

## **Post-harvest Losses and Food Safety in Tomatoes Produced in Laikipia County**

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## Background

Kenya is one of the main producers of tomato within Africa south of the Sahara, with an estimated market value of USD 237 million as of 2012, most of which was produced for the national market (Sibomana et al., 2016). Within Laikipia, the total value of tomato production was estimated as 148.5million KSh in 2014 (Ministry of Agriculture). Due to their softness and perishability, tomatoes have significant potential for both quality and quantity losses post-harvest.

Tomatoes are also vulnerable to a number of pests. As a result, pesticides are commonly applied to tomato in Kenya (Macharia, 2009; Mutuku, 2014). Further, tomato's fleshy nature means that chemicals can easily soak into the edible part of the crop, leading to high residual levels of pesticides (Abou-Arab, 1999).

The soil in which tomatoes are grown, and water with which they are irrigated, also affects food safety. Previous research in Kenya has shown that in some areas, soils and bodies of water used for irrigation are contaminated with heavy metals such as lead and cadmium, leading to high concentrations in produce (Makokha et al., 2008; Inoti et al. 2012). Heavy metal contamination of the environment may arise through industrial effluent, disposal of household waste, disintegration of lead-based paint into the environment, and current or previous use of pesticides or fertilizer containing heavy metals in growing sites (NASEM, 2017; ATSDR, 2012).

As tomatoes are regularly consumed by Kenyan households, microbial contamination of produce is an important food safety issue. This is especially the case since tomato is frequently consumed raw in Kenya as a key ingredient of kachumbari salad: pathogens present in these foods present a significant health risk (Kibitok and Nduko, 2016).

The goal of this study is to understand the prevalence and magnitude of post-harvest losses, and extent of food safety hazards, in tomato using data from Laikipia county in Kenya.

## Data Collection

### Study design

We collected data from farmers, intermediaries and retailers involved in the production and trade of tomatoes within Laikipia county. In Africa south of the Sahara, food losses tend to be concentrated among producers – as opposed to further along the value chain, at trade or retail (Gustavsson et al., 2011). Further, many food safety hazards including pesticide residues, heavy metals, and microbial contamination, originate on-farm. For these reasons, and to enable comparison of tomato farmers operating at different scales of production, farmers make up the largest part of our sample.

To identify farmers, sub-locations within the county where commercial tomato production occurs were identified through interviews with officials within the Laikipia Ministry of Agriculture. The survey team visited these sublocations and interviewed local key informants to identify areas where a large share of farmers grow tomatoes for sale.

In this way, tomato-growing areas in 7 wards were identified. A census of tomato growers in areas was obtained from community leaders, and based on this, 58 villages that included farmers growing tomato on a variety of land sizes (less than 2 acres, 2-5 acres, and more than five acres) were selected for inclusion in the study.

Contact information for intermediaries and retailers to whom farmers sold was obtained from farmers. Intermediaries in turn were asked for contact details of their customers. In this way, a dataset was constructed for the tomato value chain originating in Laikipia, including intermediaries and retailers based outside the county (Table 1).

Table 1 – Intermediary and retailer locations

County	Intermediaries	Retailers
Laikipia	38	18
Nairobi	1	0
Naivasha	1	1
Nakuru	0	1
Nyeri	1	3
Total	41	23

## Structured interviews

For each of the three groups (farmers, intermediaries, and retailers), a separate quantitative survey instrument was developed. All participants were asked to provide basic information on their location and personal demographic and educational attainment. A standardized module on post-harvest losses (adjusted for each group to fit the activities associated with their role) was also administered to all respondents. Other components of the survey were only asked to specific respondent groups (for example the farmer form contained a module on irrigation which was not asked to intermediaries or retailers).

## Data management and informed consent

Data was collected on password-protected tablet computers by field staff. Submitted data was transferred to a secure online server which was only accessible to members of the research team. Personally-identifying information (PII) was removed from all data files and stored on an encrypted computer, and will be destroyed following completion of the project.

The study protocol was approved by IFPRI's Institutional Review Board (IRB), and by the International Livestock Research Institute's Institutional Research Ethics Committee (IREC). All subjects interviewed gave their informed consent to participate in both the survey and request for food samples. Field staff were trained in appropriate procedures for research on human subjects and read the consent form to participants prior to obtaining their signature. Contact information for both the study investigators and the IRB chair was provided to participants.

## Results

### Sample characteristics

Summary statistics for farmers in the sample are presented in

Table 2. Farmers in the sample are generally male (89%) with an average age of 41 years. Most farmers have not completed secondary education (64%), while 14% have not completed primary education. Most respondents own their farm (72%) while 12% report managing a farm for others.

Table 2 - Farmer characteristics

		Mean	SD	N
Demographic	Age	41	11	210
	Is female	0.11	0.31	210
Education	Did not complete primary	0.14	0.35	210
	Completed primary	0.50	0.50	210
	Completed secondary	0.25	0.44	210
	Any tertiary education	0.11	0.31	210
Role on farm	Owner	0.72	0.45	210
	Manager	0.12	0.33	210
	Missing/Don't know	0.15	0.36	210

We present the same statistics for intermediaries and retailers in Table 3. On average intermediaries and retailers are approximately the same age as farmers. In terms of sex, intermediaries are generally male (80%) however retailers are generally female (74%). The distribution of education is similar for both groups: a majority have not completed secondary education, though the share with secondary education or higher is slightly larger for intermediaries. Almost all intermediaries and retailers report owning their own business.

Table 3 - Intermediary & retailer characteristics

		Intermediaries			Retailers		
		Mean	SD	N	Mean	SD	N
Demographic	Age	40	8	41	41	9	23
	Is female	0.20	0.40	41	0.74	0.45	23
Education	Did not complete primary	0.12	0.33	41	0.22	0.42	23
	Completed primary	0.49	0.51	41	0.48	0.51	23
	Completed secondary	0.32	0.47	41	0.26	0.45	23
	Any tertiary education	0.07	0.26	41	0.04	0.21	23
Role in business	Owner	0.98	0.16	41	0.96	0.21	23
	Manager	0.02	0.16	41	0.00	0.00	23

Statistics on tomato inputs and production are reported in Table 4. Most farms in the sample are relatively small family farms, with some larger, more commercialized operations. Hence while the mean area cultivated is 2 acres, the median farmer reports a single plot of tomatoes, with a size of one acre.

Fewer than 20% of farmers report cultivating multiple plots for tomato, and fewer than 10% cultivate more than two.

The median farmer produced 1.2 tons of tomato in the most recent growing season, and the median yield is also 1.2 tons/acre (since most farmers report planting one acre). The mean yield is somewhat higher at 2.89 tons/acre, though still substantially below the potential value which could be achieved using improved inputs and best practices.<sup>1,2</sup> In terms of labor used, slightly more than half (52%) of all respondents use family labor, while almost all (97%) report hiring casual labor. Relatively few farms have permanent employees (17%).

Table 4 – Farmer production summary statistics

		Mean	SD	Min.	Median	Max.	N
Landholdings	Total area under tomatoes (Acres)	2.02	3.48	0.13	1.00	30.00	210
	Number of tomato plots	1.30	1.04	0.00	1.00	12.00	210
	Average plot size (Acres)	1.59	2.77	0.13	1.00	30.00	207
Production	Harvest quantity produced (Tons)	5.90	30.82	0.01	1.20	420.00	191
	Estimated yield (Tons/acre)	2.89	4.43	0.02	1.23	24.00	191
Fertilizer use	Uses organic fertilizer	0.81	0.39	0.00	1.00	1.00	210
	Uses inorganic fertilizer	1.00	0.07	0.00	1.00	1.00	210
Labor used	Family Labor	0.52	0.50	0.00	1.00	1.00	210
	Casual labor	0.97	0.18	0.00	1.00	1.00	210
	Permanent employees	0.17	0.37	0.00	0.00	1.00	210

## Commercialization

Farmers generally sell their produce in multiple transactions: 91% of farmers report more than one sales transaction for the current season, with the median farmer reporting five.

<sup>1</sup> For example, the most commonly used variety, Rio Grande has an estimated potential yield of approximately 18 tons/acre (Biovision 2020).

<sup>2</sup> A small number of farmers (13 individuals) report landholdings and production values above 25 tons/acre, which are likely the results of reporting error. We exclude these observations from the above production statistics, and from subsequent calculations based on them for losses.

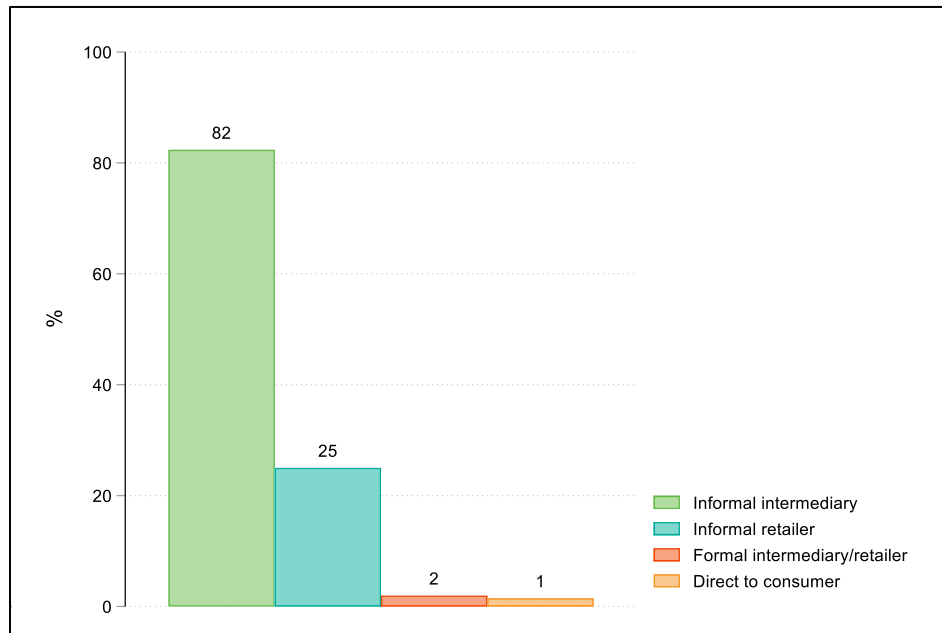
Table 5 presents summary statistics for the three most recent tomato sales reported by farmers.

Table 5 - Farmer sales, three most recent transactions

	Mean	SD	Min.	Median	Max.	N
Total number of sales this season	6	5	1	5	40	204
Mean quantity per transaction (Tons)	1.92	3.48	0.01	0.57	26.40	204
Most recent sales (up to three)						
Total quantity sold (Tons)	5.50	10.38	0.01	1.66	79.20	204
Mean sales price per kg (KSH)	48.66	37.98	13.33	41.67	500.00	204
Total sales value (KSH '000s)	305	720	1	71	5520	204
Of which, sold to intermediaries	278	709	0	57	5520	204
Of which, sold to retailers	25	148	0	0	1940	204

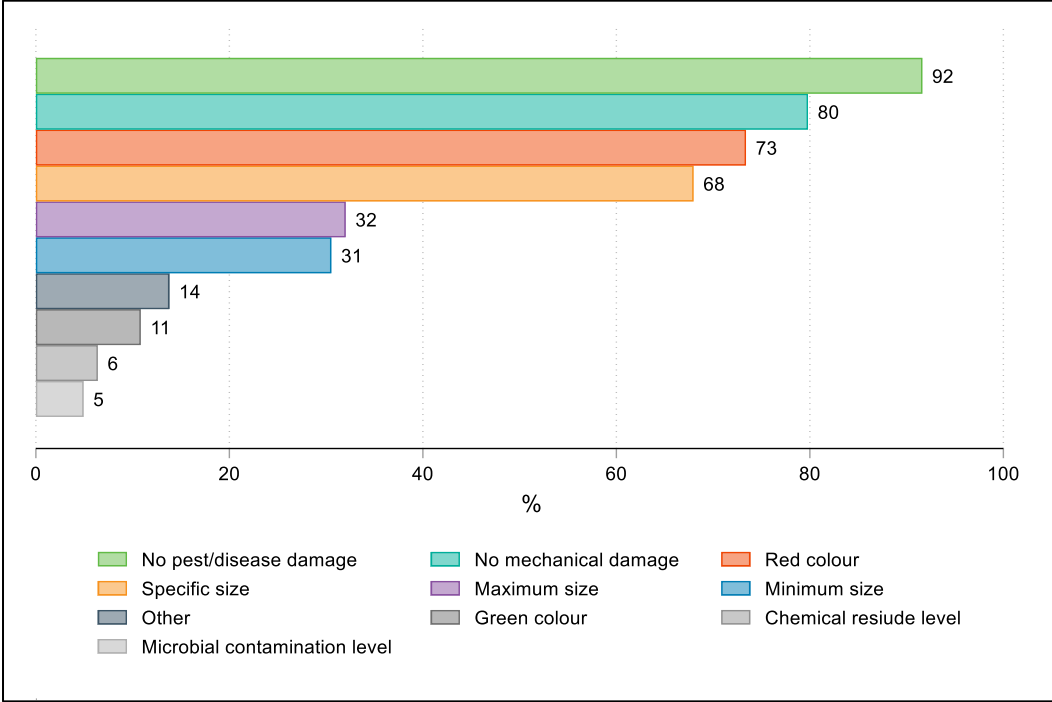
In line with production, there is significant variation in the volume of recent farmer sales. The median farmer reports selling a total of 1.7 tons of tomatoes, with an estimated value of 71,000 Kenyan shillings (KSH). In terms of price, there is less variation: the mean sales price of 48.7 KSH per kg is only slightly larger than the median value of 41.7 KSH. Most farmers sell to intermediaries rather than retailers, which is reflected in the value of sales to each. Sales to intermediaries account for 91% of the value of all sales, on average. Almost all purchasers are in the informal sector (as reported by farmers), with only 2% of farmers reporting a sale to a formal trader or retailer (Figure 1).

Figure 1 – Share of farmers reporting a recent sale to each buyer type



When asked to specify what quality requirements purchasers require from farmers, the most commonly specified factors relate to visually observable properties, as show in Figure 2.

Figure 2 – Percentage of farmers reporting quality requirement



The most important requirement is that tomatoes are not damaged, whether by pests or disease (92%) or mechanical damage (80%). Most purchasers demand ripe tomatoes that are red in colour (73%) and of a specific size (58%). Smaller shares of farmers report sellers requiring an upper or lower bound on size (32% and 31%) respectively. Lack of chemical (6%) or microbial (5%) contamination are the least frequently specified requirements, suggesting that very few purchasers prioritize (or are aware of) food safety in selecting tomatoes from farmers. This is reflected in record-keeping by purchasers: less than 20% of intermediaries, and no retailers, reported maintaining written records indicating the source of tomatoes they had purchased.

**Input use and safety**

An important consideration for food safety is the appropriate use of chemical inputs during production. If proper procedures are not followed, unsafe levels of residues from pesticides and inorganic fertilizers may be present on food, posing a risk to consumers. In this section we present descriptive statistics on the use of chemical inputs, beginning with pesticides.

Table 6 presents summary statistics on source of pesticides, awareness and reported adherence to pesticide safety recommendations, prior training on pesticide use, and pesticide storage by farmers in our sample.

Table 6 – Pesticide practices

		Mean	SD	Min.	Max.	N
Farmer uses pesticide(s)		1.00	0.00	1	1	210
Source	Agrovet dealer	0.99	0.10	0	1	210
	Shop/Market	0.02	0.14	0	1	210
Proper usage	Has heard of PHI	0.95	0.22	0	1	210
	Reads label & follows instructions	0.93	0.25	0	1	210
	Any training in safe pesticide use	0.52	0.50	0	1	210
Training provider	Agro-vet dealer	0.08	0.28	0	1	110
	Extension agent	0.16	0.37	0	1	110
	Tomato buyer	0.00	0.00	0	0	110
	Other farmers	0.05	0.21	0	1	110
	NGO	0.05	0.23	0	1	110
	Chemical company	0.55	0.50	0	1	110
	Export company	0.15	0.35	0	1	110
	Other	0.15	0.35	0	1	110
Storage location	Living room	0.03	0.17	0	1	210
	Farm produce store	0.12	0.27	0	1	210
	Separate store	0.60	0.49	0	1	210
	Uses immediately	0.23	0.42	0	1	210
	Other	0.03	0.26	0	1	210

All farmers who were surveyed report using pesticides for tomato production, and almost (99%) report purchasing these pesticides from an agro-vet dealer. An important concept for safe use of pesticides is the pre-harvest interval (PHI) which is the minimum number of days which should be allowed to pass between pesticide application and harvest. Over 95% of farmers who were interviewed said that they had heard of PHI, and 93% reported that they read manufacturer instructions on the PHI and follow these.

The majority of farmers (60%) reported storing pesticides appropriately in a location separate from the home and farm produce. However, 12% of farmers reported storing pesticides in a produce store, which could lead to contamination of crops, and 3% reported storing within their homes, a potential health risk to the farmer's family. 23% of farmers claimed that they use pesticides immediately upon purchase, and hence do not store pesticides. The remaining 3% report storing on the farm, but without enough information to determine whether stored separately or as part of the farm store.

Proper training on the handling, application and storage of pesticides is key, however only around half (52%) of farmers surveyed reported that they had attended any form of training on safe pesticide usage. Among those that did, the majority (55%) reported attending a training given by a pesticide company, with few reporting trainings by extension workers (15%) or NGOs (5%). This represents a potential opportunity for county government to build farmer capacity.

As

Figure 3 shows, the primary source of farmers' information on pesticide use is other farmers (82%). In line with their reports on training, very few farmers reported having received information on pesticides from a public or private extension agent (8%) or NGO (4%). Lastly 3% of farmers reported never having received any information on pesticide usage, despite reporting using them for their production.

Figure 3 – Sources of information on pesticides

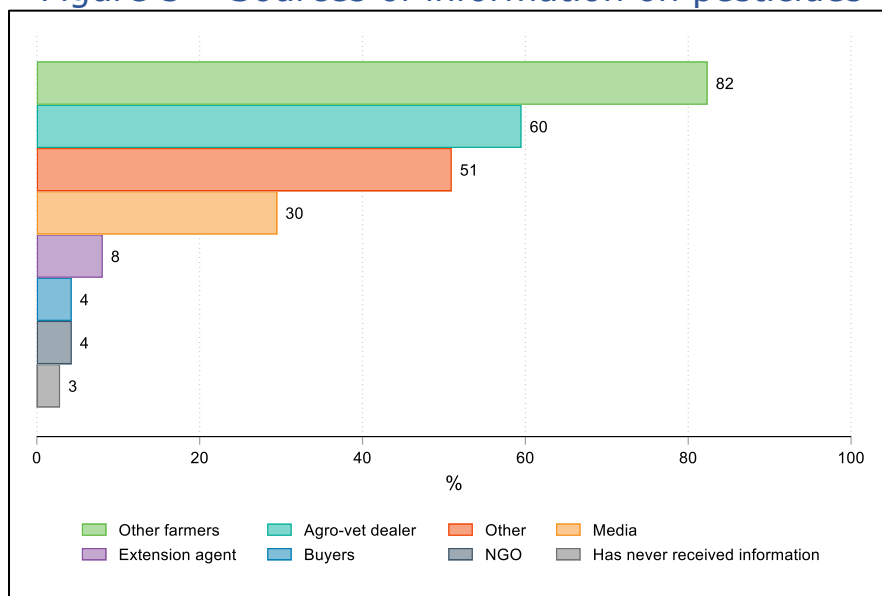


Table 7 lists the main pesticide brands used in tomato production by farmers in the sample, the active ingredient in each of these, and the recommended PHI. There is considerable variation in the share of farmers who report leaving the specified interval between harvest and application. In general, compliance, perhaps unsurprisingly, decreases as the length of the PHI increases. The brands with the shorts PHI (Ridomil and various alpha-cypermethrin based brands) have very high compliance but only a three-day interval. For brands with a 7-day PHI, between 27-31% of those who report applying the pesticide

report harvesting too soon after application. The brands with the longest PHI, Mistress and Belt, have the longest PHI requirements and also the worst compliance: 48% and 30% respectively. This suggests that farmers may adopt a blanket rule independent of the type of pesticide used, which could potentially be addressed by capacity building by local government.

**Table 7 – Usage & adherence to PHI, selected pesticides**

Pesticide		Recommended interval	Full sample		Users	
Brand name	Active substance		Used (%)	N	Follows PHI (%)	N
Bestox/Tata Alpha/Fastac	Alpha-cypermethrin	3 days	38.10	210	97.50	80
Mancozeb	Mancozeb	7 days	19.52	210	68.29	41
Mistress	Cymoxanil, mancozeb	10 days	12.86	210	48.15	27
Ridomil	Mefenoxam	3 days	21.90	210	100.00	46
Belt	Flubendiamide	20 days	33.81	210	29.58	71
Ivory	Mancozeb	7 days	28.10	210	84.75	59
Dudu	Dimethoate	7 days	40.00	210	72.62	84

Appropriate use of chemical fertilizers is important to ensuring safe tomato production.

Table 8 provides summary statistics on the use of organic and inorganic (chemical) fertilizers by farmers in the sample, along with storage practices for inorganic fertilizer.

**Table 8 – Fertilizer usage and storage practices**

		Mean	SD	Min.	Max.	N
Organic fertilizer	Uses organic fertilizer	0.81	0.39	0	1	210
	Uses manure	1.00	0.00	1	1	170
	Uses crop residues	0.03	0.17	0	1	170
Inorganic fertilizer	Uses inorganic fertilizer	1.00	0.07	0	1	210
	NPK	0.90	0.29	0	1	209
	CAN	0.82	0.38	0	1	209
	DAP	0.89	0.31	0	1	209
	Urea	0.03	0.18	0	1	209
	Micro-nutrients	0.64	0.48	0	1	209
	Other	0.11	0.32	0	1	209
Storage	In an open area	0.01	0.10	0	1	210
	With pesticides	0.11	0.32	0	1	210
	With harvested produce	0.05	0.22	0	1	210
	Separate from produce	0.28	0.45	0	1	210
	At home	0.04	0.20	0	1	210

Most farmers in the sample (81%) report using composted manure as an organic fertilizer, with a small proportion also reporting using crop residues. Depending on the composting time and temperature reached, manure can potentially contain pathogens that pose a risk to human health.

All respondents reported using inorganic fertilizers. The most commonly used are NPK (90% of farmers), DAP (89%) and CAN (82%), while a majority of farmers (64%) also report using micro-nutrients for production.

As with pesticides, a substantial share of farmers report using fertilizers immediately following purchase (and hence not storing them). Among those who store, 10% (5% of the full sample) report storing chemical fertilizers in the same location as harvested produce, while a further 8% (4%) report storing them in the home.

Lastly, we consider the application of chemicals to tomatoes in storage. Farmers, intermediaries and retailers were all asked a series of questions on storage chemicals, however in each of these samples reported usage was very low. Only two farmers (1%) of the sample report using chemicals for storage, while none of the intermediaries or retailers interviewed reported using storage chemicals.

### Irrigation and on-farm washing of produce

Irrigation is an important concern for food safety, since microbial contamination (through exposure to animal or human fecal matter) or the presence of heavy metals in water used for crops can lead to the transference of these substances to produce.

Table 9 summarizes farmer reports of irrigation practices on their tomato crop.

Table 9 – Irrigation of tomato and treatment of irrigation water

		Mean	SD	Min.	Max.	N
Reports using irrigation		1.00	0.00	1	1	210
Reports washing tomatoes		0.00	0.07	0	1	210
Irrigation type	Furrow	0.93	0.25	0	1	210
	Manual	0.03	0.17	0	1	210
	Sub-surface	0.01	0.10	0	1	210
	Other	0.02	0.15	0	1	210
Irrigation source	River	0.96	0.19	0	1	210
	Dam	0.02	0.14	0	1	210
	Other	0.03	0.18	0	1	210
Treatment	Tested (last 12 months)	0.06	0.23	0	1	210
	Treats water	0.03	0.17	0	1	210

All of the farmers surveyed reported irrigating their tomato crop. The most common method was furrow irrigation, a traditional form of surface irrigation in which rows are dug between crop rows and then flooded which allows the water to seep into the crop soil. The principle source of irrigation water used was rivers (96% of responses). Using these methods presents opportunities for contamination if there are pathogens or heavy metals already present in the river water, or if water becomes contaminated in the process of irrigation through microbial exposure (for example from livestock or from unwashed hands). Despite these risks, only 6% of farmers reported having had their irrigation water tested in the last year, while only 3% reported treating their water for pathogens.

### Worker access to sanitation facilities

Workers across the value chain are potential agents of microbial contamination if good personal hygiene practices are not followed. If an individual comes into contact with produce after toileting and not washing their hands well, they can transmit pathogens to produce.

Table 10 summarizes reports from farmers, intermediaries and retailers on their workers' access to toilet and handwashing facilities.

Table 10 – Access to sanitation facilities

	Farmers		Intermediaries		Retailers	
	Mean	N	Mean	N	Mean	N
Facility has toilet	0.84	210	0.56	41	0.74	23
Enumerator able to observe toilet facility	0.82	210	0.29	41	0.65	23
Type: Pit latrine	1.00	172	0.33	12	0.27	15
Type: Flush toilet	0.00	172	0.67	12	0.73	15
Hand-washing facility available	0.30	210	0.27	41	0.57	23
Hand-washing facility with soap available	0.11	210	0.15	41	0.43	23

Farmers were more likely (84% of respondents) than intermediaries (56%) or retailers (74%) to report having a toilet present at their location, though this was typically the same bathroom used by their household. Farmers exclusively report having pit latrines, an unimproved toilet facility which while preferable to open defecation, is a significant source of risk of groundwater contamination if proper management practices are not followed.

A substantial concern is that even where toilets were present, very few respondents had a handwashing facility available. Soap was observed at the handwashing facility in even fewer cases. Overall, 89% of farmers, 85% of intermediaries and 57% of retailers did not have a toilet facility at which proper handwashing could be carried out, posing a substantial risk of microbial contamination through tomatoes handling. It is important that this source of post-harvest risk is addressed alongside interventions earlier in the production process.

## Post-harvest losses

We next explore the extent of post-harvest losses in the Laikipia tomato value chain. Data on losses was collected by activity, and farmers report on a different set of activities than intermediaries and retailers, reflecting their distinct roles in the sector. For each group, we present data on three related outcomes: the prevalence of losses (the share of respondents reporting any loss for a given activity); the extent of losses (the quantities lost or damaged and the total loss in value); and lastly the causes of losses respondents report.

Table 11 presents the share of respondents reporting participating in each respective activity, and the share who report a loss. We report the share experiencing losses both for the overall sample and restricted to those who report doing the activity in question.

Table 11 – Loss prevalence, by activity

		Full sample			Sample reporting activity	
		Did activity (%)	Reports loss (%)	N	Reports loss (%)	N
Farmers	Harvest	97.62	73.81	210	75.61	205
	Transport (field)	26.19	7.62	210	29.09	55
	Storage	0.48	0.48	210	100.00	1
	Transport (buyer)	7.14	3.33	210	46.67	15
Intermediaries	Transport (farm)	78.05	60.98	41	78.13	32
	Storage	12.20	12.20	41	100.00	5
	Processing	0.00	-	41	-	0
	Repackaging	2.44	2.44	41	100.00	1
	Transport (client)	39.02	24.39	41	62.50	16
Retailers	Transport (farm)	43.48	39.13	23	90.00	10
	Storage	73.91	69.57	23	94.12	17
	Processing	0.00	0.00	23	-	0
	Repackaging	0.00	0.00	23	-	0
	Transport (client)	4.35	4.35	23	100.00	1

Among farmers, almost the entire sample reported having completed at least one harvest during the current season. Among those who had harvested, 76% reported experiencing a loss during this activity. Losses during transportation are also common, with 29% of farmers who transported from their field to their homestead, and 47% who transported to buyers reporting a loss (8% and 3% of the overall farmer sample respectively). Only one farmer reported storing their produce between harvest and sale.

The most common activity reported by intermediaries is, unsurprisingly, transport of the crop. Among those who transported tomatoes from farm gate, 78% reported a loss at this stage, while 63% of those who transported produce to buyers report a loss. Very few intermediaries repackaged produce prior to selling it.

Among retailers, a similarly high share of those transporting from the farm gate report losses: 90% report a loss of either quantity or quality during this activity. 74% of retailers reported storing tomatoes, and among these the share reporting losses is very high, with fewer than 6% reporting no loss during this stage. No intermediaries or retailers reported processing tomatoes—hence we exclude this activity from subsequent analysis.

Next, we explore the magnitude of reported losses. In Table 12 we present these for farmers. The first row for each activity shows the percentage of values reported lost by all farmers (including those not

experiencing a loss). The next three rows give the value lost (in thousands of shillings) and the quantity lost or damaged for farmers who report a loss.

Table 12 – Farmer losses, by activity

		Mean	SD	Min.	Median	Max.	N
Harvest	% of value lost (all)	14.48	16.00	0.00	8.81	75.00	197
	Value lost (if any loss) (KSH '000s)	41.61	149.92	0.00	11.50	1550.00	139
	Quantity lost (if any loss) (tons)	0.59	1.80	0.00	0.16	18.00	142
	Quantity damaged (if any loss) (tons)	0.32	1.12	0.00	0.05	12.00	142
Transport (farm)	% of value lost (all)	1.02	4.95	0.00	0.00	46.43	197
	Value lost (if any loss) (KSH '000s)	50.33	168.88	0.10	3.00	660.00	15
	Quantity lost (if any loss) (tons)	0.17	0.30	0.00	0.07	1.20	15
	Quantity damaged (if any loss) (tons)	0.06	0.18	0.00	0.00	0.72	15
Storage	% of value lost (all)	0.01	0.13	0.00	0.00	1.88	197
	Value lost (if any loss) (KSH '000s)	0.90	-	0.90	0.90	0.90	1
	Quantity lost (if any loss) (tons)	0.01	-	0.01	0.01	0.01	1
	Quantity damaged (if any loss) (tons)	0.01	-	0.01	0.01	0.01	1
Transport (buyer)	% of value lost (all)	0.68	5.06	0.00	0.00	48.33	197
	Value lost (if any loss) (KSH '000s)	35.00	30.71	3.00	27.25	72.50	6
	Quantity lost (if any loss) (tons)	0.71	0.80	0.03	0.27	1.74	6
	Quantity damaged (if any loss) (tons)	0.25	0.36	0.00	0.06	0.90	6
All stages	% of initial value lost	16.38	18.77	0.00	10.94	97.80	190
	Total value lost (KSH '000s)	32.04	129.48	0.00	5.63	1550.00	190
	Total quantity lost (tons)	0.48	1.61	0.00	0.08	18.00	190
	Total quantity damaged (tons)	0.25	0.98	0.00	0.00	12.00	190

The largest share of value lost is during the harvest stage. Farmers reported on average losing 14% of the value of their production during this stage. The median value lost by those reporting a loss in quantity or damage was 11,500 KSh, though the magnitude of losses for larger farmers is naturally greater, as a result the mean value lost is higher: 41,600 KSh. Losses at other stages are much lower, with most occurring during transport. Overall, losses among farmers account for 16.4% of the initial estimated value of the crop.

Table 13 – Intermediary losses, by stage

		Mean	SD	Min.	Median	Max.	N
Transport (farm)	% of value lost (all)	1.31	2.48	0.00	0.00	10.95	41
	Value lost (if any loss) (KSH '000s)	66.75	319.47	0.00	0.65	1600.00	25
	Quantity lost (if any loss) (tons)	0.19	0.49	0.00	0.04	2.50	25
	Quantity damaged (if any loss) (tons)	0.29	0.99	0.00	0.03	5.00	25
Storage	% of value lost (all)	0.15	0.96	0.00	0.00	6.15	41
	Value lost (if any loss) (KSH '000s)	1.60	3.58	0.00	0.00	8.00	5
	Quantity lost (if any loss) (tons)	0.10	0.10	0.04	0.07	0.28	5
	Quantity damaged (if any loss) (tons)	0.06	0.07	0.00	0.05	0.16	5
Repackaging	% of value lost (all)	0.11	0.72	0.00	0.00	4.62	41
	Value lost (if any loss) (KSH '000s)	27.00	-	27.00	27.00	27.00	1
	Quantity lost (if any loss) (tons)	0.20	-	0.20	0.20	0.20	1
	Quantity damaged (if any loss) (tons)	1.80	-	1.80	1.80	1.80	1
Transport (buyer)	% of value lost (all)	0.53	1.28	0.00	0.00	5.56	41
	Value lost (if any loss) (KSH '000s)	257.15	662.60	0.00	3.77	2100.00	10
	Quantity lost (if any loss) (tons)	2.59	7.54	0.00	0.05	24.00	10
	Quantity damaged (if any loss) (tons)	4.99	15.12	0.00	0.05	48.00	10
All stages	% of initial value lost	2.10	3.04	0.00	0.21	11.11	41
	Total value lost (KSH '000s)	104.28	451.90	0.00	0.19	2100.00	41
	Total quantity lost (tons)	0.77	3.77	0.00	0.04	24.00	41
	Total quantity damaged (tons)	1.45	7.52	0.00	0.02	48.00	41

Among intermediaries, the overall share of value lost is lower than for farmers: slightly more than 2% of estimated initial value. The largest share of this value loss occurred during transportation after purchase from farmers: 1.3% of total value was lost at this stage, with a mean loss in value of 66,800 KSh. An additional 0.53% of value on average is lost in transport to buyers. Losses during storage and repackaging are modest, as few intermediaries participate in these activities.

Table 14 – Retailer losses, by stage

		Mean	SD	Min.	Median	Max.	N
Transport (farm)	% of value lost (all)	3.79	9.41	0.00	0.00	33.33	19
	Value lost (if any loss) (KSH '000s)	0.85	0.82	0.11	0.65	2.00	4
	Quantity lost (if any loss) (tons)	0.01	0.01	0.00	0.00	0.03	6
	Quantity damaged (if any loss) (tons)	0.00	0.00	0.00	0.00	0.00	6
Storage	% of value lost (all)	8.55	11.92	0.00	1.43	39.29	19
	Value lost (if any loss) (KSH '000s)	0.76	1.04	0.03	0.28	3.00	10
	Quantity lost (if any loss) (tons)	0.01	0.02	0.00	0.00	0.05	14
	Quantity damaged (if any loss) (tons)	0.00	0.00	0.00	0.00	0.01	14
Transport (buyer)	% of value lost (all)	0.10	0.42	0.00	0.00	1.84	19
	Value lost (if any loss) (KSH '000s)	0.09	-	0.09	0.09	0.09	1
	Quantity lost (if any loss) (tons)	0.00	-	0.00	0.00	0.00	1
	Quantity damaged (if any loss) (tons)	0.00	-	0.00	0.00	0.00	1
All stages	% of initial value lost	12.48	12.63	0.00	10.00	39.29	19
	Total value lost (KSH '000s)	0.58	0.88	0.00	0.14	3.00	19
	Total quantity lost (tons)	0.01	0.02	0.00	0.00	0.05	19
	Total quantity damaged (tons)	0.00	0.00	0.00	0.00	0.01	19

Overall, the share of value lost for retailers is higher than for intermediaries, with 12.5% of overall value lost across stages. However, as retailer volumes are much smaller than those traded by intermediaries, the values of these losses shown per retailer in the table below are smaller. Losses during transportation from farmers account for 3.8% of overall losses to retailers, though it should be noted that these are concentrated among a small number of retailers who report transporting from producers. The major cause of losses among retailers is storage, with accounts for 8.6% of overall value lost.

Based on these values for losses among different value chain actors, we can generate some estimates of overall losses across the value chain, from farmer to point of sale. To do so, we classify farmers (and intermediaries) based on the main person to whom they sell (or from whom they purchase).<sup>3</sup> We then disaggregate losses based on these categories to estimate the overall value lost (

Table 15).

<sup>3</sup> Note that for retailers our dataset does not permit us to disaggregate in this manner, hence we assume a constant loss rate across the different value chain categories.

Table 15 – Estimated cumulative losses, by transaction chain

Type of value chain	Share of value lost by type of chain (%)					Aggregate share of production value lost	
	% of transactions	Farmer	Intermediary	Retailer	Total loss	% of quantity produced	Weighted loss %
Farmer - Consumer	3.05	22.93	-	-	22.9	0.67	0.15
Farmer - Retailer	17.77	24.44	-	12.48	33.9	19.8	6.7
Farmer - 1 Intermediary - Retailer	75.33	14.22	2.2	12.48	26.6	75.6	20.1
Farmer - 2 Intermediaries - Retailer	3.86	14.22	10.42	12.48	32.8	3.88	1.27
<b>Overall losses</b>							<b>28.2</b>

Aggregate losses in terms of share of value are lowest among farmers who sell directly to consumers, at 22.9% of total value- though note that these cases account for a relatively small number of overall sales. Farmers who sell directly to retailers have the highest estimated overall loss rate, slightly higher than our estimate for cases where tomatoes are sold to multiple intermediaries before the retailer.

To put these losses in terms of value in context, we lastly re-weight the share of value lost by the estimated quantity sold via each category of transaction.<sup>4</sup> We estimate an overall average value loss of 28.2% across transaction categories, driven primarily by farmer losses. If we assume that this is representative of the overall market, then applying this loss rate to the total value of tomatoes produced in Laikipia in 2014 gives an estimated total loss valued at approximately 58 million KSh (Ministry of Agriculture, 2015).

Disaggregating by category, we can observe that (pre-consumer) losses when a farmer sells directly to the consumer are lowest across the types of value

<sup>4</sup> Note that the share of overall transactions is highly correlated with the share of quantity produced, with the exception of direct farmer to consumer sales where the average quantity traded is much lower than for other sales types.

chains.<sup>5</sup> Losses in all other types of value chains (farmer to retail, farmer to one intermediary to retail, farmer to multiple intermediaries to retail) were similar, ranging from an average of 26.6% to 33.9%.

Lastly for this section, we look at the causes of losses reported by each group. Table 16 shows the causes of losses reported by farmers who reported a loss for each activity.

*Table 16 – Loss causes reported by farmers (%), by stage*

	Farmer stages			
	Harvest	Transport (farm)	Storage	Transport (buyer)
Transport	0.00	12.50	0.00	42.86
Poor roads	0.00	25.00	0.00	0.00
Packaging	0.00	68.75	0.00	100.00
Insects	37.42	0.00	0.00	0.00
Fungal infestation	3.23	0.00	0.00	0.00
Rodents/animals	10.97	0.00	100.00	0.00
Heat	0.00	0.00	100.00	0.00
Moisture/Humidity	12.26	0.00	100.00	0.00
Mechanical damage	71.61	0.00	0.00	0.00
Theft	0.00	0.00	0.00	0.00
Spoiled	56.13	50.00	0.00	71.43
Weather	49.03	0.00	0.00	0.00
Timing	10.97	0.00	0.00	0.00
Other	7.74	0.00	0.00	0.00
Observations	155	16	1	7

At harvest, mechanical damage is the most common cause of loss reported (72%) followed by spoilage (55%), losses due to poor weather (49%), and losses as a result of insects (37%). Insect losses are primarily due to the moth *Tuta absoluta* which was reported by a large share of farmers reporting losses due to pests. Problems with packaging are the most common cause of losses reported during transport, followed by spoilage.

Losses for intermediaries and retailers are presented in

<sup>5</sup> Data were not collected on food losses at the consumer level.

Table 17. As for farmers, packaging issues are also a commonly cited cause of losses during transportation for these groups: 53% of those experiencing losses transporting tomatoes from the farm cite them as a cause, as do 73% with losses transporting tomatoes to buyers. Problems with vehicles and poor roads are also commonly cited issues for transportation of tomatoes, as is spoilage.

During storage, problems with packaging were the most commonly cited cause of losses (67% of respondents) followed by spoilage (48%) and losses cause by heat or exposure to moisture (33% and 24% respectively) and losses to insects (29%) or rodents (24%).

Table 17 – Loss causes reported by intermediaries & retailers (%), by stage

	Intermediary/retailer stages			
	Transport (farm)	Storage	Repackaging	Transport (buyer)
Transport	52.94	0.00	0.00	72.73
Poor roads	58.82	0.00	0.00	72.73
Packaging	47.06	66.67	0.00	72.73
Poor crop quality	11.76	0.00	0.00	9.09
Insects	0.00	28.57	0.00	0.00
Fungal infestation	0.00	19.05	0.00	0.00
Rodents/animals	0.00	23.81	0.00	0.00
Heat	0.00	33.33	100.00	0.00
Moisture/Humidity	0.00	23.81	0.00	0.00
Mechanical damage	0.00	0.00	100.00	0.00
Theft	0.00	0.00	0.00	0.00
Spoiled	50.00	47.62	0.00	72.73
Other	14.71	14.29	0.00	36.36
Observations	34	21	1	11

	Intermediary/retailer stages			
	Transport (farm)	Storage	Repackaging	Transport (buyer)
Transport	52.94	0.00	0.00	72.73
Poor roads	58.82	0.00	0.00	72.73
Packaging	47.06	66.67	0.00	72.73
Poor crop quality	11.76	0.00	0.00	9.09
Insects	0.00	28.57	0.00	0.00
Fungal infestation	0.00	19.05	0.00	0.00
Rodents/animals	0.00	23.81	0.00	0.00
Heat	0.00	33.33	100.00	0.00
Moisture/Humidity	0.00	23.81	0.00	0.00
Mechanical damage	0.00	0.00	100.00	0.00
Theft	0.00	0.00	0.00	0.00
Spoiled	50.00	47.62	0.00	72.73
Other	14.71	14.29	0.00	36.36
Observations	34	21	1	11

[Access to training, food safety testing, and advice](#)

Finally, we look at access to training, food safety testing, and advice on post-harvest handling and food safety among value chain actors.

Table 18 presents this information for farmers.

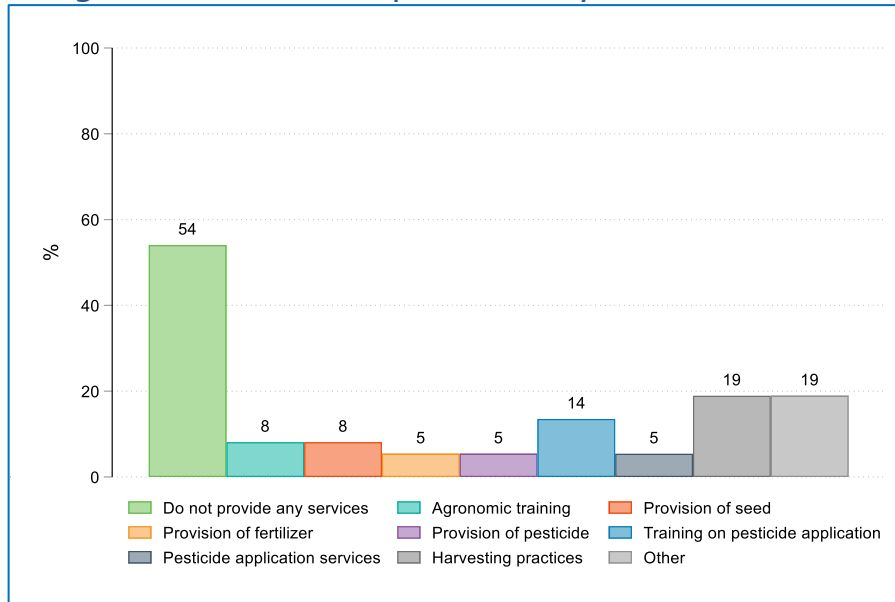
Table 18 – Access to training, testing and advice, farmer reports

		Mean	SD	Min.	Max.	N
Training	Any training (PHL)	0.14	0.35	0	1	210
	Any training (Food safety)	0.10	0.30	0	1	210
	No training	0.81	0.39	0	1	210
Testing	Facility inspected (last 12 months)	0.03	0.18	0	1	210
	Produce tested (last 12 months)	0.03	0.18	0	1	210
	Received test results	0.02	0.15	0	1	210
Did you ask for advice from traders?	0.47	0.50	0	1	210	
Asks for advice on	Production management	0.59	0.49	0	1	98
	Fertilizer use	0.52	0.50	0	1	98
	Pesticide use	0.71	0.45	0	1	98
	Markets	0.61	0.49	0	1	98
	Post-harvest handling	0.03	0.17	0	1	98
	Other	0.07	0.26	0	1	98

Relatively few farmers reported receiving training. Only 14% of farmers said they had been trained on how to reduce post-harvest losses, while 10% reported having received training on food safety. A large majority of farmers (81%) reported that they had received neither type of training. Similarly, very few farmers reported having had their farm inspected within the last 12 months (3%) or having their produce tested (3%), and only 2% reported that they received results after such testing.

There does appear to be demand for advice among farmers. Slightly fewer than half (47%) of farmers reported asking for advice from traders. Among those who did, the most common topics were appropriate pesticide use (72%), advice on local markets (for example where to get the best prices, or which varieties or attributes are preferred by buyers) (61%), production management (59%), and fertilizer application (52%). Very few farmers (3%) reported asking for advice on post-harvest handling.

Figure 4 – Services provided by intermediaries



Most intermediaries (54%) indicated that they do not provide advice, inputs, or other services to the farmers from whom they source tomatoes (

Figure 4). Despite information about pesticides being the most desired type of advice by farmers, only 14% of intermediaries offered advice or training on pesticide application and only 5% provided pesticide application services.

Turning to intermediaries and retailers, no member of either group reported having received any training on either post-harvest losses or food safety (Table 19). Only 6% of those surveyed reported that their facility had been inspected for food safety practices within the previous 12 months, and no one reported that their produce had been tested for food safety hazards within that period.

Table 19 – Access to training, testing, intermediary and retailer reports

		Mean	SD	Min.	Max.	N
Training	Any training (PHL)	0.00	0.00	0	0	64
	Any training (Food safety)	0.00	0.00	0	0	64
	No training	1.00	0.00	1	1	64
Testing	Facility inspected (last 12 months)	0.06	0.24	0	1	64
	Produce tested (last 12 months)	0.00	0.00	0	0	64

## Laboratory analyses

To test for food safety hazards, the research team randomly sampled a selection of survey participants from whom we purchased 1kg of tomatoes which were then sent for laboratory analysis to test for pesticide residues and contamination with heavy metals.<sup>6</sup> Details of the analysis are included in Appendix I. Table 20 presents the results for pesticide residues. Overall, 39% of samples tested positive for at least one pesticide above the minimal detectable threshold. None of the samples tested showed pesticide residue levels above the maximum residue level required by the European Union.

Table 20 – Presence of pesticide residues in tomato samples

	Any residue		Share of EU Maximum Residue Level				
	Share	N	Mean	SD	Min	Max	N
Chlorantranilipole	0.18	61	0.27	0.23	0.02	0.65	11
Matalaxyl	0.03	61	0.17	-	0.07	0.27	2
Hexythiazox	0.02	61	0.04	-	0.04	0.04	1
Indoxacarb	0.10	61	0.04	0.02	0.02	0.08	6
Difenoconazole	0.05	61	0.01	0.01	0.00	0.01	3

<sup>6</sup> Samples were also sent to be tested for microbial contamination, however due to logistical delays too much time elapsed between taking and testing the samples for microbial levels to be accurately measured.

Azoxystrobin	0.02	61	0.01	-	0.01	0.01	1
Carbendazim	0.05	61	0.23	0.22	0.03	0.47	3
Profenofos	0.05	61	0.02	0.03	0.00	0.05	3
Acetamiprid	0.03	61	0.04	-	0.04	0.04	2
Cypermethrin	0.02	61	0.06	-	0.06	0.06	1
Fluopyram	0.02	61	0.02	-	0.02	0.02	1
Any residue detected	0.39	61					

Table 21 presents results from laboratory analysis of contamination of samples with lead and cadmium.

Table 21 – Heavy metal contamination in tomato samples

Contaminant	Mean level (mg/kg)	Share of samples exceeding limit*	N
	[95% CI]	[95% CI]	
Lead	0.45 [0.26, 0.63]	0.52 [0.38, 0.66]	50
Cadmium	0.05 [0.04, 0.05]	0.24 [0.12, 0.36]	50

\* Lead: WHO limit (0.3 mg/kg); Cadmium: EU limit (0.05 mg/kg)

More than half of all farmer samples (52%) tested were found to have lead levels above the WHO limit of 0.3mg/kg (0 of the 4 retailer samples had lead levels above this threshold). Lead poisoning is a serious health risk which affects cognitive and nervous system function. Exposure to lead is a particular risk for children, for whom it can have life-long negative effects on brain development, and exposure is regarded as unsafe at any level (American Academy of Pediatrics, 2005).

Sources of lead in the environment are diverse, and may include industrial effluent, household waste, paint, and pesticides (NASEM, 2017). While no farmers reported using pesticides that contained lead, such chemicals could potentially have previously been used on the same sites, leading to contamination in the soil. A recent study documented lead, mercury, and arsenic pollution in the Likii River, within Laikipia county (Githinji, Mwaura, and Wamalwa, 2019). This study found high levels of lead in two parts of the river: one of these was associated with horticultural and quarrying activities and was downstream of a military base, the other was downstream of a low-income residential area. Lead contamination may arise from residential areas through paint dust and flakes, as well as disposal of waste such as batteries near water sources.

While regulations exist in Kenya limiting the use of lead, for example in paint, there are concerns with compliance and enforcement (WHO, 2018). A 2017 study found that 71% of paints sold in Kenya exceeded this standard, with 50% over 7 times above the limit, and one almost 18,000 times over the limit (CEJAD and IPEN, 2017).

Cadmium was also found to be above the limit specified by the EU in approximately one quarter of tests (including 2 of 4 retailers). Cadmium is classified as a human carcinogen. Exposure to unsafe levels can lead to renal disease and damage to bones and the respiratory system (WHO, 2019).

Sources of cadmium in water and soils may include phosphate fertilizers, sewage sludge, mining and other industrial activities, and disposal of certain materials such as NiCd batteries, plating, pigments and plastics (Tucker, 2008; ATSDR 2012). A recent report on fertilizer quality in Kenya indicated cadmium content well below the maximum of 15 parts per million (ppm) set out under KS157:2018 fDAP/MAP, as well as international standards (Sanabria et al., 2018).

## Conclusions

Overall losses in tomato production were estimated at 28.2% of value, primarily as a result of farmers losses around harvest. Intermediaries and retailers primarily purchased based on visual properties, suggesting that tomatoes that are safe to consume may be rejected because of blemishes. Supporting links between farmers and processors could potentially create a market for this produce and mitigate losses.

Unsafe levels of heavy metal contamination were found in a large number of tomato samples. Lead levels in particular pose a significant health risk for young children, whose cognitive development is negatively affected by lead exposure.

Contrary to requirements set out in KS 1758-II section 11.3.1B, very few farmers reported having their irrigation water tested for potential chemical or microbiological hazards within the previous year.

92% of farmers reported that absence of pest or disease damage was required by buyers. The importance of this quality attribute may encourage farmers to overuse pesticides.

While almost all farmers reported that they read and follow manufacturer instructions regarding the post-harvest interval (PHI), the number of days

between application and harvest were often lower than the recommended PHI. This indicates widespread lack of adherence to the Horticulture Industry Code of Practice, also known as Kenya Standard 1758 Part II (KS 1758-II), section 12.2.11.1A.

Over 80% of farmers applied manure to their tomato crop. Manure can contain dangerous pathogens such as *E. coli* 0157:H7, *Salmonella spp.*, *Listeria*, *Streptococcus spp.*, *Campylobacter*, *Clostridium spp.*, *Giardia* and *Cryptosporidium*. The prevalence of pathogens can be greatly reduced if manure is well composted (meaning that a minimum temperature is attained for certain number of days). Training farmers on the importance of composting manure, and on good composting techniques is important for the avoidance of pathogen transmission.

The vast majority of tomato farmers and intermediaries, and over half of retailers did not have a toilet facility at which proper handwashing could be carried out by food handlers, posing a substantial risk of microbial contamination. This contravenes requirements set out in KS 1758-II, sections 13.1.6A, 13.12.5A, and 13.13.3, which require access to clean toilets and hand washing facilities at all stages of food production and handling.

Finally, there is an unmet need among farmers for advice on various aspects of tomato production and marketing, particularly regarding use of pesticides. While over half of farmers reported asking those to whom they sell for advice on these topics, few intermediaries provide such advisory services.

## Recommendations

- Coordinated action by the National Environment Management Authority, the Ministry of Agriculture Livestock and Fisheries, the Ministry of Health, and county governments is required to investigate sources of heavy metal pollution in the environment and prioritize existing regulations to reduce human exposure to these toxins.
- County governments should test irrigation water and soil and inform farmers of the results. Contaminated water and soil should be treated or remediated if possible, or otherwise shifted to non-agricultural uses.
- County government should work with private sector providers to develop and implement extension activities, particularly targeting:
  - Integrated pest and disease management
  - Loss-preventing tomato harvesting techniques
  - Safe and effective use of pesticides
  - Techniques for composting manure to ensure pathogen safety

- Action should be taken to make packaging material (e.g. packing trays) for tomato more widely available. National authorities could encourage local manufacturing of such products and/or reduce import tariffs.
- Counties should improve road quality to reduce mechanical damage and tomato losses during transport.
- To reduce commercial pressures for pesticide use, consumers should be educated, either through government bodies or private sector associations such as SOCAA, that cosmetic damage due to pests and disease can be safely removed.
- Access to toilet and handwashing facilities, including soap, is required under law for all food workers, but compliance in the tomato sector is very low. County governments should act to improve this situation by first advising all firms involved in food handling about sanitation and hygiene requirements, and then monitoring their compliance.
- Farmers have an unmet need for advice on various aspects of tomato production, including pesticide and fertilizer use, general production management, and marketing. Training intermediaries on these topics could be an efficient way to reach farmers.

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## Appendix I – Summary of laboratory procedures



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**RE: REPORTS OF ANALYSIS OFFERED – METHOD OUTLINE**

The above subject refers to your request for method outline for the analysis offered.  
Below is the summary of method outlines:

### **a. Methodology including Analytical Method for pesticide residue analysis**

The method used for analysis of the samples for pesticide residues was the Quechers multi-residue method. "Quechers" is the simple acronym given to the method since it is "*Quick Easy Cheap Effective Rugged Safe*" method commonly used in many residue analysis laboratories. The method has been peer reviewed and is published in the international Journal of the Association of Official Analytical.<sup>1</sup>

With the method, the laboratory screens each sample for 276 pesticides using Liquid Chromatography - Tandem Mass Spectrometry and Gas Chromatography - Tandem Mass Spectrometry (LC-MS-MS and GC-MS-MS respectively) techniques. Spiked samples and internal standards were used for quality control purposes to ensure validity of the results produced by the laboratory.

<sup>1</sup> (Anastassiades, M., S.J. Lehotay, D. Stajnbaher: „Quick, Easy, Cheap, Effective, Rugged and Safe (QuEChERS) approach for the determination of pesticide residues"). The detailed method was first published in 2003 (M. Anastassiades, S. J. Lehotay, D. Stajnbaher, F.J. Schenck, *JAOAC Int* 86(2) 412-31

**b. Analysis Of Escherichia coli (*E. coli*) in Food Products Using Colony Count Technique**

The method specifies a horizontal procedure for the enumeration of Escherichia coli in agricultural foodstuffs intended for human consumption. It uses a colony-count technique at 44 °C. It involves duplicate plating of Violet Red Bile Lactose Agar (VRBL) are inoculated with the specified quantity of the test sample or the initial suspension. Incubation is done for 24 hrs at 35°C then examined to detect the presence of colonies which, from their characteristics (purplish colored colonies q). The characteristic colonies are counted and, if required, a number of colonies are confirmed by fermentation of lactose. The number of coliforms per milliliter (CFU/ml) or per gram (CFU/g) of sample is calculated from the number of characteristic colonies obtained in the plates chosen<sup>2</sup>.

**c. METHOD OUTLINE FOR HEAVY METAL ANALYSIS**

The procedure involves microwave assisted digestion of samples of different matrices which includes soils, sediments; Plant tissue and biological tissue (e.g. fish). The quantification of analyte heavy metals is by Inductively Coupled Plasma – Mass Spectrometry (ICP-MS)<sup>3</sup>.

Thank you for your continued support.



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<sup>2</sup> ISO 4832: Horizontal Method for the Enumeration of Coliforms by Colony-count technique, Bacteriological Analytical Manual (BAM): Enumeration of Escherichia coli and the coliform Bacteria.

<sup>3</sup> United States Environmental Protection Agency, Method 3052, SW846, Microwave Assisted Acid Digestion of Siliceous and Organically Based Matrices, 1996.