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An Overview of Post-Harvest Losses in Tomato Production in Africa: Causes and Possible Prevention Strategies

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Abstract
Tomato (*Solanum lycopersicum L.)* is an important crop cultivated and consumed worldwide. It provides a wide variety of nutrients and many health-related benefits to the human body. Tomato production can improve the livelihoods of small-scale producers by creating jobs and serving as source of income for both rural and peri-urban dwellers. Despite all these benefits, many constraints make tomatoes production unprofitable in Africa. Post-harvest looses is one of such constraints. Post-harvest losses have been found to be either an on-farm or off-farm problem. On-farm losses are caused by improper harvesting stages, excessive field heat, improper harvesting containers, poor farm sanitation and improper packaging materials. Causes of off-farm losses includes lack of access roads, inappropriate transportation system, lack of processing factories and lack of reliable market information. Using low-cost intermediate technology intervention can help reduce some of these post-harvest losses making tomato production a more profitable venture in Africa.
Keywords*:* Post-harvest, Losses, Tomatoes.

1.0 Introduction

Tomato (*Solanum lycopersicum L.)* is one of the most popular produced and extensively consumed vegetable crops in the world (Grandillo *et al.* 1999). It can be eaten raw in salads or as an ingredient in many dishes, and in drinks (Alam *et al*. 2007). Tomatoes and tomato-based foods provide a wide variety of nutrients and many health-related benefits to the body. In regions where it is being cultivated and consumed, it constitutes a very essential part of people's diet. Tomatoes production accounts for about 4.8 million hectares of harvested land area globally with an estimated production of 162 million tonnes (FAOSTAT, 2014). China leads world tomato production with about 50 million tonnes followed by India with 17.5 million tonnes (FAOSTAT, 2014). Tomato production can serve as a source of income for most rural and peri-urban producers in most developing countries. Despite all the numerous benefits from the crop, many challenges are making its production unprofitable in most developing countries especially those in Africa. The challenges faced by producers is seen either in production, post-harvest, marketing or a combination of any of them. The purpose of this paper is to look at the post-harvest challenges that results in losses and recommend some low cost intermediate technologies needed to remedy the situation.

1.1 History of tomato as food

According to Tan *et al.* (2010) the present-day tomato has a very short history of human consumption. It was believed to have its origin in the South American Andes (Naika *et al.* 2005) which is in present day Peru where it was growing in the wild at the foot of hills. It was then taken to other parts of the world by the early explorers where it was planted as ornamental curiosities but not eaten. In Europe for instance it was planted in gardens as decorative plants and was considered poisonous. Although tomato was accepted later as an edible crop in Europe in about 1840 (Paran and van der Knaap 2007) there was still strict opposition to its consumption in other parts of the world.

Global tomato production increased during the 1920s as a result of breakthroughs in technologies that made mechanised processing possible (Tan *et al.* 2010). With increasing knowledge in benefits derived from genetic modification of tomatoes, more desirable parameters have been selected for varietal improvement to enhance the crop for human consumption. Today, countless varieties of tomatoes are consumed all over the world in different recipes.

1.2 Recipes of tomatoes

Tomatoes can be used for a variety of recipes. It can be consumed fresh in salads, cooked in other dishes or processed into other food products (Ahmed *et al.* 2012; Ayandiji *et al.* 2011; Babolala *et al*. 2010; Grandillo *et al.* 1999). A few common recipes of tomatoes include: tomato-egg sandwich, tomato-watermelon sorbet, fried green tomato with bread and butter pickle, grilled chicken-tomato salad, tomato stew, tomato-chili soup and tomato-egg sandwich.

1.3 Nutritional values in tomatoes

Tomato has become an important cash and industrial crop in many parts of the world (Ayandiji *et al.* 2011) not

only because of its economic importance but also its nutritional value to human diet and subsequent importance in human health (Willcox *et al.* 2003). Tomato is rich in vitamins, minerals, sugars, essential amino acids, iron, dietary fibers and phosphorus (Ayandiji *et al.* 2011). It therefore serves as source of these nutrients when consumed. The table below gives 15 main nutrients and their quantities that can be derived from consuming a 123-gram of ripened tomatoes.

Table 1: The 15 Major nutrients derived from tomatoes

Nutrient	Amount
Calcium	1.2mg
Carbohydrate	4.7g
Copper	0.073mg
Dietary fiber	1.5g
Fat	0.2g
Iron	0.33mg
Magnesium	1.4mg
Niacin	0.731mg
Pantothenic acid	0.109mg
Phosphorus	3mg
Potassium	292mg
Protein	1.0g
Thiamin	0.046g
Total sugars	3.23g
Vitamin C	16.9mg

Source: The USDA National Nutrient Database (2010)

1.4 Health benefits of tomatoes

Tomato contains higher amounts of lycopene, a type of carotenoid with anti-oxidant properties (Arab and Steck 2000) which is beneficial in reducing the incidence of some chronic diseases (Basu and Imrhan 2007) like cancer and many other cardiovascular disorders (Freeman & Reimers 2010). This anti-oxidant property and its health benefit have raised the interest in tomato research and its consumption as a crop with medicinal properties (Di Mascio *et al.* 1989). Lycopene is believed to be the main contributing compound in tomatoes responsible for lower risk of prostate cancer (Pohar *et al.* 2003). Other studies have also shown that consumption of tomatoes and tomato-base foods can be linked to reduced incidence of a variety of cancers in general, including pancreatic, lung, stomach, colorectal, oral, bladder, breast and cervical cancers (Giovannucci 1999). Lycopene in tomatoes enhance fertility by improving the quality and swimming speed of sperm whilst reducing the number of abnormal sperm in men (Innes 2014). Consumption of tomatoes can prevent old-age related diseases like dementia, osteoporosis, Parkinson's and Alzheimer's (Freeman & Reimers 2010). Tomatoes have high sources of vitamin C and vitamin A which are vital in warding off muscular degeneration and improve eyesight. It is also believed to be powerful blood purifier and clear up urinary tract infections. Tomatoes are high in fibre which aids easy digestion and can assist in weight loss. These numerous health benefits of tomatoes and tomato-based foods may be linked to its high production globally.

2.0 Tomato production in Africa for 2012

Tomato is an important and popular grown horticultural commodity in the world and by weight ranks third in global production of all horticultural produce only behind potatoes and sweet potatoes (Tan *el al* 2010). In Africa, the total tomato production for 2012 was 17.938 million tons with Egypt leading the continent with 8.625 million tonnes. Table 2 shows the list of the top 15 producing countries in Africa.

Table 2: The top 15 tomato producing countries in Africa.

Rank	Country	Production (tons)
1	Egypt	8 625 219
2	Nigeria	1 560 000
3	Morocco	1 219 071
4	Tunisia	1 100 000
5	Cameroon	880 000
6	Algeria	796 963
7	South Africa	564 740
8	Sudan (former)	529 200
9	Kenya	397 000
10	Ghana	321 000
11	Tanzania	255 000
12	Mozambique	250 000
13	Benin	244 742
14	Libya	225 000
15	Niger	188 767

Source :(FAOSTAT 2014)

2.1 Challenges confronting tomato production in Africa

Tomato has the tendency of improving the lives of small scale rural farmers in most developing countries of the world. Besides the health benefits derived from tomatoes and tomato-based foods, the crop can serve as a source of income for farmers as a result of its numerous uses. The tomato industry can increase the foreign exports earning of many African countries thereby contributing to GDP. In Ghana for instance, the tomato industry has been identified as an area that has the ability for poverty reduction because of its potential for growth and employment creation (Anang *et al*. 2013) whilst in Nigeria, the production of the crop has improved the livelihood of most rural and peri-urban farmers (Adenuga *et al.* 2013).

Although tomato can improve the livelihoods of rural farmers, studies have shown that the full potential of the crop has been under exploited because of many challenges. For instance most tomato farming in Nigeria (as well as most African countries) is rain fed (Adenuga *et al.* 2013) because of the lack of effective irrigation systems. Production therefore takes place in the rainy seasons only. The incidence of pests and diseases, low quality and insufficient quantity of tomato produced among competition from foreign imports (Robinson and Kolavalli 2010) are also some constraints hampering the production of tomatoes in Africa.

Even though the above are all constraints hampering tomato production in Africa, the focus of this paper is the post-harvest related challenges. Post-harvest losses are losses faced by producers, processors, distributors, retailers as well as exporters in handling the produce after it has been harvested until it gets to the final consumer.

3.0 Causes of post-harvesting losses in tomatoes

The causes of post-harvest losses in tomato production can be categorized into two major groups. They are on-farm and off-farm causes.

3.1 On-farm causes of postharvest losses

The following are examples of some on-farm causes of post-harvest losses in tomatoes production in Africa.

3.1.1 Inappropriate harvesting periods

The physiological maturity of the fruit at harvesting stage has a major effect on quality (Beckles 2012). Care must therefore be taken as to when to harvest the fruit in order to attain the best quality. Post-harvest physiologists describe three stages in the life span of fruits and vegetables: maturation, ripening and senescence. The maturation is indicative of the fruit being ready for harvest (FAO 2008) and there are three maturity states at which tomatoes can be harvested. It can be harvested either in matured green, partially ripened or ripened state. Tomato being a climacteric fruit can be harvested at the matured green state allowing ripening and senescence to occur during the postharvest period of the fruit.

According to Moneruzzaman *et al.* (2009) and Orzolek *et al*. (2006), farmers targeting distant markets must harvest their tomatoes in a matured green state. This will not only give the producers ample time to prepare the fruit for the market but also prevent mechanical injuries during harvesting. Meanwhile, farmers in most African countries harvest tomatoes when they are partially or fully ripened. Fully ripened tomatoes are susceptible to injuries during harvesting resulting in shorter shelf life (Toivonen 2007; Watkins 2006; Reid 2002). This may be the reason why there are high level of losses in tomatoes harvested at fully ripened stage in Africa.

3.1.2 Lack of appropriate harvesting containers

Tomatoes are harvested by manual picking instead of mechanical picking in most developing countries. In harvesting, care should be taken to avoid mechanical damage which can be an entry point for disease causing pathogens. The majority of farmers from Africa use wooden crates and woven baskets with hard and sharp surfaces which cause mechanical injuries to the harvested fruits.

Overloading during harvesting can cause a buildup of excessive compressive stresses resulting in crushing of fruits that are found at the base of the containers (Hurst, 2010). The use of smooth surface and shallow containers that will prevent overloading will reduce both mechanical injuries and crushing of the harvested fruits. Kitinoja (2008) has therefore recommended the use of plastic basket for harvesting tomatoes.

3.1.3 Excessive field heats & lack of on-farm storage facilities

The field heat of harvested crop is usually high especially in the tropics, and should be removed as quickly as possible before any postharvest handling activity (Janet and Richar, 2000). Field heats also give rise to a sudden increase in metabolic activity hence prompt cooling after harvest to reduce the metabolism is very important (Akbudak *et al.* 2012). The optimum temperature for tomato harvesting of about 20 ^{o}C can be attained either in the early hours of the morning or late in the evening. Harvested fruit must be pre-cooled to remove excessive field heat if harvested at times other than the recommended periods. This can be achieved by assembling harvested fruits at a central point with a cooling system in place. A study by Olayemi *et al.* (2010) revealed that, although about 46% of Nigerian farmers harvest their tomatoes in the morning and 12% in the evening, most of them store the harvested tomatoes under tree shades until buyers arrive. Tree shades are not reliable as they are likely to shift away from the produce when the sun changes its position. The fruits are therefore exposed to the scorching sun causing a buildup of field heat in the produce. Farmers in developed countries make use of on-farm cooling systems in dealing with excessive field heats. An example of such facility is the force-air cooling system as shown in figure 1.

Figure 1: A commercial forced-air cooling system (Source: FAO 2002).

Farmers in developing countries on the other hand however do not have the capacity to install such technologies on their farms and have therefore improvised other cooling systems. 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 those in Africa (Olayemi *et al.* 2010). This is an indication that over 90% of farmers have no on-farm storage facilities and therefore leave their harvested produce at the mercy of the weather. This can result in excessive loss of moisture and subsequent deterioration of the produce. The adoption of a simple on-farm structure like a small hut or poly net (figure 2) for temporal storage of harvested produce can be very beneficial in pre-cooling (the first step in good temperature management of harvested produce).

Figure 2: Some low-cost cooling system used in developing countries (Source: Saran *et al.* 2010)

3.1.4 Inappropriate packaging materials

A good packaging system should protect the commodity against pathogens, natural predators, moisture loss, temperatures extremes, crushing, deformation and bruising of the product. Some of the most common packaging materials used in developing countries include large green leaves, clay pots, woven cane baskets, wooden crates, cardboard crates, cardboard boxes, plastic buckets, nylon sacks, jute sacks and polytene bags. The majority of these packaging materials do not allow good aeration within the packaged tomatoes, thereby causing a buildup of heat due to respiration. The shortcomings in some of the packages such as the wooden crates used in Ghana and the woven basket in Nigeria are highlighted below.

The wooden crate in Ghana

The inefficiencies in using the wooden crate lies in the inadequate ventilations provided for cooling, sharp surfaces and edges and depth of the package. The depth of the crate is not appropriate as there is always crushing of fruits near the base as compression pressure increases with depth (Hurst 2010). Figure 3 is an example of the wooden crate in use in Ghana.

Figure 3: A wooden crate used for packaging tomatoes in Ghana (Source: Kitinoja & AlHassan 2010).

Naika *et al.* (2005) suggested that the weight of the produce and the crate should not be more 25kg to prevent the compression stress developing within the packaged tomatoes. Meanwhile the weight of the wooden crate when fully packed with tomatoes in Ghana is about twice the weight as been recommended by Naika et al (2005) and this can cause crushing injuries. It is therefore advised to reduce the depth of the crate and provide padding material at the bottom and in between layers of tomatoes to prevent mechanical injuries.

The woven cane basket in Nigeria

Farmers in Nigeria also use woven baskets from palm fronds to package their tomatoes for sale to customers (Idah *et al.* 2007). The inside of the baskets have sharp edges which cause mechanical injuries to the fruits. The over sized nature of the baskets also results in excessive crushing forces acting on the fruits located at the base of the basket (Hurst 2010). This results in bruising and crushing of the fruit which breaks the integrity of the fruits for the introduction of disease causing pathogens. It is therefore recommended by Idah *et al.* (2007) that the palm baskets should be woven with the smooth side of the material turned inward to give the inside of the basket a smooth touch to reduce mechanical injuries. The diagram below (Figure 4) is an example of woven basket used

by most tomato farmers in Nigeria.

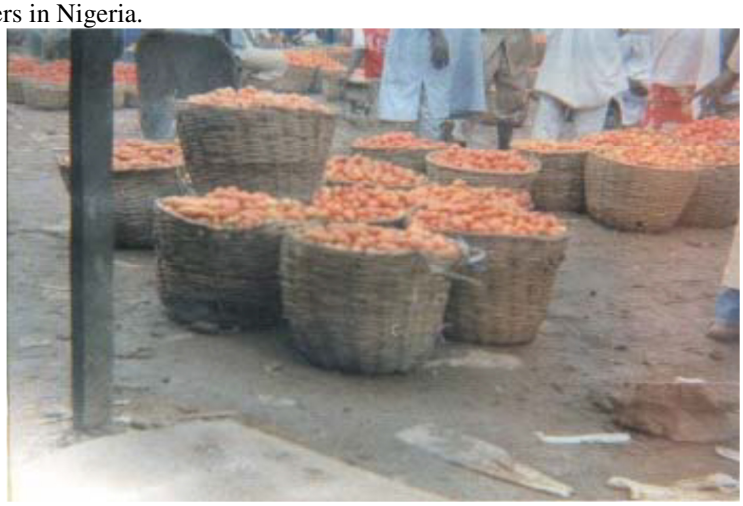

Figure 4: Woven cane baskets used by farmers in Nigeria (Source: Idah *et al.* 2007)

3.1.5 Poor Field Sanitation

Sanitation is of great concern to produce handlers, not only to protect produce against post-harvest diseases, but also to protect consumers from food-borne illnesses. Fresh produce is one of the main sources of food-borne illnesses (Gombas *et al.* 2003). For example, *Salmonella, Hepatitis and Cyclospera* are among the disease-causing organisms that can be transferred via fresh fruits and vegetables like tomatoes (Government of India, undated). Use of a disinfectant in pre-cooling water can help to prevent both post-harvest diseases and field heat in produce. Fruits and vegetables are usually treated with chlorinated water after washing to reduce the microbial load prior to packaging. Workneh *et al.* (2012) indicate that anolyte water dipping disinfection of tomatoes did not only reduce the microbial loads on the fruits but also maintained superior quality of tomatoes during storage. The majority of farmers in developing countries especially those in Africa have no such facilities on-farm to disinfect their produce. Sorting is also not done and rotten fruits which may be carrying disease causing pathogens are mixed with healthy fruits. This practice cause a rapid spread of pathogens within the packaged produce resulting in high deterioration.

3.2 Off-farm causes of postharvest losses in tomatoes

The following are example of off-farm causes of post-harvest losses in tomatoes production in Africa.

3.2.1 Lack of good access roads

Lack of access roads to production fields in many African countries is a major challenge hampering the success of the tomato industry. Majority of the production fields are located in remote areas, which are far from improved roads making access to competitive markets difficult and costly. In cases where there are roads linking these farming sites, these roads are in a very deplorable condition. A study conducted by Yeboah (2011) indicated 76% of farmers and traders in Brong Ahafo region of Ghana complained of bad roads affecting their business. The bad state of road infrastructure makes it very difficult, expensive and time consuming to transport harvested tomatoes to the marketing centres. Meanwhile any delay between harvest and consumption of the tomatoes can result in losses (Kader 1986). Losses of up to about 20% are incurred by farmers due to transportation delays (Babatola *et al.* 2008). This claim may even be an underestimation of the actual transportation losses as vehicles which ply these deplorable roads sometimes get stuck in the mud (as in the case in figure 5) and may take hours or even days to get them out which may result in losses higher than the 20% assertion by Babatola *et al.* (2008). Bad road infrastructure is a major challenge facing most developing countries and this challenge is likely to affect both producers and distributors of tomatoes for a long period. The inaccessible nature of most farming sites has led farmers in Ghana to adopt the use of the "Motor King"– a motorized tricycle (figure 5) which can easily access most of the inaccessible sites.

Figure 5: A motorized tricycle used to convey goods in Ghana (Source: Arah 2015).

3.2.2 Inappropriate mode of transport

The use of appropriate transportation is another factor to consider in postharvest handling of tomatoes. During transportation, the produce should be immobilised by proper packaging and stacking to avoid excessive movement or vibration. Vibration and impact during transportation as a result of undulations on roads is one of the major causes of post-harvest losses to most fruits and vegetables especially tomatoes (Idah *et al*. 2007). The bad nature of roads in most African countries coupled with the inappropriateness of the transportation options (i.e. figure 6) therefore provides these unfavorable factors during transportation resulting in great losses.


Figure 6: A man transporting tomatoes on a motor bike in Nigeria (Source: Scan News 2015)

Farmers in developed countries use refrigerated containers and trailers which travel on reasonably good roads. Transporting tomatoes in refrigerated trucks is not only convenient, but also effective in preserving the quality of fruits. However, both the initial investment and the operating costs are very high and beyond the affordability of most farmers in developing countries. Farmers therefore transport their produce using the most affordable mode of transport without considering the effect it will have on the quality of produce. The nature of these transportation options available to the farmers in Africa does not provide the stability the stacked produce needs during transportation. The wobbling nature of such vehicles coupled with the bad roads cause a lot of mechanical damage to the produce before it reaches its destination.

3.2.3 Lack of processing equipment and factories

The unavailability of processing factories or redundancy in the available ones is also another challenge tomato producers in developing countries are faced with. Senegal promoted the farming of tomatoes and established processing plants that made Senegal the 23rd largest processor in the world during the early 1970s (Food processing Africa, 2012). Produce from farmers were used as the raw materials for these processing industries.

A study in 2007 revealed that Senegal's processing had fallen from 73,000 tons of concentrate tomatoes in 1990 to 20,000 tons in 1996 processing year, while imports from EU's tomato increased from 62 tons in the year 1994

to whooping 5,348 tons in 1996. The Senegalese processors apparently found out that it was cheaper to buy and dilute tomato paste from Italy than purchasing tomatoes from local farmers. Local producers were therefore left to their fate with their harvest which has eventually caused a reduction in production figures over the years.

Producers in Ghana were also faced with similar fate when a processing plant that was producing around 100 tons of tomato paste in a day at Pwalugu in the Upper East Region was closed down. Ghana is now the largest importer of tomato and tomato-base products, importing from as close as neighboring Burkina Faso and to as far as Europe and Asia (Aryeetey 2006). Meanwhile local producers, who were established to supply the processing company, continue to produce at a glut, resulting in very low prices for sales to households use. The lack of market coupled with the high investment incurred during production led to three local producers committing suicide in the 2008 farming year (IRIN 2009).

The solution to this challenge is to promote the use of low cost postharvest processing technologies that can be used to process the raw materials into a more durable form. An example of such technology used in Ghana is the Cottage Italia Industries Limited's "Tomato master" (figure 7), a processing unit used to process tomatoes into puree for bottling.

Figure 7: Tomato master in use.

3.2.4 Lack of reliable market

Market availability is a big challenge facing most tomato producers in developing countries especially those in Africa. This challenge can be attributed to many factors. One of the factors is the pattern of production resulting in gluts. Although there has been a tremendous improvement in the use of irrigation scheduling in dry season tomato production (Ofori-Sarpong 2001), a greater proportion of producers still rely on rain fed production. The bulk of tomato production in Nigeria for example is carried out during the wet season of the production year (Adenuga *et al.* 2013). This causes high peaks in production which is always more than consumption demand of the fresh fruit locally. The problem is further compounded by the lack of processing facilities which can be used to process and preserve the fruits for later consumption. Producers from developed countries always have supply contract with multinational supermarkets to supply tomatoes. An example is the Blush tomatoes in Australia which supplies Coles and Woolworth with tomatoes making access to market already predetermined. In the case of producers in Africa, there is no information on reliable market availability. There is lack of communication between producers and consumers and also lack of market information (Kader 2005). This has been the main reason for the mismatch between production and available markets. Producers therefore have to sell their harvest at very low cost to prevent total loss. Marketing cooperatives are needed by producers in African countries in major tomatoes producing areas to create market for producers. Figure 8 shows crates of tomatoes lined up by the road in Ghana waiting for prospective buyers.

4.0 Conclusion

Tomatoes and tomato-based foods provide a wide variety of nutrients and many health-related benefits to the body. The tomato industry has the ability to increase the export earnings of African countries whilst improving the living standards of the individuals producing it. Postharvest losses and other challenges however, pose a great threat in the quest to attain all these benefits. Postharvest challenges, both on-farm and off-farm are gradually collapsing the tomato industry in most African countries. Importation of finished tomato products is an indication that most developing countries are not self-sufficient in tomato production. Even though there is always a glut on the market, this is only short-lived, as tomatoes are highly perishable and difficult to store if not processed. The inefficiencies in the post-harvest handling of tomatoes have therefore created a demand shortfall which is being filled with imports of processed products. Until these gaps of inefficiencies are closed using the appropriate intermediate technologies, producers as well as the governments in African countries will not derive

the maximum benefit from tomato production.

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