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Commodity system assessment studies on the postharvest handling and marketing of tomatoes in Nigeria, Rwanda and Maharashtra, India

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ABSTRACT

Purpose: This study was conducted to identify and quantify the main causes and sources of losses in the tomato postharvest chain from harvest to retail market and identify appropriate interventions for reducing these losses in Nigeria, Rwanda and India. **Research method:** Modified Commodity Systems Assessment Methodology on tomato was conducted in the study area during the July - August 2017 harvest season. **Findings:** Generally, production is increasing with high postharvest losses. Tomato postharvest losses were uniformly high on the farm during harvest but generally lower during marketing in India than in Rwanda or Nigeria. Nigeria loses 10-40% of tomato produced from the farm to the retail market due to poor handling and unavailability of storage facilities. In Rwanda, tomato losses were exceedingly high, reaching 50 to 60%. These losses begin with the use of poor quality seeds to rough handling and use of inappropriate packaging materials. Losses in India varied between 1-18% mainly due to pest and disease attack and low price realization during glut season. However, in India, improved practices have been widely adopted on farm to retail market**. Limitations:** Resources were limited, so a single two week time period were randomly selected to conduct each of the studies which focused on one state, district or region, so data cannot be used to describe losses for the entire country. **Originality/Value:** These studies identified priority tomato postharvest problems, key issues that currently limit market access, earnings for small farmers and rural marketer, training and advocacy issues for the three countries.

INTRODUCTION

The challenges faced by crop producers is seen either in production, post-harvest, marketing or a combination of any of them (Arah et al., 2015). A Commodity System Assessment Methodology (CSAM) is a step-by-step assessment developed by the Inter-American Institute for Cooperation on Agriculture (IICA) in the late 1990s for describing and evaluating the planning, production, postharvest handling and marketing of agricultural commodities. A CSAM study seeks to identify weaknesses throughout agricultural value chains that lead to postharvest food losses and, at the same time, identify solutions and prepare proposals for improving their efficiency (La Gra et al., 2016).

This assessment methodology for studying postharvest losses in fruits, vegetable crop and staple food crops in many countries was recently updated and modified to include many types of crops (LaGra et al., 2016). The original CSAM used many lengthy written surveys, face to face interviews and observation checklist (La Gra, 1990). The modified CSAM now includes summary list of key questions to guide interviews of stakeholders, checklists for making observations of handling practices, worksheets for use in direct measurements of quality and quantity losses on farm, packinghouse, storage and at wholesale and retail market levels, as well as cost/benefit worksheets. The development and field testing of these CSAM data collection surveys and worksheets have been used on several commodities for Bill and Melinda Gates Foundation funded postharvest project in Rwanda, India, Benin and Ghana (WFLO, 2010), on farm losses assessment for maize and bananas in Uganda, tomatoes in Egypt and cassava and sweet potatoes in Nigeria (Kitinoja et al., 2016) on tomatoes in Rwanda (Chahine et al., 2017) and bananas in India (Tokola, 2014). This study utilized on the modified CSAM for tomatoes in Rwanda, Nigeria and India.

Tomato is a major vegetable crop that is used widely throughout the different strata of the population over the last century (Jaiswal et al., 2018). It is one of the most important 'protective foods' because of its special nutritive value and also an important source of antioxidants in the human diet (Khubone & Mditshwa, 2018; Osemwegie, 2010). The fruit can be eaten raw or processed into other forms such as paste, powder, purees, sauces and juices. Tomatoes are an important crop in Nigeria, Rwanda and India and production is increasing. The production accounts for about 4.8 million hectares of harvested land area globally with an estimated production of 177 million tonnes. China leads in the world tomato production with 56,423,811 tonnes followed by India with 18.399,000 tonnes, followed by Nigeria with 2,243,228 tonnes while production in Rwanda is 118,774 tonnes (FAOSTAT, 2016). However yields are relatively low in the study countries compared to the commercial potential achieved under irrigated and fertilized conditions. Tomato yields in India and Rwanda in 2016 according to FAOSTAT were 24.2 MT ha^{-1} and 11.37 MT ha^{-1} respectively, which was lower than the global average of 33 MT ha^{-1}, while yields in Nigeria were extremely low at only 3.90 MT ha^{-1}.

Despite the huge production quantity in these countries, postharvest loss is reportedly high (WFLO, 2010; Kitinoja & AlHassan, 2012; Chahine et al., 2017). These losses may occur as result of negative climatic conditions, poor physical facilities, technology used, cultural practices, high costs of farm inputs, low market prices, low motivation of human resources and a nearly infinite number of other causes (LaGra et al., 2016). Salami et al., (2010) reported that postharvest losses are huge in developing countries because of poor storage and food-handling technologies. More so there is low adoption of the little technology that is available on reducing food losses due to the enormous information gap between the farmers and research institutes involved in the dissemination of information on the use of such technology (Odeyemi et al., 2015). Postharvest losses show up as decreased nutritional

quality (loss of vitamins, development of health dangers such as myco-toxins) or decreased market value (Kitinoja & AlHassan, 2012). It also depresses incomes along agricultural value chains, and can have particularly devastating impact on smallholder farmers. However, overcoming the socioeconomic constraint of inadequate infrastructure is essential to achieving the goal of reducing postharvest losses (Kader, 2005).

In view of all these challenges, this study was carried out to identify and quantify the main causes and sources of loss in the postharvest chain of tomatoes from the harvest to the retail market in Nigeria, Rwanda and India using the CSAM approach. This analysis identified where farmers, wholesalers and retailers are losing the most tomatoes in terms of quantity, quality and economic value, and identifies appropriate interventions for reducing these losses.

MATERIALS AND METHODS

CSAM Study process

Modified CSAM studies on tomatoes were conducted in Nigeria, Rwanda and India during the July-August 2017 harvest season. The CSAM is made up of 26 components of the agricultural value chain from production to marketing of a crop. A CSAM study begins with a literature review of published articles and unpublished documents, review articles and government reports on the food commodity. The entire process is systematic, using survey questions, interviews, checklists and observations to collect data on the key aspects of the value chain, including pre-production, production, postharvest handling and marketing. It considers the entire commodity system, from planning and production to processing and marketing, but focuses heavily on the postharvest handling and marketing aspects in order to determine the relative costs and benefits of any potential or observed changes in handling practices, containers, value addition or marketing practices. The modified CSAM included worksheets (LaGra et al., 2016) for data collection via direct measurements of food losses (quantity, quality and economic value) rather than relying on interviews, recall or estimates.

Sites selection

Nigeria and Rwanda were selected from the Sub-Saharan Africa while India was selected from Southern Asia, in order to conduct comparative studies in the two regions. The studies were carried out in the rainy season with focus on rain fed tomato crop production. The greenhouse tomato cultivation was not included in this study. In Nigeria, the Southwestern region of the country was at the peak of tomato production during the study period. Ogun State (Imeko, Odeda and Abeokuta areas) was selected for the on-farm CSAM, while the wholesale and retail CSAM spread across Ogun State (Olomore market), Oyo State (Shasha market) and Lagos States (Mile 12 market). Principal growing areas were identified in Rwanda for cultivating tomato in the open field. The farms selected were located in Kamonyi, Nyagatare and Bugesera Districts. Wholesale markets included daily, year-round marketplaces in Nyarugenge, Kicukiro and Gasabo Districts. Retail vendors were located in and around the capital of Kigali in Nyarugenge, Kayonza and Gasabo Districts. In India, tomato was being harvested in Maharashtra State between July-August. The major tomato growing districts were Pune, Nasik, Nagpur and Sangli, however data collection for on-farm, wholesale and retail markets were centered on the areas of Pune and Nasik on the western side of the state of Maharashtra.

Data collection

Data on the tomato value chain in each of the selected countries were collected via literature review, interviews following a set of written questions, observations of the harvest and postharvest handling practices and direct measurements in the field. Questions related to production were asked mainly to farmers while traders and marketers were asked about postharvest handling and marketing. Researchers, project staff and extension workers were questioned about the entire commodity system. CSAM interviews were conducted with 10-15 persons in each country via stratified samples of known crop experts, extension workers, farmers, traders, processors and marketers. The field teams also made use of standardized worksheets for on-farm, wholesale and retail market data collection on postharvest losses, quality characteristics, market value changes and a worksheet on the costs and benefits of potential changes in practices. The field based assessment sampled postharvest losses for a random selection of 10-13 farms, 10 wholesale markets and 10 retail markets in Nigeria, Rwanda and India using direct measurements, questions and observations (Table 1). No packinghouses or collection center was identified during the course of survey.

Tools for Assessment

Tools used during the CSAM studies included; digital scale (5 kg capacity), hanging scale (30 kg capacity), digital temperature probe to determine air and tomato pulp temperature, color chart (Fig. 1) for assessing ripeness stage, refractometer (model MT-032ATC) for measuring soluble solid content (%SSC), digital camera, set of data collection worksheets with protocols. Quality characteristics were determined via non-destructive assessment by sorting a random sample of 20 fruits into pertinent categories for ripeness, appearance, damage, defects and decay. Fruit firmness was determined on a non-destructive 5-point scale via a gentle 3-finger "squeeze test" where 5 = hard and 1 = very soft. The undamaged fruits were returned to the farmer or vendor.

Data Analysis

The data collected were simple and data analysis included sums, ranges, averages and standard deviation.

Table 1. Interviews with stakeholders and tomato value chain actors during CSAM assessment and field visits during July-August 2017

Country	Chiefs, community leaders	Agro-dealers	Crop Experts	Extension	Farmers	Wholesalers	Retailers
Nigeria	2	-	1	5	13	10	10
Rwanda		2	3		11	10	10
India	-	-	2	3	25 (10 were also traders)	10	10
Total	2	2	6	8	49	30	30

Table 2. Characteristics of the farms in the study area

Country	Number of farms	Average size of tomato farms Hectares	Distance to market (range)	Data collection timing (average hours after harvest)
Nigeria	11	0.6 ha Range: 0.4 to 1	6 to 35 km	1 hour Range 0 to 2.5
Rwanda	11	0.7 ha Range: 0.1 to 1	From walking distance to 160 km	0 hours (all data was collected during the harvest)
India	10	0.6 ha Range: 0.4 to 2	2 to 9 km	1.1 hours Range 0 to 3 hours

RESULTS AND DISCUSSION

Postharvest loss on-farm

Postharvest losses (PHLs) at the farm level were similar in Nigeria, Rwanda and India from the CSAM studies conducted with a wide range from 2-40%. The size of the tomato farms visited was very small, ranging from 0.1 to 2 hectares. The range for the distance to market was 2 to 160 km. The data collected on farms was completed either during or within 3 hours of the harvest (Table 2). From interviews conducted, it was observed that losses begins from planning because farmers make use of tomato seeds of unknown quality from previous harvest with the exception of India where farmers have access to good quality seeds in Maharashtra. In Nigeria and Rwanda, tomato plants on-farm were found sprawling on the ground in the field predisposing them to soil borne diseases (Fig. 2). In Rwanda, farm workers typically step on the plants during harvest (Fig. 3). Farmers in India however, make use of trellises which protected the tomato fruits from some diseases (Fig. 4).

Harvesting was carried out manually in all the study areas using color change as the harvest index. In Rwanda, tomato fruits are harvested at fully ripe and very soft texture leading to very high losses due from damage and decay as the fruits travels from the farm to final market. According to Toivonen (2007) fully ripe tomatoes are very susceptible to mechanical injuries during harvesting resulting in shorter shelf life. Over stacking of field containers and very large transport containers (traditional woven baskets or sacks) were used on farm in Rwanda. These packaging materials offered little no protection for the fruits and exposing them to mechanical injuries (Fig. 5). Dari et al. (2018) stated that although the size of packaging crates and nature of the packing liners influenced the level of damage or deterioration in tomato, the initial quality of the fruits, handling and prevailing climatic conditions influence deterioration greatly. In India harvested tomatoes at ¾ ripe stage are kept for local market while those at turning to ½ ripe are designated for distant markets. The fruit are harvested, marketed and transported in plastic crates which are covered with newspaper (Fig. 6). These plastic crates have been subsidized by the Indian government and private sectors to make them relatively cheaper for farmers to purchase. Tomatoes at all stages of ripening were harvested for both short and distant markets in Nigeria. The tomatoes were harvested and transported in traditional woven basket similar to the baskets used in Rwanda. Other causes of on farm tomato loss from the study areas were from pests and diseases such as anthracnose and fungi infection (Fig. 7). Physiological disorder such as cracking was also evident in tomato fruits in Nigeria and some of the fields were weedy.

Postharvest loss at wholesale marketing

Major causes of PHLs at wholesale marketing identified in Nigeria and Rwanda included use of inappropriate means transportation, packaging materials and rough handling during loading and offloading. Transport used included open buses, cars, bikes and fuel tanker (tomato placed in woven baskets are strapped on top and at the sides of the tanker) to avoid multiple taxes (Fig. 8). The packaging materials were traditional woven baskets with loose spikes, rough, dirty interior and poorly ventilated which lead to bruising of the soft fruits, spoilage and encourage the growth of deteriorating agents (fungal and bacterial growth). Kutama et al. (2007) reported that freshly harvested tomato fruits are usually stored, and conveyed in traditional weaved wicker baskets in Nigeria, and these baskets are often reused over and again until they become contaminated with primary fungal spores from previously infected fruits.

These baskets carry an average weight of 40 kg tomato in Nigeria while in Rwanda could be as high as 130 kg, heaped on one another by bracing with planks/bamboo wood and overloaded into transport vehicles also resulting to heat build-up. During transit, especially on rough roads, these planks may shift causing baskets to fall on one another resulting in compression injury to tomato. Sacks used in packaging tomatoes in Rwanda offered no protection to tomato leading to huge mechanical damages at wholesale marketing (Fig. 9). This findings are similar those previous tomato loss assessments carried out in Rwanda (WFLO, 2010; Kitinoja & Alhassan, 2012; Van Dijk et al., 2015; Kitinoja & Kader, 2015; Chahine et al., 2017). Mechanical damage is known to affect flavor, as bruising is related to the development of off-flavors (Kader, 1986).

In India, an improved handling practice was observed with the use of improved containers (vented plastic crates) which resulted in lower PHLs during wholesale market ing. This plastic crates had 20 kg of tomato fruits packed in single standard size stackable and the produce was not overloaded nor exposed to direct sunlight. These plastic crates can be lined with ventilated fiberboard liners to further prevent bruising and vibration damage during transportation (Saran et al., 2012). More so, in a comparative study conducted by Babarinsa et al. (2018) the plastic crates achieved the recorded 88% reduction in average damage losses caused by use of basket in the truck by protecting the packaged tomato fruit. The main causes of loss identified during wholesale marketing in India occurred during transport, mainly due to rough handling during loading and offloading.

Postharvest loss at retail marketing

The main source of PHLs during retail marketing in all the study area occurred from damages during transport. Arah et al. (2016) stated that the wobbling nature of most of the vehicles coupled with the bad nature of roads causes a lot of mechanical damage to the produce before it reaches its destination. More so, vibration and impact during transportation as a result of undulations on roads are one of the major causes of postharvest losses to most fruits and vegetables especially tomatoes (Idah, 2007)

At some retail markets in Nigeria, tomato was displayed under direct sunlight heating up the produce while in Rwanda, tomatoes offered for retail sale are fully ripe and covered with a powdery coating (these were determined to be pesticide residues, deliberately applied just prior to or even after the harvest). Vendors and traders claim that the presence of the pesticide spray induce ripening faster in tomato fruits and buyers see the residue as a proper protection from pest damage (Fig. 10). However, this practice poses a serious health risk to consumers. Improved postharvest handling and the use of shade in India are related to much lower PHLs during retail marketing. The main sources of distribution losses in India are damages during transport. However, compressed fruits and fruits with ruptured skins are removed at this stage. Since the fruits are picked at turning stage and half pink stage and are firm throughout the supply chain the damages reported in the retail market are low. The shelf-life of fruits harvested at turning and half pink stage is about 2 weeks compared to three days in those harvested at full ripe stage at 22-33 °C and Relative Humidity of 90% (Dubey et al., 2014).

Postharvest losses measured quantitatively

The measurements of percent defects, decay, mechanical damage and discards for tomatoes in Nigeria, Rwanda and India are summarized in Table 3. Damage and defects were extremely high in Rwanda and high in Nigeria, which generally resulted in lower sales prices rather than as discarded produce. Only the very worst quality, rotten, inedible produce was discarded. PHLs measured in Nigeria on farm ranged from 10 to 40% (average 15.2%). Sorting discards at the wholesale level was 23.3%, and mechanical damage in the assessed samples was 23%.

At the retail level, average sorting losses were 20%, with a range of 10 to 30%. PHLs cannot simply be added across these value chain stages, due to the very wide range of losses measured in each sample. If the minimum level of the range of measured PHLs is added up for the farm, wholesale and retail sites, the total is 35%, which is the most conservative estimation of overall losses. PHLs measured in Rwanda on farm ranged from 2 to 40% (average of 18.3%). There was little or no sorting at the wholesale level (therefore no discards), but mechanical damage in the assessed samples was 92%. At the retail level, average sorting losses were 7.3%, with a range of 2 to 20%. PHLs measured in India on farm were reduced when compared with Nigeria or Rwanda. The loss ranged from 7 to 18% (average of 14%). The fruits were harvested at earlier maturity and so have a naturally longer shelf lives, and higher firmness, which protected the crop during transport and marketing. There was little or no sorting at the wholesale level (therefore no discards), and little to no defects, decay or mechanical damage in the assessed samples. At the wholesale and retail levels, average sorting losses were 4.8% and 4.2% respectively, with a range of 1 to 10%. Very rapid turnover and minimal handling in India wholesale markets also reduced PHLs.

In Nigeria, the weight of the tomatoes left in the field after the final harvest was collected and weighed in a farm. Based upon the average weight collected from 3 sample plots, 290 kg ha^{-1} was either left on the plants or discarded on the ground in the field. Therefore, the PHL for that farm during the final harvesting day alone was 7.3% of the total anticipated harvest of 4 MT ha^{-1}. Tomato samples at each marketing sites in both Nigeria and Rwanda was measured for initial weight at delivery and weight at the time of sale (generally 4 to 6 hours later). Lack of shade and exposure to the weather (wind, heat) and rough baskets allowed the average rates of water loss to reach 2% at the wholesale market (range 0 to 4%), and 7.1% at the retail market (range 2 to 20%) in Nigeria while the average rates of water loss range from 1.1 to 1.5% from farm to retail market in Rwanda (Table 4). The time elapsed before tomato sales in Rwanda was very short so average weight loss in tomato tended to be lower when compared with tomatoes displayed in Nigeria. No data was available for India due to very rapid turnover and sales. Whenever fruits are resold by weight, water loss results in an immediate loss in earnings.

Postharvest loss measured qualitatively

Tomato quality characteristics were found to be closely related to the market value. During harvesting, tomato fruits in Nigeria and Rwanda were left in the open field under direct sunlight until harvesting is completed, thereby heating up the produce. The highest tomato pulp temperature was recorded in India during retail marketing (Table 5). Temperature is the most important environmental factor that influences the rate of deterioration of harvested fruits. According to Kitinoja and Kader (2015) throughout the period between harvest and consumption, temperature control has been found to be the most important factor in maintaining product quality. Produce exposed to the sun after harvest gains an enormous amount of heat and will have reduced shelf life. Furthermore, temperature does not only reduce shelf life but also the appearance, texture, nutritional value and organoleptic characteristics such as flavor and aroma of the produce is affected (Nunes, 2008; Burden & Wills, 1989). Quality characteristics such as ripeness and firmness were measured on the farm and in the marketplaces. It was observed that tomato firmness decreased as the fruits moved from the farm to retail market which implies continued ripening of the fruits with increased perishability of the fruits in Nigeria and Rwanda. Fruits were of higher SSC% in India than in SSA and considered to be a high quality, good flavor and texture throughout the value chain (Table 6).

Table 3. Postharvest % loss measured for tomatoes

Country	Location	Ripeness	% defects	% decay	% Mechanical damage	% sorted out/ discarded before sale
Nigeria	Farm	46% red 19% light red	13	12	17	15.2% Range: 10 to 40% SD = 6
	Wholesale market	46% red 19% light red	23	5	23	23.3% Range: 15 to 35% SD = 4.5
	Retail market	55% red 24% light red	21	11	28	20% Range: 10 to 30% SD = 4
Rwanda	Farm	46% red 19% light red	65	32	63	18.3% Range: 2 to 40% SD = 13.76
	Wholesale market	46% red 19% light red	75	60	92	No discards
	Retail market	46% red 19% light red	74	52	81	7.3% Range: 2 to 20% SD = 7.63
India	Farm	All pink or earlier	Very low to no damage, defects or decay			14% Range: 7 to 18% SD = 6
	Wholesale market	All light or earlier				4.8% Range: 2 to 8% SD = 2.8
	Retail market	All light red or earlier				4.2% Range:1 to 10% SD = 5

Table 4. Average rate of water loss in tomatoes sold in Nigeria and Rwanda

Country	Sites	Initial average sample weight (g)	Average weight at the time of sale (g)	Range of weight loss (%)	Average weight loss (%)	Average time elapsed before sale (hours)
Nigeria	Farm	*	*	*	*	*
	Wholesale market	644	632	0 to 4	2.0	4.5
	Retail Market	424	394	2 to 20	7.1	6.9
Rwanda	Farm	1338	1315	0 to 6	1.5	< 1
	Wholesale market	1240	1223	1.2 to 1.8	1.4	2
	Retail Market	1273	1259	0.1 to 5.5	1.1	1

* = No data available

Table 5. Air temperature and tomato pulp temperature of tomatoes in the study area

Country	Air temperature (^{0}C)			Pulp temperature (^{0}C)		
	Farm	Wholesale	Retail	Farm	Wholesale	Retail
Nigeria	26.7	25.0	26.4	28.0	25.9	27.4
Rwanda	28.2	29.1	28.5	26.8	26.6	26.6
India	28.4	30.5	31.7	30.8	28.8	32.0

Table 6. Qualitative characteristics of tomatoes in the study area

Country	SSC %			Firmness*			Relative perishability**		
	Farm	Wholesale	Retail	Farm	Wholesale	Retail	Farm	Wholesale	Retail
Nigeria	3.9	4.3	4.7	3.4	3.0	2.3	3	5	5
Rwanda	4.6	4.7	4.1	4.2	2.6	2.4	5	5	5
India	8.5	7.8	*	4.0	3.0	3.0	3	3	3

* scale of 1-very firm, 2- moderately firm, 3- firm, 4- Not firm 5-very soft

** 1=low (breaker-turning stage), 3=moderate (pink stage), 5=highly perishable (red ripe)

Score	Class	Description*
1	Green	Entirely light- to dark-green, but mature
2	Breaker	First appearance of external pink, red or tannish-yellow color; not more than 10%
3	Turning	Over 10% but not more than 30% red, pink or tannish-yellow
4	Pink	Over 30% but not more than 60% pinkish or red
5	Light-red	Over 60% but not more than 90% red
6	Red	Over 90% red; desirable table ripeness

*All percentages refer to both color distribution and intensity.

Fig. 1. Colour chart for tomato (Source: Kader and Cantwell, 2005)

Fig. 2. Sprawling tomato vines in Nigeria

Fig. 3. Workers carrying stacks of filled plastic basins and stepping on tomato fruits during harvest in Rwanda

Fig. 4. Tomato vines on a trellis in India

Fig. 5. Traditional woven baskets for tomato transport in Rwanda

Fig. 6. Plastic crates for packaging tomatoes in India

Fig. 7. Diseases on harvested tomatoes

Fig. 8. Fuel tanker transporting tomatoes in Nigeria

Fig. 9. Sacks for packaging tomatoes in Rwanda

Fig. 10. Pesticides residue on tomatoes in Rwanda

Estimated economic losses in quantity and quality

In Nigeria and India the market value of tomato was highly dependent on the season of production and supply. In India there was a huge seasonal farm gate price from Rs 50 to Rs 1200 per standard plastic crate. Farmers and traders are reported to abandon their tomatoes rather than spend money to harvest, transport and market the crop during glut. In Rwanda and Nigeria the market value of the tomato crop also decreased as the quality decreased due to rough handling and inappropriate packaging materials. Excellent quality tomatoes were sold for 350 to 500 Rwf/kg in Rwanda, while the market value for lower quality tomatoes (soft fruits) was sold at 200 Rwf/kg and extremely damaged/broken fruits were sold at 50 Rwf/kg. The price varied from ₦350/kg for excellent quality tomatoes to ₦50/kg for the damaged/broken tomatoes. This is an economic opportunity for both Nigeria and Rwanda to improve on postharvest handling and investment in improved containers. Overall for these three countries, depending upon their total tomato production and conservatively estimated % PHLs with 30% in Nigeria, 50% in Rwanda and 10% in India, the annual economic losses for tomatoes amounts to $446 million in Nigeria been the highest, followed by $206 million in Maharashtra, India and $48.2 million in Rwanda (Table 7). These PHLs for tomatoes in the study area are likely to be even higher than the value obtained during the CSAM in most areas especially when gluts are been experienced due to over production. These food losses result in lost earnings for farmers and vendors, as well as lost GDP for the nations assessed in these CSAM studies.

Table 7. Estimated range of the value of postharvest losses of tomato in the study area

Country	Annual production (2014)	Market value range for high quality	Market value range for low quality	Market value (average)	Estimated PHL from CSAM (%)	Annual economic loss	Annual economic loss in $US
Nigeria	2,143,500MT	₦350/kg ₦750 billion	50/kg N107 billion	N250/kg N533.75 billion	30	N160.7 billion	$446 million
Rwanda	154,000MT	500 Rwf/kg 77 billion Rwf	200 Rwf/kg 30.8 billion Rwf	250 Rwf/kg 38.5 billion Rwf	50	38.5 billion Rwf	$48.2 million
India	1,058,000MT	-	-	Rs 30/kg Rs 31.74 million	10	Rs 3.17 million	$206 million

N360= $US 1, 800Rwf=$US 1, Rs 65=$US 1 in 2017.

Table 8. Calculations of calorie, protein and vitamin nutritional losses due to PHLs for tomatoes

Country	Percentage losses	Weight losses	Kilocalorie Losses	Protein Losses (g)	Vitamin A Losses (IU)	Vitamin C Losses (mg)
Nigeria	30%	642,950 MT	116 million	5.65 billion	5,356 billion	88 billion
Rwanda	50%	77,000 MT	13.8 million	678 million	641 billion	10.5 billion
Maharashtra, India	10%	105,800 MT	18.9 million	931 million	881 billion	14.5 billion

(Author calculations based on nutritional information for red tomatoes via USDA website. https://ndb.nal.usda.gov/ndb/ accessed October 2017).

In addition to earnings losses, these same tomato losses can be equated to a loss in calories and nutrition such as protein, vitamins A and C. Per kg in the traditionally used units of measure, tomatoes contain 180 kilocalories, 8.80 g of protein, 8,330 IU vitamin A and 137 mg of Vitamin C. Per metric ton, tomatoes contain 180,000 kilocalories, 8.8 kg protein, 8.33 million IU of Vitamin A and 137 g Vitamin C (USDA, 2017). Tomatoes do not contain a lot of food value in terms of calories or protein, but they are relatively high in vitamin content. Vitamin C daily requirements range from 75 to 90 mg per person (about 29,500 mg per year). Nigeria has the largest loss in terms of calorie, protein and vitamins followed by India and Rwanda experiencing the least (Table 8). The vitamin C losses due to postharvest losses of tomatoes in Nigeria could satisfy the nutritional needs of 3 million people for one year.

CONCLUSION

The postharvest handling of tomatoes in Nigeria, Rwanda and Maharashtra, India were at different stages of development. The postharvest losses and quality problems for the tomato crop were found via the CSAM studies to be similar in the two Sub-Saharan African countries were largely due to inappropriate harvesting and rudimentary postharvest handling practices such as use of very poor quality, large (inappropriate size, with rough interior) containers, lack of storage options and processing facilities, while in India were mainly due to farm level pest or weather problems and to marketing gluts when very low prices led to abandonment of the crop. In general, there was disjointed production and marketing of fruits.

However, in Maharashtra, India, improved practices have been widely adopted on the farm (trellising, improved varieties, planting marigolds as pest control aids), during tomato harvesting (use of maturity indices, use of shade, gentle handling, use of picking aids) and during the postharvest period (use of plastic crates, shade and sorting/grading practices) and processing. Farmers in Maharashtra do not overload crates and marketers do not sit on the produce during marketing delays. Overall, the tomato commodity system in Maharashtra,

India is a positive example of how losses can be reduced via improved postharvest handling on the farms and during marketing. The success story of the use of improved harvesting, improved postharvest handling practices and technology adoption for tomatoes in Maharashtra provides a model that should be replicated whenever possible in other states of India, as well as in Nigeria, Rwanda and many other countries in Sub-Saharan Africa.

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CONFLICT OF INTEREST

The authors have no conflict of interest to report.

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مطالعات ارزیابی سیستم محصول در جابجایی پس از برداشت و بازاریابی گوجه‌فرنگی در نیجریه، رواندا و ماهاراشترا، هند

لیزا کیتینویا، اولوبوکولا موتونرایو عدیعی، نیرو دوبی، سولژن موسیان و گربرینینگ سینگ گیل

چکیده:

این مطالعه به منظور شناسایی و تخمین علل و منابع ضرر و زیان در زنجیره پس از برداشت گوجه فرنگی از برداشت به بازار خرده فروش و شناسایی مداخلات مناسب برای کاهش این ضررها در نیجریه، رواندا و هند انجام شد. روش تحلیل سیستم ارزیابی اصلاح شده در گوجه فرنگی در منطقه مورد مطالعه در طول فصل برداشت در ماه ژوئیه تا اوت ۲۰۱۷ انجام شد. به طور کلی، تولید بالا و افزایش ضایعات پس از برداشت وجود دارد. ضایعات پس از برداشت گوجه فرنگی طور یکنواختی در مزرعه در طول برداشت وجود داشت اما معمولا در هنگام بازاریابی در هند کمتر از رواندا و نیجریه است. نیجریه ۱۰-۴۰ درصد از گوجه فرنگی تولید شده را از مزرعه به بازار خرده فروشی از دست می‌دهد که به دلیل در دسترس نبودن امکانات انبارداری و جابجایی نامناسب است. در رواندا ضایعات گوجه فرنگی بسیار زیاد بود و به ۵۰ تا ۶۰ درصد رسید. این ضایعات با استفاده از بذور با کیفیت پایین و مواد بسته بندی نامناسب آغاز می‌شود. ضایعات محصول در هند بین ۱ تا ۱۸ درصد به طور عمده به علت حمله آفت و بیماری و قیمت پایین قیمت در طول فصل پرمصرف متفاوت بود. با این حال، در هند، روش‌های بهبود یافته به طور گسترده برای جابجایی از مزرعه به بازار خرده فروشی وجود دارد. این مطالعات، مشکلات اولویت‌دار پس از برداشت گوجه فرنگی را مشخص کرد، مسائل کلیدی که در حال حاضر محدودیت دسترسی به بازار، درآمد کشاورزان کوچک و بازاریابان روستایی، مسائل آموزش و پشتیبانی را برای سه کشور تعیین می‌کند.

کلمات کلیدی: سبزیجات میوه‌ای، جابجایی، ضایعات پس از برداشت، کیفیت، زنجیره ارزش