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THE MANAGEMENT OF POST-HARVEST LOSSES OF TOMATO IN DEVELOPING COUNTRIES

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Abstract

Reducing post-harvest losses of fresh produce has been demonstrated to be an important part of sustainable agricultural development efforts meant to increase food availability. Failure to achieve food security in most developing countries can be attributed to over-reliance on production related activities and the lack of adequate training of farmers on post-harvest handling practices, slow or no development of appropriate post-harvest infrastructure or neglect of other aspects of the post-harvest chain during transportation and marketing. Reducing food losses offers an important pathway of availing food, alleviating poverty, and improving nutrition. Moreover, reducing post-harvest losses has positive impacts on the environment and climate as it enhances farm-level productivity and reduces the utilisation of production resources or expansion into fragile ecosystems to produce food that will be lost and not consumed. Tomato is a major vegetable crop that has achieved tremendous popularity over the last century. It is grown in practically every country of the world in outdoor fields, greenhouses and net houses. Global post-harvest losses of tomato are as high as 30-50%, but this can be much higher in developing countries due to improper handling procedures and lack of appropriate methods to prevent decay.

Keywords: Food supply, post-harvest handling, post-harvest losses, storage, tomato

INTRODUCTION

Tomato is the second most important and popular vegetable crop in many developing countries, after cabbage (Department of Agriculture, Forestry and Fisheries, Republic of South Africa, 2014). It is not only cultivated commercially, but also commonly grown by subsistence, resource-poor farmers and home gardeners. According to Department of Agriculture, Forestry and Fisheries, Republic of South Africa (2014), tomato marketing, like all other commodities is influenced by international factors, such as:

i) competing against subsidised products from the developed countries;
ii) the value of local currency against major trading currencies like the Euro and dollar; and
iii) poor climatic conditions over many tomato producing areas.

The growing importance of vegetable production in most developing countries can be appreciated in terms of:

i) the rising domestic demand on account of increasing population and per capita income; increasing export potential;
ii) need for providing employment opportunities in the rural areas; and
iii) vegetables being relatively more lucrative crops as compared to agronomical crops.

According to Richardson (2013), tomato is cultivated in both the tropics and temperate zones. Approximately 160 million tonnes of tomato are produced annually on 4.7 million hectares worldwide. Tomatoes are consumed fresh, cooked or processed into various products. Tomato contributes to a healthy human diet. It is rich in minerals (especially iron and phosphorous), vitamins (vitamin B and C), lycopene (anti-oxidant), essential amino acids, sugars, and dietary fibres (Ayandiji *et al*., 2011; Etebu *et al*., 2013). It helps reduce incidences of prostate and breast cancer (Etebu *et al*., 2013).

Canned and dried tomatoes are economically important processed products. Tomato has become an important cash and industrial crop in many parts of the world. Tomato is considered as an important cash and industrial crop. It is grown for fresh market and for processing purposes. Domestic consumption and demand for tomato in many

countries have been increasing over the years due to increase in population. It is consumed in many homes in different modes, such as a vegetable, salad, tomato sauce, puree, as an ingredient in many dishes, and also in drinks (juices) (Awan *et al*., 2012; Department of Agriculture, Forestry and Fisheries, Republic of South Africa 2014).

Richardson (2013) reported that tomato is a highly perishable crop and cannot be stored for extended periods. The internal structure of the tomato fruit varies from cultivar to cultivar and plays an important role in the qualities such as uniformity of shape, size and firmness (Richardson, 2013). Firmness is a quality consideration that impacts storability and shelf-life of the fruit and is strongly affected by cultivar, environment, nutrition and physiological disorders. Tomato cultivars with thicker pericarp are better able to withstand transportation over long distance and remain firm for a longer duration, when compared to thinly fleshed types. In addition, larger fruits usually have thicker pericarp as compared to small ones (Richardson, 2013).

POST-HARVEST LOSSES OF FOOD IN THE DEVELOPING COUNTRIES

According to Kitinoja and Al Hassan (2012), field observations over the past four decades have indicated that 40-50% of the horticultural crops produced in developing countries are lost before they can be consumed, mainly because of high rates of bruising, water loss and subsequent decay during post-harvest handling. Losses can also show up as decreased nutritional quality (loss of vitamins, development myco-toxins) or decreased market value. The magnitude of these losses and their impact on farm income varies greatly from place to place and has often been difficult to assess since losses are related to improper temperature management, and the post-harvest handling chain includes all steps between harvesting and consumption (Kitinoja and Al Hassan, 2012). According to Rehman *et al*. (2007), evidence suggests that these losses tend to be the highest in those countries where the need for food is greatest. However, these losses may be lower in less urbanised regions, where the products need to be transported a shorter distance to market, and there is a shorter time lag period between harvesting and consumption.

In some developing countries, a major obstacle in the efforts to achieve post-harvest loss mitigation is the lack of clear knowledge of the real magnitudes of losses, which makes it impossible to measure progress against any loss reduction targets (Affognon *et al*., 2015). Uncertain estimates of post-harvest losses, coupled with imprecise understanding of the points in the value chains where the losses occur as well as the socio-economic factors for the losses could end in policy errors and sub-optimal choices of mitigation approaches (Affognon *et al*., 2015).

Until recently, modern technologies of post-harvest handling of fruits and vegetables such as improved storage, packaging, transportation and handling techniques in developing countries were virtually non-existent (Addo *et al*., 2015). Post-harvest losses have been highlighted as one of the determinants of the food problem in most developing countries. Post-harvest loss prevention technologies are paramount as more produce is transported to non-producing areas to supply the growing population as well as storing for longer period to obtain a year round supply (Addo *et al*., 2015).

Despite the remarkable progress made in increasing food production at the global level, approximately half of the world population in the third world does not have access to adequate food supplies (Rehman *et al*., 2007). There are many reasons for this, one of which is food losses occurring in the post-harvest and marketing system (Rehman *et al*., 2007; Ferreira *et al*., 2005). According to (Rehman *et al*., 2007; Ferreira *et al*., 2005), primary factors responsible for post-harvest produce losses include:

i) poor pre-harvest measures;
ii) adoption of poor production techniques (varieties with low shelf-life;
iii) imbalance use of nutrients;
iv) insect pest infestation;
v) disease infection;
vi) abiotic stresses;
vii) non-application of pre-harvest recommended treatments/practices;
viii) harvesting at improper stage and improper care at harvest;
ix) removal of field heat;
x) moisture condensation causing pathogen infestation;
xi) packaging in bulk without sorting and grading;
xii) improper transportation and storage; and
xiii) distant and time consuming market distribution.

These losses bring low returns to growers, processors and traders and the country also suffers in terms of foreign exchange earnings (Rehman *et al*., 2007; Ferreira *et al*., 2005).

POST-HARVEST LOSSES IN TOMATO

Losses of horticultural produce especially tomato are a major problem in the post-harvest chain. Losses are caused by a myriad of factors ranging from growing conditions through handling at retail level. Not only are the losses clearly a waste of food, but they also represent a similar waste of human effort, farm inputs, livelihoods, investments, and scarce resources such as water (Addo *et al*., 2015). Etebu *et al*. (2013) reported that application of biological, chemical and physical methods to control post-harvest losses in tomato is more sustainable and environmentally friendly than increasing production areas to compensate for these losses.

Etebu *et al*. (2013) postulated that tomato fruits, by nature have low pH, higher moisture content and nutrient composition, and these inherent attributes renders them very susceptible to attack by pathogenic fungi, which in addition to causing rots may also make them unfit for consumption by producing myco-toxins. Fungi are the most important and prevalent pathogens, infecting a wide range of fruits causing destruction and economically important losses during storage, transportation and marketing. Poor handling, packaging, storage, and transportation eventually result in decay and increase the growth of micro-organisms, which become activated because of the changing physiological state of the produce (Etebu *et al*., 2013). Pathogens found in packaging materials like crates and baskets, farm tools etc., can initiate disease upon contact with healthy tomatoes, which eventually result to losses (Etebu *et al*., 2013).

Olayemi *et al*. (2010) stated that, to achieve food self-sufficiency, there is urgent need to match all efforts at increasing crop production with equal if not greater efforts of post-harvest technology to save the crops that are produced from deterioration and wastage. Being a climacteric and perishable vegetable, tomato has a very short shelf-life, usually 2-3 weeks (Gharezi *et al*., 2012). Post-harvest recommendations indicate that tomatoes should be stored at 10^{o}C or higher to avoid chilling injury (Gharezi *et al*., 2012).

Bartz *et al*. (2015a) and Aidoo *et al*. (2014) observed that post-harvest decay losses for field-grown, fresh-market tomatoes are usually associated with harvests that occur when fields are wet and warm (>32^{o}C). During wet periods, decay pathogens infect damaged fruits on the plant as well as injuries to petioles and stems. During harvest, enormous pathogen populations created by these infections spread via picking operations throughout the harvested fruit. Inadvertent harvest-related wounds are particularly vulnerable to infection. Growing conditions that increase colour defects, like speckling, in tomato include using cultivars that are not resistant to blossom end rot, excess irrigation, application of fertilisers high in Cl^{-} (relative to SO_4^{2-} and NO_3^{-}) and high P and Ca^{2+}, high Ca/K ratios, and higher nitrate, along with a high relative humidity environment (Bartz *et al*., 2015b).

Samuel (2015) reported that an alarming 45% of tomatoes harvested in Nigeria are lost due to poor food supply chain management, price instability, resulting from seasonal fluctuation in production and the supply preference of farmers and middlemen for urban markets than processors due to low farm gate prices. Genanew (2013) argued that extending post-harvest life of horticultural products require knowledge of all the factors that cause loss of quality so as to develop affordable technologies that minimise rate of deterioration. Length of storage, respiration, transpiration, chemical composition, external appearance, anatomical structures, delay harvesting, taste qualities, and other post-harvest characteristics have a significant impact on produce quality (Genanew, 2013; Samuel, 2015).

Post-harvest losses in tomato are most often caused by insect pests, microbial infection, physiological breakdown due to ripening processes, and environmental conditions such as heat and drought. Furthermore, improper post-harvest sanitation, poor storage, improper packaging practices, and mechanical damage during harvesting, handling and transportation resulting from vibration by undulation and irregularities on the road mechanical can enhance spoilage (Olayemi *et al*., 2010). Saeed and Khan (2010) observed that, deterioration of tomato due to packaging material was 25%; transportation system 10%; and storage, grading and distribution 5% in Lahore, Pakistan. Time lag in transportation, bulky packaging in the traditional wooden crates wrapped with papers cause high humidity making the micro-climate favourable for micro-organisms.

According to Aidoo *et al*. (2014), inappropriate storage facilities and rough handling during harvesting result in bruising and increased possibilities of contact of the produce with the soil, which leads to contamination with micro-organisms. Long distance from farms to market as well as insufficient storage conditions can lead to losses. Improper harvest and post-harvest practices result in losses due to spoilage of the product before it reaches the market, and loss of quality attributes such as appearance, firmness, taste, and nutritional value (Aidoo *et al*., 2014). Long distance from farm to the market results in high losses due to congestion of the tomato fruits and resultant heat build-up. Skilled labour pick and handle produce with care and hence do little damage to the fruit. Tomato fruit should be harvested at mature green stage for long distance marketing and full ripen stage for fresh consumption in order to reduce post-harvest losses (Aidoo *et al*., 2014). The variety of tomato produced affects the level of post-harvest losses as different cultivars have different characteristics such as firmness, disease resistance, longer shelf-life, thick skin, which help the fruit to withstand pressure during harvesting and maintain quality during storage. It is also advisable to harvest tomato in the morning, when temperatures are cool to reduce field heat and consequently losses (Aidoo *et al*., 2014).

Aidoo *et al*. (2014) reported that male gender, large household size, membership to farmers based organisations (FBO), and cultivation of right tomato cultivar in Ghana were associated with lower levels of post-harvest losses. However, large farm size, and high number of days of storage after harvesting before sale were found to be associated with higher levels of post-harvest losses (Aidoo *et al*., 2014). Reduction of post-harvest losses can contribute to tomato self-sufficiency without increasing hectarage under production. Through formation of FBOs, farmers can establish small processing centres that would process tomato into puree and other alternative products, when there is a no

ready market for fresh fruits (Aidoo *et al*., 2014). Farmers should be encouraged to stager production to allow for harvesting in stages, which comes with reduced labour requirements and reduced post-harvest losses. Periodic training in harvesting and proper handling of harvested tomato should be organised for farmers. Private entrepreneurs should be encouraged to invest in the tomato industry by building appropriate cold storage facilities in the major production areas, in order to reduce losses (Aidoo *et al*., 2014).

According to Rupasinghe *et al*. (2015), pod borer (*Heliothis zea*) attack and blight (*Alternaria solani* and *Phytophthora infestans*) are major causes of post-harvest losses in tomato at farm level. Over maturity at harvest, bird attack and losses due to sun scorch also contribute significantly to post-harvest loss in tomatoes. In addition, tomato growers with small hectarage were associated with increased harvesting intervals, which resulted in high percentage of over-maturity.

CONTROL OF POST-HARVEST LOSSES IN TOMATOES

Sanitation

Buonassisi (2013) argued that following strict sanitation is critical in preventing storage rot and other production area diseases using 70% alcohol (ethanol, iso-propanol) 10% bleach, peroxides and quaternary ammonia. It involves:

i) regular cleaning and disinfection of production areas especially at the end of production to prevent carry-over of diseases to new crop;
ii) maintaining a high level of sanitation throughout crop growing, harvesting and transportation phase;
iii) adopting sanitation procedures recommended in each country;
iv) keeping records documenting all sanitation procedures implemented;
v) visitors and workers should use footbath and hand wash at all entrances and exits of greenhouses; and
vi) sanitising tools, knives, and picking containers before and after use.

Post-harvest sanitation methods include:

i) cleaning and sanitisation of packing house facilities;
ii) cleaning and sanitisation of walls, floors, equipment, containers, and pallets to ensure harvested tomato is not contaminated;
iii) sanitisation of holding areas, packing house, storage,, and distribution facilities;
iv) sanitisation all harvesting, sorting, weighing, and packaging equipment; and
v) immediate disposal of waste.

Grading and sorting

Chohan and Ahmad (2008) observed that essentially all fruits and vegetables sold in modern markets are graded. Sophisticated marketing systems require grading and standards for each kind of product. Less developed markets may not use grading and standards but products are sorted to some extent. An inefficient grading operation can cause significant injuries to produce.

Kitinoja and Al Hassan (2012) stated that the general lack of field sanitation and lack of pre-sorting to remove decayed produce before packing promoted spread of fungal and bacterial diseases and insect pests during handling. Pre-sorting losses of tomatoes at farm level from decay and insect damage in the field was reported to be 12.9% in Ghana and 23.0% in Benin.

Packaging

Chohan and Ahmad (2008) indicated that container-packing is considered ideal for fruits and vegetables because these are easier to handle, provide protection from mechanical damage, have adequate ventilation, and convenient for merchandising. They are easily printed with information about the product packed and are helpful in advertising about the product. Fibreboard boxes, wooden or plastic crates are often used for high value products. Inexpensive containers such as bamboo baskets or nylon nets sacks are commonly used for low-priced products.

Precooling

Temperature plays a vital role in maintaining good condition of harvested fresh produce. Good temperature management is the most effective way to reduce post-harvest losses and preserve the quality of fresh produce. Chohan and Ahmad (2008) postulated that rapid removal of field heat by precooling is effective in quality preservation and this procedure is widely used for highly perishable fruits and vegetables. Currently precooling methods used include:

i) room cooling;
ii) vacuum cooling;
iii) forced air cooling, water cooling; and
iv) package icing.

Similarly, desirable storage and transportation temperatures are necessary to maintain freshness of produce (Chohan and Ahmad, 2008).

Storage

Storage is usually required to ensure continuous supply of raw materials to the processing industries so as to extend the length of the processing season (Genanew 2013). The ultimate role of post-harvest technology is to device methods by which deterioration of produce is restricted as much as possible during the period between harvest and use, which provides flexibility to producers and traders on when and

where to market commodities in order to maximise net returns (Genanew 2013). Many horticultural crops have a relatively short harvesting season. Storage is needed to extend the marketing period. Air-cooled storage houses are often used in this regard (Genanew 2013).

Transportation

Etebu *et al*. (2013) observed that, most tomato growers use trucks, cars and passenger vehicles (buses and mini-buses), to bring them to the market. Inappropriate transportation system results in high losses of the produce. Stacking of containers can result in compression of produce from the weight. Apart from the mechanical damage caused to tomatoes, proper ventilation in such cases is non-existent or grossly inadequate. The result is usually produce rot arising from high level of physiological activities of the produce occasioned by lack of proper and/or inadequate ventilation (Etebu *et al*., 2013). Market assessment has revealed that tomatoes found in the market show signs of bruising, rot, compression, and water soaked areas on the fruits (Etebu *et al*., 2013).

Etebu and Enaregha (2013) stated that in most countries, tomatoes can be produced in particular areas necessitating distribution to other areas. Appropriate transportation vehicles may not be available in most developing countries, resulting in using harsh and indecent methods such as fastening tomato consignments onto fuel tankers, combination of tomato with charcoal, construction material in trucks (Etebu and Enaregha, 2013). Freshly harvested tomato fruits are usually stored and conveyed in traditional weaved wicker baskets in Nigeria, and these baskets are often reused over and over again until they become contaminated with fungal spores from previously infected fruit (Etebu and Enaregha, 2013).

Sharma and Singh (2011) reported that the extremely perishability of vegetables results in inability on the part of the producer to manage supply effectively. Further, the long distance that separate production areas and the markets; sub-optimal post-harvest technologies used in harvesting, grading, packaging, storage, and transportation results in a large proportion of vegetables lost or spoiled at various stages of the supply chain (Sharma and Singh, 2011).

Pesticides

Tomato production in many developing countries is often challenged by an array of plant diseases that are promoted by a warm, moist climate (Bartz *et al*., 2015b; Saeed *and* Khan 2010). Conditions promoting plant diseases also favour the development of fruit rots, both in field and during handling and shipping (Bartz *et al*., 2015b). Fruit rots are generally caused by opportunistic pathogens (like *Aspergillus niger, A. fumigants, A. flavus, Fusarium equiseti, F. chlamydosporum, Rhizophus stolonifer, Alternaria solani, Phytophthora* spp., *Fusarium* spp., *Penicillium* spp., *Botrytis cinerea, Geotrichum candidum*, soft rot-causing bacteria like *Erwinia carotovora*, *Xanthomonas* spp, and *Clavibacter* spp.), which are found on plant debris (Bartz *et al*., 2015b; Saeed *and* Khan 2010). Mechanical injuries (e.g. cuts, punctures) that occur during harvesting and handling are a frequent site of decay development beginning on the fruit surface (Bartz *et al*., 2015a; Bartz *et al*., 2015b; Etebu *et al*., 2013).

Synthetic fungicides treatments have been the main method of controlling post-harvest diseases. However, there is increasing international concern over the indiscriminate use of fungicides because of the possible harmful effects on human health (Bartz *et al*., 2015b; Saeed *and* Khan 2010). According to (Etebu *et al*., 2013), a variety of strategies have been employed to control post-harvest disease and losses of tomato, which include:

i) biological control (*Bacillus subtilis, Saccaromyces cerevisae, Candida tanuis,* and *Trichoderma virens* are some of the bacteria and fungi that have been used in the control of post-harvest tomato diseases);
ii) bio-active compounds (potassium bicarbonate, sodium metabisulphite, calcium chloride, nitrous oxide etc.);
iii) plant extracts (garlic, ginger, *Tridax procumbens, Veronica amygdalina, Chromoelena odoarata, Azadirachta indica, Ocinum gratissimum* etc.);
iv) heat treatment (four minutes at 49^{o}C and above);
v) irradiation; fumigation; and
vi) waxing (reduce water loss in tomato by 30-50%, entry by microbes and shrivelling).

CONCLUSION

The deterioration of tomato starts during harvesting operations, because fresh fruits are inherently perishable. The more carefully a product is handled, the slower the deterioration process during subsequent handling operations. The causes of tomato losses include physical damage during handling and transportation, physiological decay, water loss, or sometimes simply because there is a surplus or glut in the market. In developing countries, storage, packaging, transportation, and handling techniques are practically non-existent leading to considerable losses of produce. Thus, as more fresh produce is needed to supply the growing populations in most parts of the world and as more commodities are stored longer to obtain a year-round supply, post-harvest loss prevention technology measures become paramount. The losses of quality and freshness of the produce could also be due to improper temperature management, drying of the product, mechanical injury, and attack by bacteria and fungi. These losses can lead to decrease in returns to the farmers. Despite remarkable progress made in increasing world food production at the global level, approximately half of the population in the third world does not have access to adequate food supplies. One of the reasons is food loss occurring in the post-harvest and

marketing systems. These losses tend to be higher in countries where the need for food is greatest. Unfortunately, in many countries experiencing food problems, there seem to be no consistent food policy framework, which should form the foundation of effective implementation of programmes. Food supply can be improved either by increase in production or more importantly, reduction in loss.

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