Uganda Journal of **Agricultural Sciences**
ISSN: 1026-0919 (Print); 2410-6909 (Online)
Volume 22 Number 1 (2024) pp. 75 – 87
DOI: http://dx.doi.org/10.4314/ujas.v22i1.6

https://www.ajol.info/index.php/ujas

Measures for Reducing Tomato Post-Harvest Losses at Farmer Level in the Lake Victoria Crescent Agro-Ecological Zone

Damalie Babirye Magala [1,] *, Jerry Egessa [1]; Jackie Atim [1], Godfrey Sseruwu [1]; Teopista Namirimu [1]

[1] Mukono Zonal Agricultural Research and Development Institute, National Agricultural Research Organisation.

*Corresponding author. dbmagala@gmail.com +256778804248

Received 29/5/2023. Accepted 17/4/2024. Published online 17/5/2024.

Abstract. Globally, tomatoes (*Solanum lycopersicum*) are recognized as a significant vegetable crop with nutritional, health, and economic importance. In Uganda, small-scale tomato farmers, obtain low yields due to biotic and abiotic conditions of pests, diseases, lack of irrigation, and insufficient knowledge of sustainable farming practices. Post-harvest losses further hinder tomato production by limiting the amount of high-quality produce reaching the market. This study used a largely qualitative approach to understand the mechanisms tomato farmers in Wakiso and Luwero districts in Central Uganda use to reduce post-harvest losses at farm level. The study reveals that the Assila F_1 Hybrid is the predominant variety—chosen for its firmness, extended shelf life, and resistance to pests and diseases. Farmers adopted staggered planting to manage post-harvest losses, harvesting mature green tomatoes in the morning and evening. However, a lack of technical expertise resulted in a deficiency of deliberate post-harvest treatments, and the absence of a mandatory body for produce inspection negatively impacted quality. Individual sales by farmers without standardized measurements also contributed to exploitation by middlemen. The study recommends farmers' capacity building in appropriate post-harvest handling practices.

Keywords: Tomato, post-harvest, losses.

Introduction

Tomato (*Solanum lycopersicum* L.) is a vegetable crop cultivated all over the world and is a good source of vitamins A, B6, C, K, and E. The fruit also contains molybdenum, copper, and potassium, and is a good source of dietary fibre (Rodríguez-Ortega, *et al.* 2019; Bergstrand, Löfkvist and Asp (2020). Owing to its rich source of vitamins and minerals, particularly as a rich source of lycopene (60–90 mg/kg), tomatoes is an important component of the human diet (Yusufe *et al.*, 2017). In Sub-Saharan Africa, horticultural crops including tomatoes offers a reliable source of employment and income generation to small- and medium-scale growers

(Sibanda and Workneh, 2020.) However, tomato is a perishable crop and deteriorates few days after harvest, loosing almost all its required quality attributes and some could likely result to total waste (Bada *et al.,*2021).

However, the current production is below the potential level. For instance, in Kenya, the current production is 658,000MT while Uganda contributes 37,637 MT, in contrast to the estimated potential of 300,000 MT (FAO, 2022). Post-harvest losses tend to prevent adequate supply of and accessibility of fresh tomatoes, thereby causing wide variation in prices of the commodity (Bada *et al*., 2021). For instance the authors noted that in Nigeria, at farm level, about 20% of the total tomato harvested was lost as a result of harvest and post-harvest activities. Reducing post-harvest losses as an important component of food security, has potential to lower food prices to vulnerable communities in the region (Sibanda and Workneh, 2020). In Ghana, about 15,300 metric tons (30%) of tomatoes harvested are lost from the annual production of 51,000 metric tons of fresh tomatoes (Wongnaa *et al.,* 2022).

In Uganda, the small-landholder tomato farmers own 2ha or less of land (Atuhaire *et al*., 2016); but the national yield of 57.0MT/Ha is much lower than the global potential of 378MT/Ha (FAO, 2022). Low tomato yields are attributed to pests and diseases, abiotic stress such as drought and low soil fertility, inadequate agricultural inputs use, limited access to quality seed, lack of improved cultivars, and insufficient information on sustainable horticultural practices among others (Dube *et al*., 2020; Tusiime, 2014). In addition to the field production constraints, tomato production is constrained by post-harvest losses, which limit the volumes of good quality produce to the market. Their perishable nature, inferior postharvest technology, and lack of awareness among producers and other market actors result in poor handling of the tomato (Sibomana *et al., 2016;* Arah *et al*., 2015; Bombelli and Wright, 2006).

Although increasing production is one aspect of fulfilling food demand, failure to reduce post-harvest losses negatively affects the desired volumes for sale and the eventual incomes of the farmers. For instance, Nigeria loses about 10-40% of tomato produced from the farm to the retail markets, while in Rwanda, tomato losses were above 60% due to poor post-harvest and handling facilities (Kitinoja *et al.,* 2019).

Most research conducted postharvest losses of the tomatoes at market level, however, limited research has been done to identify post-harvest losses at the farmer level (Alemnew, 2010; Birhanu, 2011). The study aimed to identify mechanisms used by farmers to reduce post-harvest losses, how the farmers address marketing challenges and mitigation measures used at the farm level.

Methodology

Draper (2004) argues that qualitative research is largely concerned with the quality or nature of human experiences and the meaning of such individuals attached to a given phenomenon. Qualitative research answers the how and why questions in the context of everyday life and each individual's meanings, describe and explain social phenomena as they occur in their natural settings. A qualitative multiple case study research design (Yin, 2009) was used to provide an in-depth inquiry into factors and contextual conditions to explain how tomato farmers reduce post-harvest losses at farm level. Districts were taken as cases because they represented different contexts as districts and tomato farmers with divergent behaviours and perspectives; and this, therefore, enhanced the internal validity of the study findings. Data from multiple sources were then converged in the analysis process rather than handled individually.

Purposive sampling was employed to ensure that tomato farmers with different production levels were included in the study. As such variations in the patterns of response across farmer categories would be examinable. The main aim of purposeful sampling was to select and study a small number of respondents who provided rich insights and an in-depth understanding of which mechanisms and how do tomato farmers reduce post-harvest losses at farm level? (Yilmaz, 2013). Two sample districts of Luwero and Wakiso were selected because farmers ranked tomatoes among the major commercial crops. Zirobwe sub-county was selected for Luwero district and Kakiri sub-county for Wakiso district. Data were collected between July and August 2021.

According to Morgan (1998), focus groups are essential for generating the experiences and beliefs of respondents. Using a focus group discussion checklist, the team conducted four focus group discussions (FGDs) with 55 farmers in Luwero and Wakiso districts. The main themes of discussion at the FGDs were (i) the use of the different tomato varieties, (ii) causes of post-harvest losses in tomatoes, (iii) challenges and mitigation measures for post-harvest management at the farm level.

Qualitative data was supplemented with individual interviews of 33 tomato farmers using a pre-tested and structured questionnaire to complement and compare information from secondary sources on the average acreage planted, output, post-harvest losses, causes, and coping mechanisms for reducing post-harvest losses at farm level. Secondary data regarding tomato postharvest losses were obtained from peer-reviewed publications and technical reports to supplement the primary qualitative data. Quantitative data was analysed using SPPS version 21 to generate descriptive statistics and graphs for presentation and interpretation. To guide the coding process for qualitative data the team developed a codebook by reviewing sample transcripts, guided by research questions. Data were analyzed by content and thematic analysis using the method by Schutt (2011). The analysis method is used for identifying, analysing, organizing, describing, and reporting themes found within a data set. Codes were derived using the inductive approach as suggested by Merrian (2009) by attaching meaning to individual narratives basing on the researcher's perception and experience. The themes included tomato production and marketing, causes, and mitigation measures of post-harvest losses at farm level.

Results

Demographic Characteristics

Survey results indicated that the majority of the tomato growers were men (79%), while women were 21% with an average age of 45 years (Table 1). Over 60% of the tomato growers belonged to farmer groups, though, majority of the respondents sold their produce individually at farm gate, to traders and brokers as reported by the focus group discussions. This concurs with what was reported by Ddamulira *et al*., (2021) that tomato production in Uganda is mainly undertaken by farmers working individually with only 37% working in groups. The results also indicated male dominance in tomato production, this was also observed in a previous study in Kenya (Ochillo *et al*., 2019).

In this study, most of the farmers (88%) sold their produce individually with only 12% selling through groups. In Uganda, a higher proportion of men have better access to financial resources and own land compared to women, yet tomato production requires capital investment especially in land acquisition. Besides, tomato production is considered a risky venture yet more

women are risk averse as compared to men which limits the number of women involved in tomato growing (Ddamulira *et al*., 2021).

Table 1. Social characteristics of the respondents (%, *N*=55)

Variable	Categories	%
Age	Average age of respondent in years	45
Sex of Respondent	Men	79
	Women	21
Membership to farmer group	Yes	61
	No	39

The average land allocation to tomato was 0.64Ha, resulting in a seasonal production of 17.6MT/Ha. This output is notably lower than the national average, of 40,124 MT/ Ha. The achieved yield of 10.9MT/Ha falls short of the anticipated national yield potential of 57.0MT/Ha (FAO, 2022). To reach this potential, research and development agencies must enhance farmers' capacities to adopt improved agronomic practices. The study revealed an estimated postharvest loss of 5.1% of the total production per season, adversely impacting farmers' income and ability to service the loans and investment in agro-inputs like seeds, fertilizers and labour. Nevertheless, similar studies in Nigeria, Rwanda and India reported postharvest losses (PHLs) at the farm level ranging from 2% to 40 % (Kitinoja *et al.,* 2019). This study affirms that tomato cultivation remains one of the most lucrative ventures for farming households. However, farmers still had challenges to manage the post-harvest losses at farm level. Consequently, to maximize profits, farmers cultivate the crop in both seasons, relying on rains during the wet season and in swampy areas during dry spells.

Table 2. Average area planted, output harvested and estimated post-harvest losses for tomatoes

Variable	*N*	Minimum	Maximum	Mean
Acreage planted (Ha)	32	0.1	1.6	0.64
Average harvest per Ha (MT)	32	3.3	6.6	17.6
Estimated post-harvest losses (MT)	32	0.17	3.3	0.87

Survey findings revealed that farmers mainly grew AnsalF_1, Rambo, Assila F_1 hybrid and Rio Grande. The varieties grown are selected according to market demands and performance in the area. Assila F_1 Hybrid (84%) and Ansal F_1 (8%) were the most common varieties due to their high yields, pest and disease resistance, and hardy and coarse skin which prolong their shelf life even after harvesting. In addition, these varieties have the desired market and consumer attributes. According to the farmers, traders preferred fruits with a big size, oval-shaped, longer shelf-life, and hard skin that is not easily damaged during transit as quoted;

> "Farmers mainly grow Assila F1 hybrid, Ansal, Rambo, and Rio grande. The varieties grown are selected according to market desire and performance in the area. Assila F`1 Hybrid was the most common variety because of its high yield, resistance to weather changes, not easily eaten by pests, and resistance to wilt. The hard coat of the fruit has longer shelf life compared to any other variety" (FGD, Luwero district).

Further, discussions with the farmers revealed that with proper management, Assila F_1 hybrid matures within three months; the variety can be harvested for one more month compared to the other varieties. Farmers harvested approximately 120 to 150 boxes per acre per season. However, there were other tomato varieties grown on a small scale, like Commando, Eden F_1,

Ranger F_1, which are hybrids, and open-pollinated varieties like Victoria, VFN Roma, MT 56, Marglobe, "Musununu", Vikima, Omega, Opello and Sifa among others.

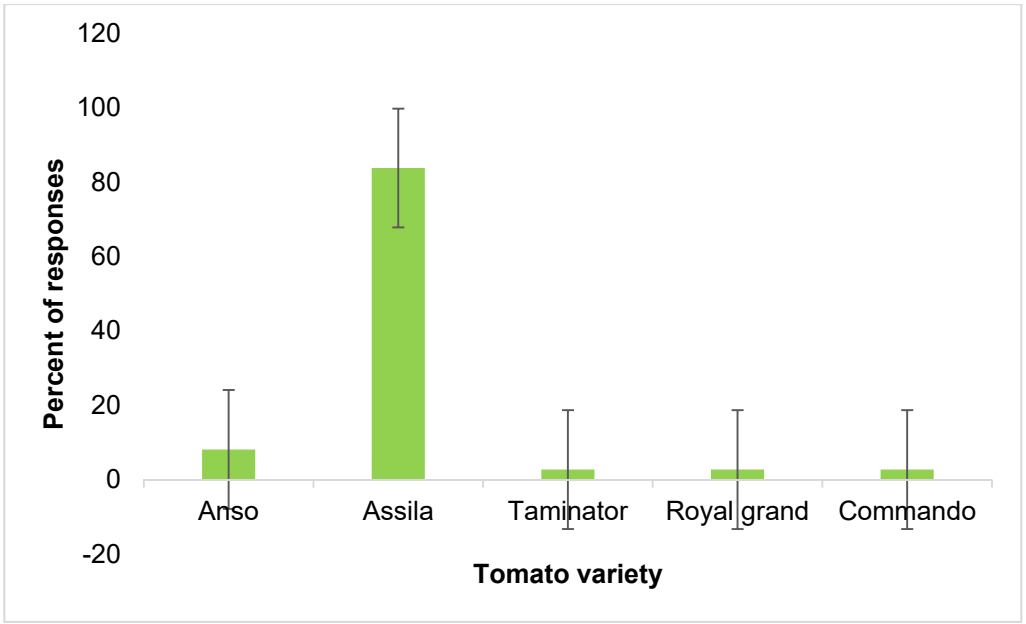

Figure 1. Major tomato varieties grown in the study area

Causes of Post-Harvest Losses

Short shelf life

Due to fluctuating prices and perishability of the crop, tomato farmers tried to reduce post-harvest losses throughout the year by practicing staggered planting. The bumper harvest during the rainy season lowered the prices for fresh tomatoes. Therefore, farmers maximized profits during dry season, by hiring swampy areas at Ushs. 200,000 per acre, In addition, farmers divided their fields into blocks and planted crops at different intervals as a strategy for managing post-harvest losses at the farm level.

Respondents reported that the maturity period for tomatoes ranges between three to four months after transplanting depending on the variety and environmental conditions. Tomatoes were harvested at different stages depending on the market requirements and distance to the market. Farmers harvested the fruit at breaker or turning stage when about 30% of the fruit surface has a definite colour break from green to yellow and pink or light red stage when 30 – 90 % fruit surface has pink or red colour.

Results from the focus group discussions revealed that farmers who targeted distant markets harvested their tomatoes at breaker or turning stage to prevent mechanical injuries during harvesting. The ripe fruits were mostly harvested for ready markets (rural and urban markets), while the mature green were mainly for regional markets, especially Kenya and South Sudan, where tomato spends some time in long transit. This study revealed that farmers mostly sold tomatoes on-farm (35%), through rural markets (33%), and the nearest urban markets (32%).

Inadequate market linkages

Study results confirmed that farmers immediately started to scout for the market as soon as the first fruit ripens. From the FGDs, farmers contacted brokers from *Owino, Nakasero, Kalerwe* as some of the major urban fresh markets. Farmers also had contacts of big buyers from Kenya, Congo, and South Sudan though these were seasonal markets. The major reason was that farmers could not sustainably meet the demand of such markets due to supply and price fluctuations which has implications on farmer's income as confirmed by farmers in Zirobwe (Luwero district);

> "Additionally, we have some important buyers from Kenya, Congo, and Sudan, but these engagements are seasonal. Unfortunately, we struggle to supply them consistently due to fluctuations in prices and our production levels (FGD, Zirobwe sub-county, Luwero)."

It was found that, commercial tomato producers especially men did not target local buyers like the roadside markets. Such markets were supplied by relatively small scale farmers especially women, who grew less than an acre. From the FGDs, farmers reported that traders have varying sizes of container boxes for selling their produce and they were rated differently. Participants noted that the boxes for the regional markets like Kenya, Juba and Congo were smaller compared to the urban outlets like Nansana, Owino and Nakasero markets. Yet most roadside traders buy fresh tomatoes in 50kg sacks and basins of approximately 30kgs per unit. During periods of scarcity, a box of fresh tomato could rise up to Ushs. 800,000 or US$217.3 while during bumper harvest, a box can be bought as low as Ushs. 50,000 or US$ 13.6, leading to losses. Although farmers reported that urban markets offer better prices, most farmers sold their tomatoes at farm gate to avoid transport costs and exorbitant market dues charged in urban markets. Therefore, farmers' inability to establish formal marketing contracts with specific buyers affected their bargaining power for a premium price and eventual income.

Poor post-harvest handling technologies

Tomatoes were harvested manually using wooden crates and woven baskets with hard and sharp surfaces which caused mechanical injuries to the harvested fruits (Figure 2). Wooden boxes were mostly used by transporters from the field to the market due to their convenience with minimal tomato damage during transportation. However, plastic basins and woven baskets were mostly used during harvesting in the field because they are easy to carry and retain the freshness of the tomato while harvesting.

Figure 2. Common post-harvesting methods at farmer level

The low adoption of available post-harvest technologies is not unique to Ugandan tomato farmers and is largely attributed to the information gap between the farmers, extension, and research institutes responsible for information dissemination on the use of such technology. Farmers mainly harvested their tomatoes in the morning and stored the crop under the tree shades until traders arrived (Figure 2). Another farmer practice to minimize post-harvest losses was the use of agro-chemicals such as fungicides; *mancozeb*, *tebuconazole* and *propnine*, and insecticides like *cypemethrin*, *dimethoate*, *diclorvos*, and *malathion*.

Poor standardization methods

Farmers generally sorted the fruit by size and sorted poor quality fruit by removing damaged, diseased, and unripe fruits. Farmers graded the fruits largely based on external appearances, bruising, and firmness. The final cull was usually sold at a lower price or used for animal feed on-farm.

Tomato pests and diseases

About 56% of the farmers reported leaf miner (*Tuta absoluta*) as the most important pest. It infests the tomatoes in the field but its effects are also manifested at the post-harvest level. The pest damages the fruits which reduces the acceptability by the consumer and traders along the tomato value chain. Tomato late blight and tomato soft rot were reported as the most important diseases affecting farmers' outputs and yields. The diseases cause early rotting of the fruit soon after harvest which reduced the shelf life and quality of the produce before it reaches the market.

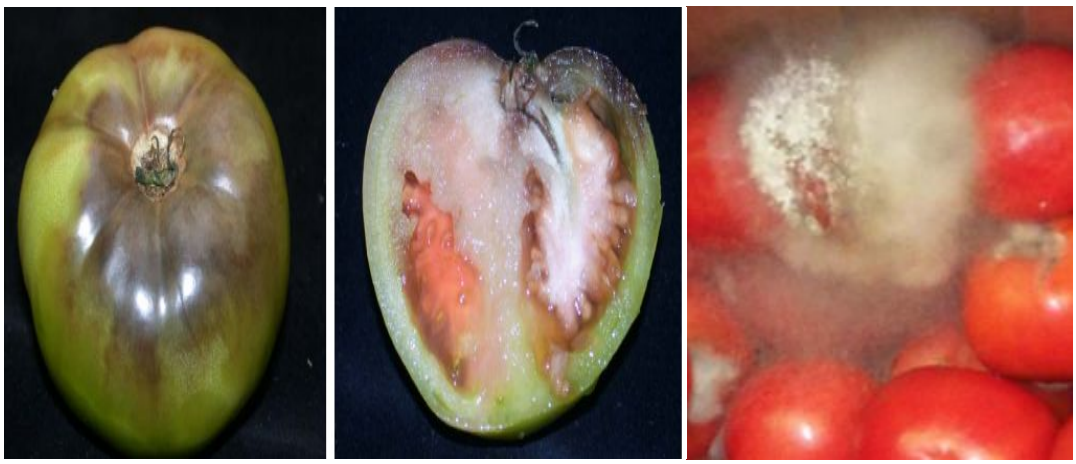

Figure 3. Signs of late blight and 9b) Rhizopus rot diseases

Mitigation measures for post-harvest losses at farm level

Current practices for reducing post-harvest losses

Despite the lack of appropriate on-farm cooling systems, packaging materials, and harvesting technologies, farmers attempted to reduce the post-harvest losses at farm level. They employed various strategies, including the use of agro-chemicals (94%), direct selling to the market (67%),

mulching the crop (28%) and sorting good produce (21%). Another coping strategy involved planting varieties that are resistant to pests and diseases.

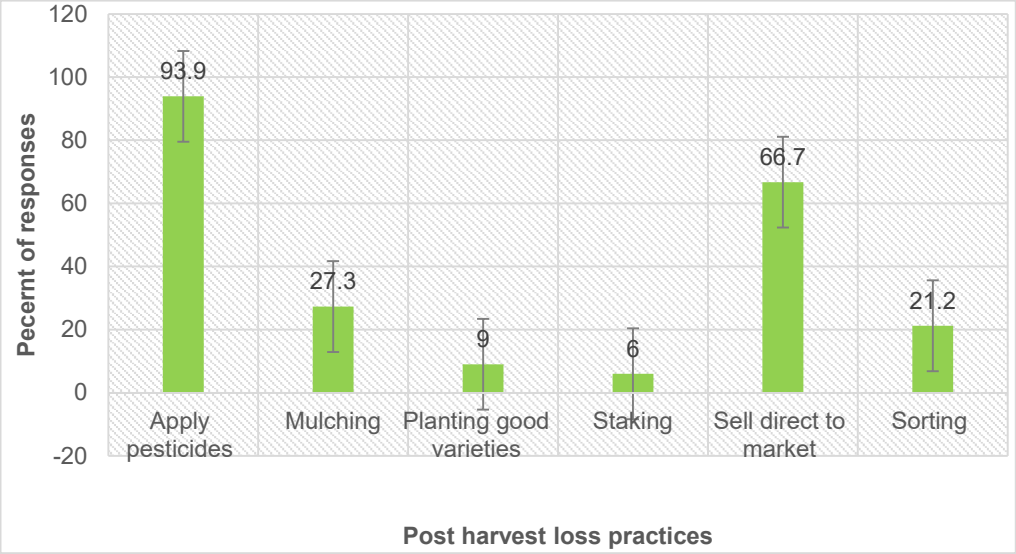

Figure 4. Current farmer practices for reducing tomato post-harvest losses

Agro-chemicals usage

As earlier discussed, to prevent fruit rotting, from the farm to the market, farmers predominantly applied agro-chemicals with the assumption that if the fruit are coated with fungicides their shelf-life will be extended for a week or longer. Although this practice works for the farmers, it does not enable farmers to follow proper instructions regarding the pre-harvest intervals which has implications on food safety for consumers. Indeed, farmers confirmed that they spray the crops a day before harvesting and after harvesting the tomato to convince the traders to buy their produce as indicated in figure 4 and reported at the FGDs.

> "For us regardless of the variety grown, we apply fungicides like macozeb 2-3 days before we harvest the tomato. When the tomato appears with chemical stains, then the traders can easily buy your tomato because they believe that it will not easily rot to make losses. (FGD, Kakiri Sub County, Wakiso district)

Market linkages

According to respondents, information sharing helped the farmers to manage their perishable crop by obtaining market information about possible markets locally and regionally and also how to minimize losses. Farmers scouted for markets early enough when the first tomato ripened which helped them to clear the field before markets were flooded with produce. Another challenge was the poor bargaining power by the farmers as prices were determined by the traders leading to economic exploitation and thus losses.

Mulching

Mulching was identified as one of the major measures for minimizing losses at farm level but it was quite costly. Primary sorting was done manually by picking diseased, damaged or rotten

tomatoes and sorting by size. However, some farmers said that they did not grade because they did not want to reduce the amount of their marketable produce.

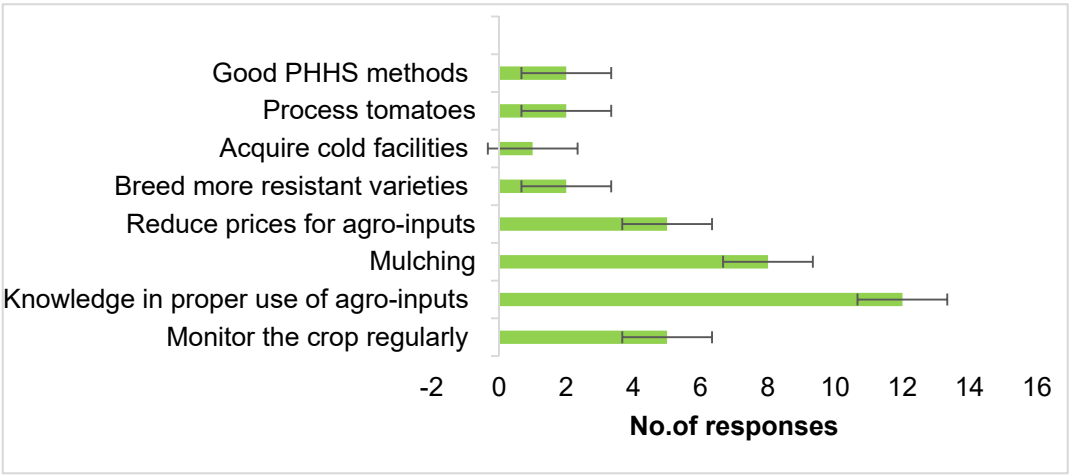

Figure 5. Proposed solutions for reducing tomato post-harvest losses at farm level

Farmers still believe that the use of agro-inputs like fungicides is the best measure for reducing post-harvest losses that is why they ranked the need for price subsidies and knowledge on agro-chemicals use as the best option (Figure 5). Mulching and rouging of the crop were proposed as options however, both have cost implications on labour requirements. A few mentioned the need for improving access to new varieties, cold facilities and the use of good post-harvest handling methods which implied a knowledge gap in appropriate post-harvest handling techniques and their benefits in managing crop losses.

Discussion

Due to short shelf life of the fruits, farmers harvested their crop at different ripening stages for diverse markets. The findings corroborate with the study by Ddamulira *et al., (*2021) that confirmed that tomato fruits were sold in four main forms; ripe fresh fruit (73%), mature green (18%), mixed green and ripe fresh fruits (8%), and others (1%). The findings further concur with other studies from other developing countries, for instance in Rwanda, tomato fruits are harvested at fully ripe stage leading to higher losses as they are damaged due to poor packaging and long distance from the farm to final market (Toivonen, 2007).

This study confirmed that tomato farmers had weak linkages with the key market actors especially the urban markets because they were not organized into formal entities like farmer groups or associations. According to Ddamulira *et al.* (2021) better prices in the urban markets were further revealed by the willingness of middlemen to move and transact business with the farmers right at the farm. Although farmers in the two districts didn't mention selling tomatoes to other outlets, Ddamulira *et al.,* (2021) reported that a small percentage of tomatoes were sold through channels such as supermarkets and local processors. Therefore, the extension delivery stakeholders need to strongly support the farmers to engage in the entire tomato value chain.

Due to poor post-harvest handling technologies, tomato farmers in both districts improvised by harvesting the fruit early during morning hours. The scenario is not different from other African countries. Olayemi *et al*., (2010) reported that 46% of Nigerian farmers harvest their tomatoes in the morning and 12% in the evening; most of them stored the harvested tomatoes under tree shades until buyers arrived. Yet tree shades are not reliable as they are likely to shift away from the produce when the sun changes its position thus exposing the fruit to the scorching sun. Moreover, farms lacked on-farm cooling systems to deal with excessive field heat. Current studies by (Ddamulira *et al*., 2021) confirmed that in Uganda tomato farmers used wooden boxes (65%), plastic basins (23%), and (18%) woven baskets for collecting and transporting tomatoes to the markets. The survey findings corroborate with Suslow and Cantwell (2012) in America who recommend that fruits should be harvested early in the morning when the temperatures are low. This study further found that apart from removing debris, there was no deliberate effort for post-harvest technological treatments like washing and coating at farm level.

Although some farmers in developing countries are already using low-cost on-farm cooling systems in the form of structures, they form a small proportion (less than 10%) of the number of tomato producers especially in Africa (Olayemi *et al*., 2010). This is an indication that over 90% of farmers have no on-farm storage facilities which exposes the fruit to excessive loss of moisture and compromises the produce quality.

Findings from this study corroborate with other studies which indicate pesticides especially ethylene bis-dithiocarbamates (EBDCs), are intensively used on this crop to combat different fungal infections, such as early and late blights (Karungi *et al*., 2011). By 2016, *mancozeb*, *maneb*, and *propnine* were the EBDCs registered for use in Uganda (MAAIF, 2016). The excessive use of these chemicals is discouraged by the Uganda Ministry of Agriculture, Animal Industry and Fisheries (Sekabojja *et al*., 2023). However, studies have shown *mancozeb* to be the most used fungicide by tomato farmers, (Atuhaire *et al.,* 2017; Kaye *et al.,* 2015; Karungi *et al.,* 2011). This practice implied that farmers were not aware of the health hazards of consumption of chemical residues which require tailored post-harvest treatments training for better product quality. In most low-income countries like Uganda, fresh produce sold at local markets is usually not analysed for agricultural chemical residues unlike export products. This raises concerns about the perceived safety levels of local food supplies in contrast to exported products (Mutengwe *et al*., 2016). For instance, a study in Uganda showed that 25% of farmers were not aware of any health risks of spraying tomatoes close to harvest time, almost 50% of farmers sprayed their tomatoes less than a week up to harvest time, 29% sprayed their tomatoes at harvest with intentions to extend the shelf-life while 50% did so to attract consumers (Kaye *et al.,* 2015; Atuhaire *et al.,* 2016; Sekabojja *et al.,* 2021).

Tomato farmers confirmed that the damage on the fruits due tomato pests and diseases reduces the shelf life of the fruits leading to post-harvest losses. This has been corroborated by Chepchirchir *et al*., 2021 in Kenya and Uganda who indicated that *T. absoluta* is the major pest affecting tomato production, with most farmers using synthetic pesticides for management. Use of agrochemicals was mentioned as one of the mitigation measures for reducing tomato losses. Other studies however, confirm that farmers applied high dosages of agro-chemicals like *mancozeb* to prevent fruit rot. Farmers assumed that highly stained tomatoes are due to poor hybrid varieties that require frequent spraying. Vendors' demand from tomato growers to spray tomatoes before they sell, coupled with a wrong perception of tomato farmers that *mancoze*b pesticide can harden the outer skin and increase tomato shelf life (Kaye *et al*., 2015; Sekabojja *et al.,* 2021; Ssemugabo *et al*., 2022). Yet the majority of the farms were not adhering to the recommended mixing concentration of 50g of the pesticide per 20 litres of water. Seventy-five

percent of the farms were found to be exceeding this concentration, with an overall average exceedance rate of 90.8%. The average mixing concentration for the 20 farms was 83.25 g/20 L. In terms of timing, all farms had applied *mancozeb* less than eight days before the day of sampling, an overall average of 3.5 days (Atuhaire *et al.,* 2016). Yet, dithiocarbamates are considered to have acute mammalian toxicity with effects such as eye irritation, skin rashes, scratchy throat, sneezing, among others.

Conclusions and Recommendations

The main causes of post-harvest losses at farm level were the short-shelf life of the crop, poor post-harvest handling facilities and standardization methods, pests and diseases, poor farmer organization, and inadequate market linkages. To address the challenges above, farmers largely have short-term mitigation measures of stagger planting, mulching, and individual identification of markets for immediate sale. Pesticide usage was perceived as the main mitigation practice to prevent fruit rotting. Yet, the study results indicated pesticide misuse by farmers which poses health risks to tomato consumers.

Based on the study results, the following areas need critical attention from different stakeholders in the tomato value chain**;**

1. Farmer training and promotion of appropriate and innovative post-harvest handling and storage technologies of fresh tomatoes.
2. ICT based agro-based systems to integrate value addition technologies at farm level.
3. Establishing proper knowledge management and climate smart agriculture systems.
4. Institutional development and strengthening of market linkages across the tomato value chain.

Provision of information on the proper use and handling of agro-chemicals and compliance with food safety regulations to all tomato value chain actors including farmers, traders and consumers. The farmer's practice of not adhering to the chemical pre-harvest intervals needs to be addressed immediately. At the moment, Uganda has no pesticide residue monitoring plan for conventionally produced food and this puts the lives of consumers in danger. Integrated Pest Management (IPM) strategies need to be integrated into the tomato value chain. However, such strategies required multi-stakeholder and participatory approaches as well as coordinated integration of multiple complementary practices for pest management in a safe, cost-effective, and environmentally friendly manner.

This study largely used a qualitative approach to interpret personal perspectives and experiences of the tomato farmers as they deal with post-harvest losses. Therefore, the major gap from this study that needs further research is quantifying reliable tomato production levels and post-harvest losses at district level.

Acknowledgement

This research was funded by the Government of Uganda – Development component. This research article resulted from research on post-harvest losses in the tomato value chain. We greatly appreciate the contribution made by Mukono Zonal Agricultural Research and Development Institute (MUZARDI) and the National Agricultural Research Organization (NARO) for the financial support towards the success of the project. We acknowledge the support of all the participants for the time and support accorded to this research.

References

Arah, I. K., Kumah, E. K., Anku, E. K., & Amaglo, H. 2015. An overview of post-harvest losses in tomato production in Africa: causes and possible prevention strategies. *Journal of Biology, Agriculture and Healthcare*, *5*(16), 78-88.

Alemnew, A., 2010. Market chain analysis of red pepper: the case of Bure Woreda, West Gojjam zone, Amhara national regional state, Ethiopia. *A Master Thesis Submitted to the School of Agricultural Economics and Agribusiness Management. Haramaya University*.

Atuhaire, A., Ocan, D. and Jors, E., 2016. Knowledge, attitudes, and practices of tomato producers and vendors in Uganda. *Advances in Nutrition & Food Science*, *1*(1), pp.1-7.

Bada, M.M., Suleiman, A., Mustapha, A., Sambo, A.S. and Abdulaziz, K., 2021. Effects of Post-Harvest Losses on Profitability of Fresh Tomato (Solanum lycopersicum) Production and Marketing in Kano State, Nigeria. *American Journal of Marketing Research*, *7*(3), pp.35-43.

Bergstrand, K.J., Löfkvist, K. and Asp, H., 2020. Dynamics of nutrient availability in tomato production with organic fertilisers. *Biological Agriculture & Horticulture*, *36*(3), pp.200-212.

Birhanu, M.B., 2011. Avocado Value Chain Analysis in Jimma Zone: A Thesis Paper. *The Department of Rural Development and Agricultural Extension, Haramaya University, Ethiopia*.

Bombelli, E. C., & Wright, E. R. 2006. Tomato fruit quality conservation during post-harvest by application of potassium bicarbonate and its effect on Botrytis cinerea. *Ciencia Inv. Agraria*, *33*, 167-172.

Chepchirchir, F., Muriithi, B.W., Langat, J., Mohamed, S.A., Ndlela, S. and Khamis, F.M., 2021. Knowledge, attitude, and practices on tomato leaf miner, Tuta absoluta on tomato and potential demand for integrated pest management among smallholder farmers in Kenya and Uganda. *Agriculture*, *11*(12), p.1242.

Ddamulira, G., Isaac, O., Kiryowa, M., Akullo, R., Ajero, M., Logoose, M., Otim, A., Masika, F., Mundingotto, J., Matovu, M. and Ramathani, I., 2021. Practices and constraints of tomato production among smallholder farmers in Uganda. *African Journal of Food, Agriculture, Nutrition and Development*, *21*(2), pp.17560-17580.

Draper, A. K. (2004). The principles and application of qualitative research. *Proceedings of the nutrition society*, *63*(4), 641-646.

Dube, J., Ddamulira, G., & Maphosa, M. (2020). Tomato breeding in sub-Saharan Africa-Challenges and opportunities: A review. *African Crop Science Journal*, *28*(1), 131-140.

FAOSTAT, 2022, Crops and Livestock products, https://www.fao.org/faostat/en/#data/QCL

Forsythe, L., Fliedel, G., Tufan, H. and Kleih, U., 2018. RTBfoods Step 2: Gendered Food Mapping

Karungi, J., Kyamanywa, S., Adipala, E. and Erbaugh, M., 2011. *Pesticide utilisation, regulation and future prospects in small scale horticultural crop production systems in a developing country* (Vol. 2).

Kaye, E., Nyombi, A., Mutambuze, I.L. and Muwesa, R., 2015. Mancozeb residue on tomatoes in Central Uganda. *Journal of Health Pollution*, *5*(8), pp.1-6.

Kitinoja, L., Odeyemi, O., Dubey, N., Musanase, S. and Gill, G.S., 2019. Commodity system assessment studies on the postharvest handling and marketing of tomatoes in Nigeria, Rwanda and Maharashtra, India. *Journal of Horticulture and Postharvest Research*, *2* (Special Issue-Postharvest Losses), pp.1-14.

Merrian, S. R, 2009. Qualitative Research, A guide to design and Implementation, Jossey-Bass.

Mundingotto, J., Matovu, M. and Ramathani, I., 2021. Practices and constraints of tomato production among smallholder farmers in Uganda. *African Journal of Food, Agriculture, Nutrition and Development*, *21*(2), pp.17560-17580.

Ministry of Agriculture Animal Industry and Fisheries (MAAIF). 2016. *The Agricultural Chemicals Register of Uganda*. Entebbe, Uganda: Crop Protection Department,

Mutengwe, M.T., Chidamba, L. and Korsten, L., 2016. Monitoring pesticide residues in fruits and vegetables at two of the biggest fresh produce markets in Africa. *Journal of food protection*, *79*(11), pp.1938-1945.

Odeyemi, O.M., Bodunde, J.G. and Onifade, O.T., 2015. Low cost postharvest storage technology for smallholder fruits and vegetable farmers in south-western, Nigeria. In *The First International Congress on Postharvest Loss Prevention, Rome, Italy* (pp. 109-111). Olayemi, F.F., Adegbola, J.A., Bamishaiye, E.I. and Daura, A.M. 2010. Assessment of post- harvest challenges of small scale farm holders of tomatoes, bell and hot pepper in some local Government areas of Kano state, Nigeria. Bayero Journal of pure and Applied Sciences. 3:39-42

Rodríguez-Ortega, W. M., Martínez, V., Nieves, M., Simón, I., Lidón, V., Fernandez-Zapata, J. C., & García-Sánchez, F. 2019. Agricultural and physiological responses of tomato plants grown in different soilless culture systems with saline water under greenhouse conditions. *Scientific reports*, *9*(1), 6733.

Saeed, A. F., & Khan, S. N. 2010. Post-harvest losses of tomato in markets of district Lahore. *Mycopath*, *8*(2), 97-99.

Schutt, R.K., 2018. *Investigating the social world: The process and practice of research*. Sage publications

Schutt, R. K. 2011. Investigating the social world: The process and practice of research. 7th (seventh) Edition. Pine Forge Press.

Sekabojja, D., Atuhaire, A., Nabankema, V., Sekimpi, D. and Jors, E., 2021. Consumer risk perception towards pesticides stained tomatoes in Uganda. *Bio R xiv*, pp.2021-02.

Sekabojja, D., Atuhaire, A., Nabankema, V., Sekimpi, D. and Jórs, E., 2023. Consumer risk perception towards pesticide-stained tomatoes in Uganda. *Plos one*, *18*(12), p.e0247740.

Sibanda, S. and Workneh, T.S., 2020. Potential causes of postharvest losses, low-cost cooling technology for fresh produce farmers in Sub-Sahara Africa. *African Journal of Agricultural Research*, *16*(5), pp.553-566.

Sibomana, M.S., Workneh, T.S. and Audain, K.J.F.S., 2016. A review of postharvest handling and losses in the fresh tomato supply chain: a focus on Sub-Saharan Africa. *Food Security*, *8*, pp.389-404.

Ssemugabo, C., Bradman, A., Ssempebwa, J.C., Sillé, F. and Guwatudde, D., 2022. Pesticide residues in fresh fruit and vegetables from farm to fork in the Kampala Metropolitan Area, Uganda. *Environmental Health Insights*, *16*, p.11786302221111866.

Suslow, T.V., Cantwell, M., 2012. Tomato: Recommendations for Maintaining Postharvest Quality. University of California, Davis, USA.

Toivonen, P.M.A. 2007. Fruit maturation and ripening and their relationship to quality. Stewart Postharvest Reviews 3:1–5

Tusiime, S. M. 2014. *Evaluating horticultural practices for sustainable tomato production in Kamuli, Uganda* (Doctoral dissertation, Iowa State University).

Wongnaa, C.A., Ankomah, E.D., Ojo, T.O., Abokyi, E., Sienso, G. and Awunyo-Vitor, D., 2023. Valuing postharvest losses among tomato smallholder farmers: evidence from Ghana. *Cogent Food & Agriculture*, *9*(1), p.2187183.

Yin, R. K. 2009. Media Reviews. Thousand Oaks: Sage Publications. https://doi.org/10.1007/BF01103312.

Yin, R. K. 2013. Case study research: Design and methods: Sage publications.