the discussion sessions. The specific venue for the FGDs was either a meeting hall of government offices or a hall rented in a hotel for the purpose.

The interviews (IDI and KII) took place at the workplaces of the respondents, and they were visited based on prior appointments. The duration of interviews varied depending on the type of producers and retailers. Following up on the qualitative data collection in Harar and Dire Dawa, a visit to the central Rift Valley of Ethiopia (the main source of vegetables for the two cities) was made and three vegetable producers were interviewed (IDI). In addition, other farms in the area were visited, observed and discussed informally without interviewing. The research activity was part of a research project titled "Urban food markets in Africa: Incentivizing food safety using a pull-push approach," led by the International Livestock Research Institute (ILRI) (Amenu et al., 2021).

2.3 Quick food safety risk profiling

Responses to questions regarding the hygienic handling of tomatoes and the likelihood of contamination were converted to a four-point scale (i.e., very low, low, medium and high). The responses were given either in quantitative of various measurement units (e.g., proportion of damaged or discarded tomatoes or travel time to night storage) or qualitative terms (e.g., exposure to direct sunlight measured from low to high, and keeping conditions were recorded from good to poor). Thus, to summarize those responses in a similar scale, we used four-level scales to compare the four market outlets against the identified factors that were considered to have adverse effects on tomato quality and contamination. A very low score scale means less likely to affect quality and contamination while a high score scale means more likely to deteriorate the quality and contribute to contamination of tomatoes.

2.4 Data analysis

Thematic analysis of the qualitative data was made by reading the summaries of the IDIs, KIIs and FGDs based on the questions in the discussion guide. The themes for IDIs, KIIs and FGDs were used in the grouping of the contents of the qualitative data during analysis. Results were mostly presented as frequency distributions and proportions. The scales were used to assess the four market outlets against the potential factors that were considered to have adverse effects on tomato quality and contamination.

Ethical approval for this research was obtained from International Livestock Research Institute (Ref: ILRI-IREC2019-36). The collected qualitative data were anonymized to protect the privacy of study participants. The study participants were compensated in cash for their time and refreshments were offered during the FGDs. Informed consent was obtained prior to enrolling the participants.

3 Results

The characteristics of IDIs, KIIs and FGDs are summarized in Table 1, disaggregated by gender. Consumer FGDs involved all females.

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TABLE 1 Vegetable VC actors involved in the qualitative study disaggregated by gender.

VC actors	Study site	Data collection method	Target respondents	Number of informants by gender		Total
				Male	Female	
Vegetable producers	Harar/Dire Dawa	IDI	Small vegetable farm	3	0	3
			Medium-sized vegetable farm	1	0	1
		KII	Agricultural extension expert	1	0	1
	Meki	IDI	Medium to large-sized vegetable farmers	3	0	3
Vegetable traders and retailers	Harar	IDI	Large retailer using truck (wholesaler using crates)	2	0	2
			Medium-sized retailer (retailing more than 10 kg)	2	1	3
			Small street vendor (<10 kg)	1	2	3
		KII	Trade license issuance facilitator	0	1	1
	Dire Dawa	IDI	Small street vendor (<10 kg)	1	3	4
		KII	Cooperative promotion expert	1	0	1
Consumers	Harar	KII	Home economics expert	0	1	1
			Health regulatory expert	1	0	1
	Dire Dawa	KII	Food safety/hygiene or public health expert	2	0	2
			Vegetable expert	1	0	1
	Harar/Dire Dawa	FGD	Women from low-income households (1 group in each site)	0	8–12	-
			Women from medium-income households (1 group in each site)	0	8–12	-
			Women from high-income households (1 group in each site)	0	8–12	-

3.1 Consumers of vegetables in the two urban settings

Common vegetables consumed were onion, potato, tomato, lettuce, beetroot, cabbage, green pepper, kale and spinach. Consumption practices varied among the different economic groups (low-, middle- and high-income status) based on their financial resources, the season of cash crop harvesting and educational status. Income status highly influenced the consumption practices of the urban community in which high income families eat more vegetables compared to the low-income groups. High-income participants of the FGD had good knowledge of the nutritional value of foods they consume regularly, with clear ideas on their nutritional selection criteria. The low-income groups mentioned that without a regular income, they cannot make a choice regarding their meal types and simply eat what is available at their disposal. Low-income groups usually consume cheap food, especially poor-quality vegetables sold at lower prices. On the other hand, middle- and high-income groups could make choices and were able to buy good quality vegetables.

The results of the FGDs showed that onion, tomato, potato and lettuce are the first, second, third and fourth most highly consumed vegetables in the area. Among vegetables, tomatoes are mainly eaten raw after washing with water and sometimes cooked with other vegetables, while consumption of raw lettuce was said to be increasing. Consumption practices vary depending on the season of the year; for example, from January to March, when the availability of vegetables peaks, consumption also increases. Another important season for tomato production is from October to December, while tomatoes are much less available from June to

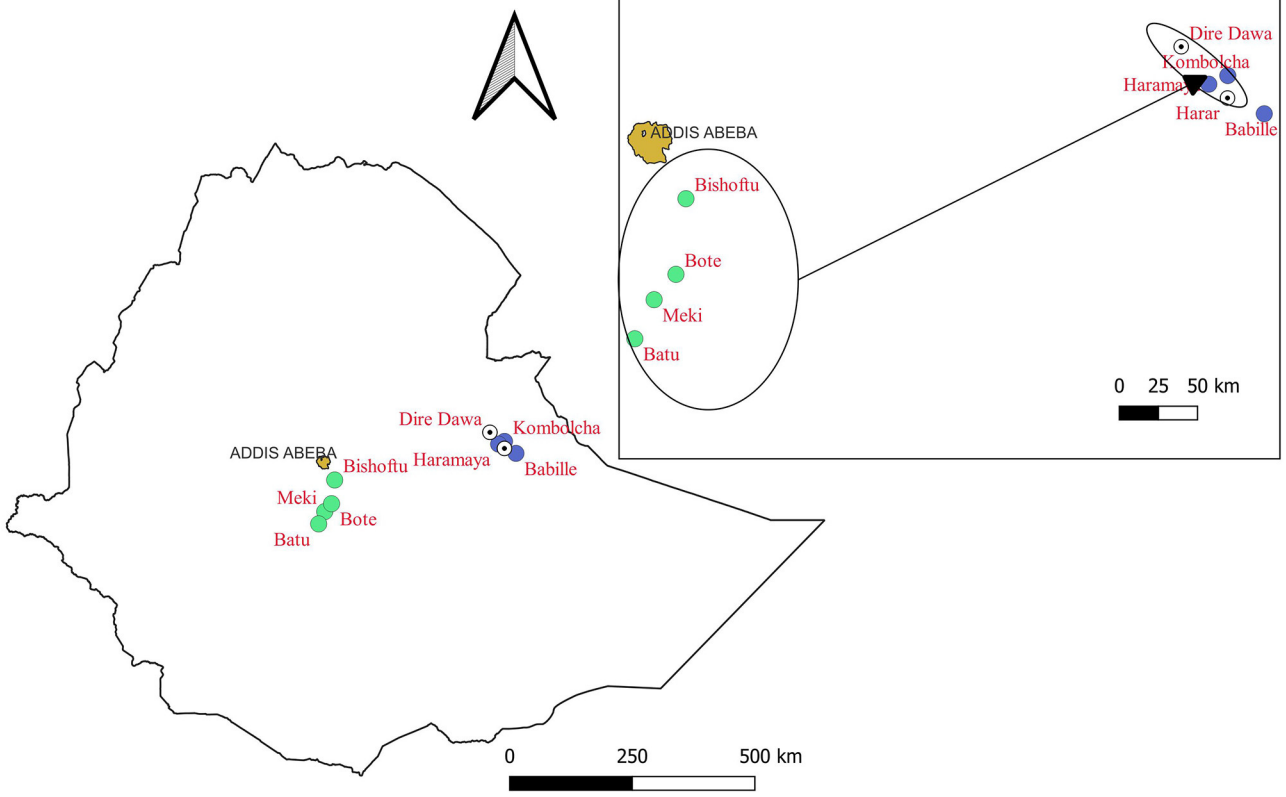

FIGURE 1
Map of Ethiopia showing the location of study areas and source of vegetables from central Ethiopia.

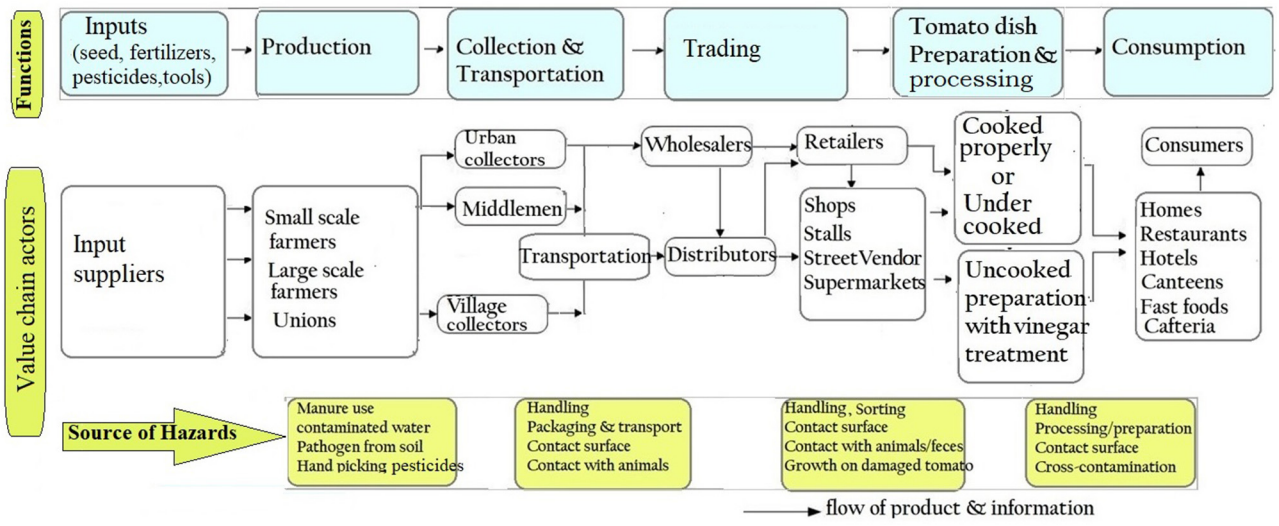

FIGURE 2
Vegetable market outlets and potential sources of hazards along the supply chain.

August and are more expensive compared to the other seasons. Small-sized tomato types, which are locally produced but less preferred by the urban community, are readily available at markets from July to September. It was mentioned that the local variety will not stay for a longer period compared with the one brought from a distant place (Central Rift Valley of Ethiopia). Irrigated farming

FIGURE 3
Pictorial representation of typical production and handling practices of tomatoes along the supply chains.

TABLE 2 Customers' preference criteria in the purchase of vegetables as reported by retailers.

Vegetables	Taste	Food safety (including pesticides)	Nutrition benefit	Appearance	Good price	Size
Tomatoes	2	2	4	5	2	5
Onion	1	4	4	4	3	NR
Potato	5	4	4	4	2	NR
Lettuce	5	4	5	5	NR	NR

NB: 1 = least preferred; 5 = highly preferred; NR, not ranked.

is the commonest vegetable production system in the rift valley of Ethiopia.

3.2 Vegetable VC descriptions

There were two types of vegetable supply systems in the study towns: the first group which accounts for the larger share of supply was from distant producers in the Central Rift Valley of Ethiopia, whereas for the second type the producers are small-scale local farmers from rural and peri-urban areas (Figure 1).

In case of the distant producers in the Central Rift Valley, tomato value chain spans between the input suppliers and consumers at extreme ends, and encompasses other actors including producers, collectors, brokers, transporters, wholesalers, and retailers. The input suppliers provide producers with fertilizer (inorganic and manure), agrochemicals, pesticide, seeds and farm tools. The value chain enablers such as agricultural extension, research institutes and market agents also are playing important roles in providing producers with information on agricultural practices, new vegetable variety, use of agrochemicals and market information. The health extension service addresses the hygienic and sanitary conditions at farming households and consumer levels so that contributes to improvement of food safety.

Besides application fertilizer, manure is widely utilized for vegetable production in the area with the time of application being during plowing, planting, growing till harvesting of vegetables. Untreated cattle manure is most used followed by that of small ruminants, then chicken manure. The cultivation of tomatoes by both large-scale and small-scale producers also utilized apparently poor-quality irrigation water. Farmers also do not follow label instructions on the application of pesticides

to vegetables, and pesticides may be used even two-three days before harvesting.

It has been noted that tomatoes are harvested by hand picking, collected and sorted on the ground, and loaded manually which may contribute to damage and contamination. Farmers believe that diseases, pests, excessive rain, insufficient watering, and poor storage are the main causes of poor-quality vegetables.

Small-scale producers (farmers) supply fresh produce either directly or indirectly to other actors, whereas brokers make connections with wholesalers and farmers, selling the farm produce to wholesalers in bulk. The wholesalers distribute vegetables to retailers and sometimes export to neighboring countries or territories like Somaliland, Somalia and Djibouti. In between, there are transporters that bring vegetables from the production area to market destinations in the country as well as outside of the country, usually by truck. The retailers sell vegetables to mainly consumers. The local producers in this small-scale, local VC bring their produce directly to the retail markets and sell them to consumers, street vendors or shops (Figure 2).

Typical production, marketing and handling practices of tomatoes along the value chains are pictorially depicted. Mishandlings of tomatoes during harvesting, sorting and loading were common in the study setting with potential contamination of tomatoes. In addition to mishandling, physical damage to the tomatoes was apparent. Similar observations were made related to market level handling of tomatoes in which poor hygienic practices were followed. Market level preparation and consumption of vegetables (tomatoes) was also observed and found to be under compromised hygiene (Figure 3).

3.3 Results of risk profiling

Vegetable traders in the urban centers of Dire Dawa and Harar get tomatoes from different sources. Regular customers such as hotels, restaurants, cafeterias, and other traders buy greater volumes than those buying for home consumption with sales volume ranging from 1 kg to 150 kg. As retailers have no specifically designed packaging materials, they put sold and stored tomatoes into different containers most commonly in plastic bags, and plastic containers, wooden and plastic boxes often reusing the containers. Tomato customers give more consideration to size, convenience, and nutrition and health benefits but give less attention to food safety issues. Retailers also give more attention to appearance, nutritional benefit and size when selecting tomatoes, but less attention to food safety (Table 2). Vegetable quality from farmers' perspective includes nutritional quality, health, appearance and size. They mainly take yield into account as important quality production. They further consider quality production mostly for the sake of market price and consumption safety (Table 3).

Practices such as sorting intact from damaged tomatoes, cleaning, washing with water and detergents may reduce the load of pathogens, but do not eliminate them. From the qualitative study, only about 20% of tomato traders practiced washing tomatoes after they purchased them and most of them (96.6%) used water but never used detergent or soap to wash fresh tomatoes. Additionally, the quality of water used for washing and cleaning tomatoes is also questionable. Analysis of potential sources of microbiological contamination along the tomato supply chains according to the present qualitative investigation encompassed various factors including soil, water (irrigation & washing), animals, pests, contact surfaces, and hands of people. Levels of contamination also vary considerably by different market outlets depending on their unhygienic handling practices, keeping facilities and environments, level of damage and the duration that tomato is kept in stock. Table 4 shows factors affecting tomato quality and likely facilitating its contamination.

TABLE 3 Quality aspect for vegetable in retailing activities as rank of average suggestions.

Quality aspects	Retailers	Consumers	Farmers
Appearance	6	2	5
Nutritional benefit	5	4	6
Size	4	5	2
Price	3	2	3
Food safety	2	3	4
Shelf life	1	1	1

NB: 1 = least preferred rank; 6 = very highly preferred.

Factors that were regarded to potentially affect the quality of tomatoes and make them liable for microbial contamination were given as four levels of qualitative score (very low, low, medium and high) and used to compare the market outlets (Table 4). The factors included the reported proportion of tomato damage, level of discarding, handling and keeping conditions, duration before selling or discarding it, and distance to night storage. Hence, street vendors had the highest score (29 out of 32 maximum) while retailers earned the lowest score (14), implying that tomatoes from the former outlet are more likely prone to quality problems and contamination than the latter with post-harvest handling practices as potential critical control points. However, if the quantity of tomato sales is taken into account, outlets that sell a large proportion of tomatoes per day i.e., retailers (57%) and stalls in markets (26%) would reach large number of the consumers and affect more number of consumers with the absence of kill step (Table 5).

3.4 Tomato food recipes, preparations, and consumptions

In Ethiopia, tomatoes are consumed in a variety of food preparations and are ingredients for cooked, semi-cooked and raw salad dishes. Fresh tomatoes are prepared and consumed in a wide range of dishes such as salads, soups, sauces, baked dishes, and grilled or roasted food items. Heat treatment varies from none to slight cooking or frying to thorough cooking. Results of the qualitative studies showed tomato was reported as the second most consumed vegetable in the area. Fresh tomatoes were commonly eaten raw after washing with water but no soap, then sliced and mixed with onion, green pepper and vinegar or lemon squash

TABLE 4 Potential sources of microbiological contaminations along the tomato supply chains.

Vectors	Production	Collection and transportation	Market outlets	Preparation and consumptions
Hands	Manual harvesting	Handlings	Handlings, sorting, cleaning	Handling, preparing
Water	Irrigation Wash water Flooding	Wettings during rain	Washing Wet cleaning	Wash water quality
Soil	Soil-borne Manure use Collecting on ground	Sorting packing on ground	Sorting, on ground mixing with tubers	Storing with tubers
Animals	Contacts Feces flooding of grazing field	Transporting with animals	Roaming shoat, dogs, chickens	Rarely cats may access to kitchen utensils
Pests, rodents	Rodents, flies	Flies	Flies, rodent	Flies, rodent
Contact surfaces	Crates, Plastic bags, carton, Cardboard box	Vehicles, Crates,	Crates, cardboard, Plastic bags, cardboard box, racks	Utensils, knife, cutting board

(tomato salad). The recipe is locally known as *"timatim kurt"*. A wide variety of undercooked and raw tomato recipes are served in the area: roasted tomato salad, spaghetti with fresh tomato sauce, sliced tomato with sandwich, and burger, slightly cooked tomato with roasted egg or omelet, and tomato salad with grilled steak and roasted meat.

4 Discussion

Understanding the food VCs is essential in food safety management, allowing identification of where hazards can contaminate foods, multiply, persist, spread and be controlled. Tomatoes can be contaminated with biological (microorganisms) and chemical hazards at various steps of the VCs, starting from production in rural areas to processing and consumption in urban consumption centers. It was observed that farmers apply untreated manure of various animals (mainly cattle followed by small ruminants and chicken) to improve soil fertility during the land preparation, planting and until harvesting, suggesting the existence of hazards at farm levels. They spray pesticides to prevent pests from damaging vegetables and this was done immediately before harvesting tomatoes. Likewise, the uses of pesticides and residue levels in vegetables and surface waters are a growing concern in the Central Rift Valley area of Ethiopia (Loha et al., 2020; Dinede et al., 2023). However, we found no study that evaluated the risk of using untreated animal manure for vegetable production in Ethiopia. A study in Kenya showed that vegetable contamination with the manure of dairy farms can be a risk of pathogen transmission to humans related to *Cryptosporidium* (Grace et al., 2012). Any damage caused by pests, bacterial diseases and physical injury also destroys the protective barrier of tomatoes facilitating the survival and growth of foodborne pathogens and increasing the risk of foodborne infections (Lynch et al., 2009).

Food safety risks can be of a greater challenge for the urban community given the complexity of the food VCs due to distances between the farm gate and consumption points of the current study settings. Tomatoes are mainly produced by small- and large-scale farmers in rural areas and consumed by urban residents after several transactions. Specifically, it is produced in remote rural areas of the Central Rift Valley mainly under traditional practices and transported long distance to the urban consumers of Dire Dawa and Harar of Eastern Ethiopia. Along the long-distances supply chain, it is likely exposed to multiple contacts with contaminated surfaces and vehicles as well as unhygienic handling. Hence, the likelihood of fresh tomato contamination might be high given the complexity of its supply chains which are characterized by several links and long transits between production and consumption.

Contamination of tomatoes thus starts at the farm level from contaminated water, soil-borne organisms, and use of untreated manure, and vegetable cultivation at sewerage outlets. Tomatoes are harvested, sorted and packed manually with possible unhygienic handlings. The use of contaminated water and untreated livestock manure are particularly important being common practice in vegetable cultivation able to carry pathogenic enteric bacteria (e.g. *Salmonella*, and pathogenic *E. coli* strains) that can be transferred to tomato fruits (Shenge et al., 2015). Any agricultural practices leading to soil contamination with human pathogens could pose a public health threat with subsequent tomato production and contamination of tomato fruit (Barak and Liang, 2008). This can be further facilitated by the presence of plant disease-causing bacteria, which cause lesions and pave away for colonization and multiplication by human pathogens.

Along such a long-distance supply chain, vegetables can be contaminated by contact surfaces and vehicles as well as unhygienic handlings by different actors such as collectors, transporters, and traders at the market outlets (wholesalers, retailers, stall near markets, street vendors). As there are no standard packaging materials and a lack of regular cleaning of the packaging material and the vehicle before reuse, maintenance of the pathogens and transfer from the contact surface to the vegetable also occurs. *Salmonella Typhimurium* and other coliforms have been detected from contact surfaces in the packinghouse showing the significance of contact surfaces in tomato contamination (Van Dyk et al., 2016).

There is also handling while buying, sorting, storing, and processing or preparing by consumers as well. Multiple human handling and contact surfaces during packing, transporting, and sorting have been also reported to cause contamination and associated foodborne outbreaks (Bennett et al., 2015). In general, the two major points of contamination, the production and processing environments, are reported to be the primary source of

TABLE 5 Risk profiling of the market outlets with regard to potential causes of contamination.

Market outlets	Conditions affecting tomato quality and favor contaminations (very low = 1, low = 2, medium = 3 and, high = 5)*								
	Damage level	Transit length/number of links	Duration of keeping before sale	Handlings intensity	Keeping condition	Exposure to direct sunlight	Discarding level	Distance to night storage	Overall severity score (%)
Retailers	4	1	1	1	1	2	3	1	14 (43.8)
Stalls in market	1	2	2	3	3	3	1	3	18 (56.3)
Street vendors	2	4	3	4	4	4	4	4	29 (90.6)
Formal shops	3	3	4	2	2	1	2	2	19 (59.4)

*The four level score scales (very low, low, medium and, high) were generated based on qualitative assessment data: overall severity scores were added for an outlet and proportion (%) was calculated out of total score.

tomato contaminant pathogens (Hanning et al., 2009). Unhygienic and improper handling of tomatoes is also potential food safety risks (Salamandane et al., 2020). In general, most cases of foodborne disease are caused by unhygienic handling practices, poor environmental sanitation; and contaminated surfaces including cross-contamination from cutting boards.

There are high post-harvest losses of produce along the value chain due to diseases, insect pest and mechanical injuries, each of them accounting for more than 20% of losses (Emana et al., 2017). Tomatoes in the study areas are usually transported in wooded crates with unprotected rough surfaces, overloaded, and stacked on top of each other, thereby causing damage to the fruits. Normally, an intact fresh tomato has physical barriers that provide protection against entry of foodborne pathogens and is less likely to support bacterial growth. Removals of barriers due to punctures, bruises and damages allow the growth of the pathogen in damaged tissues. Thus, once the protective barrier is lost, survival and growth of foodborne pathogens will be significantly enhanced, becoming a source of contamination for other fruits. Considerable proportions of damage and exposure to sunlight have been observed in the study area which favors contamination and growth of bacteria with food safety risks.

From the qualitative study, there was no sufficient cleaning and hygienic practices that reduce contamination. In another study in the areas about 20% of tomato traders practiced washing tomatoes after they purchased them and most of them (96.6%) used just water and never used detergent or soap to wash fresh tomatoes (Gemeda et al., 2023). Additionally, the quality of water used for washing and cleaning tomatoes is also questionable (Figure 3). A study has demonstrated a high level of microbial contamination of the water used for the washing of fresh tomatoes in major markets in Nigeria (Ofor et al., 2009).

Various studies on the microbiological quality of fresh tomatoes have identified a wide range of microorganisms of potential public health risks. Among the pathogens that have been identified, *Staphylococcus, Salmonella* and *E. coli* are the most frequently reported microbial hazards from tomato VCs globally (Ogundipe et al., 2012; Julien et al., 2017; Sahile and Teshome, 2019; Somda et al., 2019; Younus et al., 2020). Though detection of bacteria species from tomato samples does not necessarily imply food safety problems, various studies from Ethiopia have also reported the occurrence of coliforms, *E. coli*, *Salmonella* spp; *Staphylococcus*, *Klebsiella* spp, *Shigella*; *Pseudomonas*, *Proteus* in fresh tomatoes (Ashenafi, 1989; Dugassa et al., 2014; Alemu et al., 2018; Sahile and Teshome, 2019; Degaga et al., 2022). Some foodborne pathogens vary in their nature of occurrences and their level of detection from fresh vegetables depends on various factors whereas detections of some bacterial strain (e.g., *Salmonella*, pathogenic *E. coli* strains) are of food safety and public health significance.

As tomatoes are commonly consumed raw, without heat treatment in the two urban settings of the present study, the vegetable likely poses health risks to consumers. Recipes prepared from tomatoes that lack adequate hygiene and sanitation steps are expected to carry pathogenic bacteria and their toxins that can potentially cause foodborne diseases among consumers in urban settings. Though evidence on foodborne infections that can be traced to tomatoes is hardly available from public health records in Ethiopia, foodborne disease outbreak reports from other

countries showed large-scale outbreak episodes that have been associated with the consumption of tomatoes (Gupta et al., 2007; Greene et al., 2008; Callejón et al., 2015). For example, among the microorganisms that have been linked to fresh tomato intake, *Salmonella* was the leading (69.2%) cause of foodborne diseases (Callejón et al., 2015). In another study, the characterization of 15 foodborne outbreaks associated with consumption of raw tomatoes in the United States attributed nearly the entire causative agent to *Salmonella* serotypes (Bennett et al., 2015).

5 Conclusion

In this study, we performed a scoping analysis of vegetables focusing on tomatoes VCs to identify potential food safety risky practices. It revealed various steps at which microbial contaminations can occur, such as production (incorrect use of agrochemicals, contaminated irrigation water and manure), unhygienic handling and storage conditions at various points, contact with contaminated surfaces, including cross-contamination during preparation in the household. Exposures to direct sunlight, prolonged duration of keeping in stock and considerable levels of damage were among the factors that could facilitate contamination of the vegetable. Literature information on the microbial quality of fresh tomatoes and foodborne illness incidents that can be traced to tomato consumption further substantiated the health risk of raw tomato consumption where there is an absence of any "elimination-step". To address such food safety and hygiene issues, it is crucial to take decisive action by allocating sufficient resources and facilities to sectors, leveraging technological innovation in the production, transportation and storage of quality vegetables, and raising community awareness of safe food production and distribution is encouraged. For example, the use of proper packaging materials such as reusable plastic crates during long-distance transportation to minimize physical damage to tomatoes is recommended. Mapping the food safety value chain is important to identify and target the high-risk practices in the chain and implement targeted intervention measures to improve food safety. In general, the present study generated food safety VC maps which can be useful inputs to model the food system or design targeted actions toward improved food safety and hygienic practices.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by International Livestock Research Institute (Ref: ILRI-IREC2019-36). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

KA: Data curation, Formal analysis, Investigation, Methodology, Writing—original draft, Writing—review & editing. BM: Data curation, Formal analysis, Writing—review & editing. MJ: Data curation, Formal analysis, Writing—review & editing. GD: Data curation, Formal analysis, Writing—review & editing. HW: Formal analysis, Investigation, Writing—review & editing. KK: Formal analysis, Investigation, Writing—review & editing. MT: Formal analysis, Investigation, Writing—review & editing. AI: Data curation, Investigation, Writing—review & editing. JK: Data curation, Investigation, Writing—review & editing. LM: Investigation, Writing—review & editing. KR: Conceptualization, Funding acquisition, Methodology, Resources, Writing—review & editing. RR: Methodology, Writing—review & editing. RS: Methodology, Writing—review & editing. DG: Conceptualization, Funding acquisition, Methodology, Writing—review & editing. TK-J: Methodology, Project administration, Resources, Supervision, Writing—review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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