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Postharvest Spoilage of Tomato (*Lycopersicon esculentum* Mill.) and Control Strategies in Nigeria

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Abstract
Tomato (*Lycopersicon esculentum* Mill.) is a globally grown vegetable fruit, rich in vitamins and minerals. It is used for culinary purposes and in the production of fruit drinks. A total of one million hectares per annum is reportedly used for its cultivation in Nigeria, alone. However, the quality and shelf life of postharvest tomato in Nigeria is hampered by biotic and social economic constraints which affect its nutritional value, and account for10-30% of losses. Amongst the biotic constraints are different species of fungi such as *Alternaria, Fusarium, Penicilliun, Aspergillus, Geotrichum, Phytophthora* as well as *Botrytis*, while those of bacteria are *Xanthomonas euvesicatoria pv. Xesicatoria*, and *Clavibacter michiganensis* sub sp. *Michiganensis*. Some of the social and institutional constraints militating against the control of postharvest losses in tomato include amongst others, ineffective government agencies, lack of credit facilities that address the need of producers, lack of a clear-cut policies to encourage the utilization of human and scientific resources to prevent deterioration of the crop, inadequate institutions that would develop human resources with relevant knowledge in scientific technologies associated with preservation, processing, packaging, transporting, and distribution of food products. The application of biological, chemical and physical methods amongst others can be adopted to control postharvest diseases of tomato. Adopting strategies to reduce postharvest diseases and losses of food is more sustainable and environmentally sound than increasing production areas to compensate for these losses.
Keywords: Tomato, Fungi, Bacteria, Postharvest, Disease Control

Introduction

Tomato *(Lycopersicon esculentum Mill. Syn. Solanum lycopersicon)* is a widely grown fruit the world over (Agrios, 2005). It is native to South America (Nonneoke, 1989), but was introduced into West Africa by Portuguese traders and freed slaves from West Indies (Tindall, 1988). Tomato is rich in vitamins (John *et al,* 2010; Bugel, 2003), minerals and lycopene, an excellent antioxidant (Osemwegie, *et al.,* 2010) that helps to reduce the risk of prostate and breast cancer (Giovannucci, 1999). Global production is about 89.8 million metric tonnes from an area of about 3,170.000 ha (Samuel, *et al*, 2011). Nigeria is second largest producer of tomato in Africa (Erinle, 1989) where a total area of one million hectares is used for tomato cultivation every year (Anon, 1989; Bodunde, *et al*, 1993). Tomato accounts for about 18% of the average daily consumption of vegetables in Nigeria (Olayide *et al*, 1972), and may be pressed into pastes or purse which is used for cooking and in the production of fruit drinks (Babalola, *et al*, 2010).

The quality and nutritional value of freshly produced tomato fruits is affected by pre- and postharvest diseases, improper handling and other conditions (Kader, 1986). Fungi are the most important and prevalent pathogens that infect a wide range of host plants, causing destruction and economic loss in tomato either in the field, storage or transportation (Sommer, 1985). The estimated total loss in Nigeria due to these constraints is about 60% (Kutama, *et al*, 2007). Also Opadokun (1987) submitted that 21% of tomato harvested in Nigeria was lost to rot in the field and additional 20% to poor storage system, transportation and marketing. This huge loss has prompted the search for simple, effective and economical methods to control pre- and postharvest diseases and other losses in tomato (Wilson and Wisniewski, 1989).

The aim of this paper is to review the importance of postharvest losses and other socio-economic constraints in tomato production and harness the control measures studied by different workers in Nigeria.

Brief history of tomato cultivation

Tomato *(Lycopersicon esculentum Mill.)* is one of the most popular and widely grown plants in the world as well as in Africa (Osemwegie, *et al.,* 2010). It is the second most important vegetable worldwide, in terms of the amount of vitamins and minerals it contributes to the diet (Enrique & Eduardo, 2006). It is native to South America, but was introduced into Europe and became known to botanists about the middle of the sixteenth century. Genetic evidence shows that the progenitors of tomatoes were herbaceous green plants with small green fruit and a center of diversity in the high lands of Peru (Smith 1994). One species, *Solanum lycopersicum*, was transported to Mexico where it was grown and consumed by Mesoamerican civilization. The Spanish explorer, Cortes may have been the first to transfer the small yellow tomato fruits into Europe after he had captured the Aztec city of Tenochtitlan, now Mexico City in 1521; although Christopher Columbus, a Genoese working for the Spanish monarchy may have taken them back as early as 1493. The earliest discussion of tomato in European literature appeared in an herbal written in 1541 by Pietro Andrea Mathiolian Halian, an Italian physician and botanist, who named it pomod'oro, or 'gold apple' (Smith 1994). The word ''tomato'' is derived from the Nahuatl word tomatl, literally 'the swelling fruit' and the latin name of tomato is *Lycopersicon esculentum* Mill. Syn. *Solanum lycopersicum* (Cutler, 1998). Tomatoes were not grown in England until the 1590s. One of the earliest cultivators was John Gerard, a Herbal-Surgeon. Smith (1994) reiterates that Gerard's Herbal, published in 1597, and largely plagiarized from continental sources, is indeed one of the earliest discussions of tomato in England. Similarly, Tindall (1988) remarked that the Portuguese trader and freed slaves from West Indies introduced this plant into West Africa Countries.

Tomato production and postharvest spoilage in Nigeria

Nigeria is second largest producer of tomato in Africa second only to Egypt and 13th in the world, and produces 6 million tonnes of tomato annually prior to 1990 (Erinle, 1989). Tomato is cultivated almost all over Nigeria (Olanrewaju and Swamp, 1980). The major producing areas in Nigeria lie between latitudes 7.5 °N and 13 °N, and within a temperature range of 25 – 34 °C (Villareal, 1980); thesee areas include most States in Northern Nigeria namely- Bauchi, Benue, Borno, Kaduna, Kano, Plateau, Sokoto, and a few southern states like Kwara and Oyo (Denton and Swarup, 1983; Olanrewaju and Swamp, 1980) as shown in Fig. 1. The cultivation of tomato in the South-South region especially Bayelsa and Delta States is faced with serious constraints, because the states are situated in the heart of the tropical rainfall region with its low topography. Another constraint is the fact that the states witness a greater period of rainfall (April to November) which does not support the growth of this heat-loving crop. For this reason, cultivation by farmers is primarily for subsistence purpose rather than commercial.

The relatively low production of tomato in Nigeria as compared to Asia, Europe, North and South America is attributable to biotic, social and environmental constraints. Prominent among such constraints are pests and diseases which reduce yield and the quality of marketable fruits. In the tropics, particularly in Nigeria, many insect pests are associated directly with tomato damage and yield losses, while others are important as vectors of diseases (Anonymous, 1986; Messiaen, 1992; Tindall, 1977; Umeh and Oyedun, 1995).

Global postharvest losses of tomato are as high as 30-40% (Agrios, 2005; Kader, 1992), but this is much higher in developing countries like Nigeria due to improper handling procedures and lack of methods to prevent decay (Prigojin, *et al*, 2005). 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 mycotoxin (Philips, 1984; Moss, 2002; Stinson *et al.*, 1981). Fungi are the most important and prevalent pathogens, infecting a wide range of fruit and causing destructive and economically important losses of fruits during storage, transportation and marketing (Sommer, 1985). The extent of postharvest damage due to spoilage fungi is reportedly dependent on tomato variety. A relatively recent study carried out in Oyo State, South western Nigeria showed that whilst up to 44% of postharvest spoilage was attributed to microorganism in a given tomato variety, only 14-23% of spoilage was attributed to the same microorganism among other varieties (Adeoye *et al*., 2009)

Pre-harvest production practices may seriously affect postharvest return. Losses due to soil borne fungi like *Phytophthora capsici* is well documented (Hausbeck and Lamour, 2004; Ewin and Riberio, 1996). *P. capsici* cause late blight and other infections, resulting to wilting in tomato crops (Hausbeck and Lamour, 2004). Other soil borne fungi that can cause severe losses in tomato are *Alternaria solani* which causes early blight, *Septoria lycopersici* is responsible for *Septoria* leaf spot in tomato, *Fusarium oxysporum* cause Fusarium wilt etc.

Postharvest tomato losses during storage and transportation are estimated to be as high as 20% in Nigeria (Olayemi, *et al*, 2010). Poor handling, packaging, storage and transportation eventually result in decay and increase the growth of microorganisms, which become activated because of the changing physiological state of the produce (Wilson *et al*, 1991). In Northern Nigeria where tomato is majorly produced, freshly harvested tomato fruits are stored, and conveyed in traditional weaved wicker baskets (Kutama, *et al,* 2007). These baskets are often used until they become infected with primary fungal spores that might have previously infected the fruits. Kora and associates (2005) observed that pathogenic inocula occurring on wooden boxes and baskets can initiate disease upon contact with healthy fruits, which eventually result to losses. It has also been pointed out that the inocula responsible for storage diseases among tomato often originates from infected and infested farm tools (Snowdon, 1992). As mentioned earlier on, postharvest tomato losses are also incurred during transportation from farms and locations where they are produced to markets. There are two main modes of transportation available to domestic transporters and handlers of fresh produce in Nigeria, the rail and the road system. However, transporters complain of the non-availability and unusual delays in rail system. Consequently, most the handlers use the road system for their regular and long distance haulage (Idah, *et al*, 2007; Olayemi, *et al*, 2010).

Different types of vehicles are used to convey harvested tomato from the Northern part of Nigeria where it is majorly produced to other parts of the country. The major types of vehicles used in transporting their produce have been succinctly described by various workers (Idah, *et al*, 2007; Olayemi, *et al*, 2010). Most transporters use the 911 lorry shown in Figure 2 because of its capacity and superior ventilation. A typical example of vehicles used in transporting tomato from Northern Nigeria to the Southern parts of the country is shown in figure 2. A typical vehicle could carry between 250 and 300 baskets or jute bags load of fresh produce (about 7,500 and 9,000 kg). The problem of transportation is often exasperated by non-availability of vehicles when most needed. To avoid loss of their produce, the traders result to the use of any kind of available vehicle, sometimes even passenger buses are not spared. Marketers and distributors of tomato who convey the harvested product from Northern Nigeria to other parts of the country sometimes are seen to be very desperate as they fasten tomato consignments onto of fuel tankers and other articulated vehicles (Idah, *et al*, 2007; Olayemi, *et al*, 2010). These rather weird and desperate actions expose tomatoes to accidental fall off during the course of transportation and these losses could be heavy, though not usually quantified.

The containers (baskets) are usually arranged in 5 to 6 layers inside the vehicle with woody planks in-between these layers. Some transporters use leaves to separate the layers, which normally do not prevent compression of the produce from the weight (load) of those on top. This practice is thus one of the sources of mechanical damage to the produce. Additionally, proper ventilation is sometimes either 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 adequate ventilation (Idah, *et al*, 2007; Kra and Bani, 1988; Olayemi, *et al*, 2010).

An assessment carried out at a market in Ilorin, Nigeria revealed quite a lot of tomato fruits damage. Damaged fruits mainly consisted of bruised, rotten, compressed and water soaked fruits. In particular, an average of 13.89% of fresh tomato fruits was reportedly damaged during transportation (Idah, *et al*, 2007). This means, in every consignment of 7,500 kg (lorry load) of tomato fruits about 1041.67 kg (representing 13.89%) of the fresh tomato fruits would be bad. In terms of money, for an average price of N200.00 per kg, the losses due to this damage is about N200,000.00 per lorry load if such damaged fruits are completely discarded, which is really substantial (Idah, *et al*, 2007). It is worthy to note that Ilorin where this assessment was done is situated in Northern Nigeria where tomato is produced. The amount of spoilt tomato would increase substantially by the time they get to markets situated down south of the country.

At the market level, losses of tomato can be significant particularly in developing countries like Nigeria. A recent survey of markets in Yenagoa, capital of Bayelsa State, Nigeria revealed poor market facilities and storage arrangements of tomato displayed for sale (Fig. 2). Tomato fruits were seen washed with dirty water. Decaying and spoilt produce were indiscriminately left around packing house or shops. These conditions no doubt expose the fruits to pathogenic organisms and other environmental problems, leading to rapid deterioration of produce. Adeoye and Associates (2009) reiterate that mechanical damage to tomato ranks highest in economic postharvest losses followed by pathological damage while physiological damage causes the least, but nonetheless substantial. They further elucidated that at the market level postharvest losses were greater at retail level compared to wholesale.

Over-view of disease symptoms due to fungi and bacteria in tomato

The two primary classes of microorganisms that cause decay in tomato are bacteria and fungi. Certain other types of plant pathogens such as viruses and nematodes may be responsible for post harvest diseases and losses but do not cause progressive deterioration of tomatoes.

Bacterial diseases

Bacteria are single-celled organisms that can rapidly multiply and spread, particularly in water. Even a thin coating of water, such as on a wet fruit, leaf bin surface or packing house machinery, can support the rapid movement and growth of the organisms. Bacterial diseases of tomato have been described by various workers (Mehrotra and Ashok, 1980; Singh, 1998), examples include:

Bacterial Spot: This is caused by several bacterial species of the genus *Xanthomonas.* The most common species of this genus that causes this disease is *X. euvesicatoria* (Jones *et al,* 2004), previously known as *X. axonopodis* pv. *Vesicatoria* or *X.. campestris pv. vesicatoria* . The bacterium is a gram negative rod, motile and strictly aerobic. The associated disease symptoms have been clearly captured by various workers (Mehrotra and Ashok, 1980; Singh, 1998). The disease is characterized by circular to irregularly shaped spots with a slightly greasy feel on leaves and stems. The spots are usually initially but as the lesion enlarges, they often become surrounded by a yellow halo. Numerous spots coalesce to become bigger, leaving the leaves wither and turn brown.

Fruits symptoms are more distinctive than leaf or stem symptoms. Spots on green fruit first appear as black, raised, pimple-like dots surrounded by water-soaked areas. As the spots enlarge, they become gray-brown and scabby with sunken, pitted centers.

Bacterial Canker: This is caused by the bacterium *Clavibacter michiganensis sub sp. Michiganensis.* Symptoms are characterized by complete loss of leaves among young transplant. Older plants are often seen to have their leaflets turn brown at the edges at the onset of disease and progresses towards the leaf midrib. Diseased fruits are characterized by dark-coloured necrotic lesions with white halos of 16 – 32mm. At the beginning, the lesions appear white and slightly raised, but turn brown as the disease progresses and finally become dark-colored (Singh, 1998; Mehrotra and Ashok 1980).

Fungal diseases

Fungi are mostly filamentous microorganisms commonly known as molds. In nature, they often appear thread-like, cottony, or as yeast-like scum. Many fungal species can cause fruit decay in tomatoes. Fungi are generally more difficult to eradicate than bacteria, because fungal cells are much larger and produce spores that are highly resistant to drying and other environment stresses. The major postharvest diseases caused by fungi are Sour rot, Rhizopus rot, Buckeye rot and Black mold rot. Descriptions of these diseases have been well articulated by various workers (Mehrotra and Ashok 1980; Bartz *et al.*, 2004).

Sour rot: This is caused by the yeast *Geotrichum candidum*. The disease is characterized by lesions whose growth resembles a thick, gelatinous mass similar in appearance to cottage cheese. The lesions are usually watery in the early stages of the disease and later become coated with pathogen growth and remain relatively firm. Lesions give off an odor similar to that produce by lactic acid bacteria hence, the name, sour-rot (Bartz *et al*., 2004).

Rhizopus rot: This disease is caused by *Rhizopus stolonifer*. Disease symptoms first appear as water-soaked lesions which exudes a clear liquid with time. Resulting lesion surfaces are covered with thin, cotton-like structure. Infection is usually through natural openings (Bartz *et al.*, 2004) or wounds created by mechanical damage (Mehrotra and Ashok 1980). Studies on postharvest quality of tomato marketed in Nigeria have also shown to suffer from Rhizopus rot caused by *R. stolonifer* (Chuku *et al*., 2008).

Buckeye rot: Another postharvest disease of tomato is Buckeye rot caused by *Phytophthora parasitica*. The pathogen attacks both ripe and unripe tomato fruits. Symptoms first appear as water-soaked circular spots. As the disease progresses, the center of the spots become darkened and overgrown with sparse white mycelia of the fungus. The disease derived its name from the manner the fungal mycelia spreads from diseased fruit to adjacent healthy fruit (Bartz *et al.*, 2004).

Black mold: Unlike the fungal diseases described so far, Black mold rot is caused by any of several different fungal pathogens which include *Alternaria arborescens, Stemphyllinm botryosum* and S. *consortiale*. The disease symptoms are characterized by rots observed on the shoulder, stem scar or on the blossom end of the tomato fruit. Lesions are initially sunken and later quickly covered with a dark brown to black mold. Lesions also develop internally if the stylar pore or a vascular strand that is connected to the stem scar is infected. Severe internal bruise greatly predisposes the fruits to infection that forms internal black spots (Mehrotra and Ashok, 1980).

Several other fungi have been described as potential postharvest pathogens. Such fungi are able to infect tomato fruit in the field and later lead to postharvest decays. They are usually not considered serious problems in themselves because like, black mold rot, the causal fungi hardly spread among fruits within a box. However it has rightly been pointed out that they could predispose postharvest tomato fruits to more destructive disease pathogens (Bartz *et al.*, 2004).

Physiological disorders of tomato

These are problems or disorders that are not caused by infectious microorganisms but rather by environmental stresses on the plant. In a study involving three varieties of tomato in Southwestern Nigeria, physiological damage was responsible as much as 36 and 44% of damage respectively among two of the varieties studied (Adeoye *et al.*, 2009). Although, detail reports of works on the different types of physiological disorders in Nigeria are scarce, postharvest tomato fruits are known to suffer a good number of defects not primarily attributed to animate pathogens. Some physiological disorders common to tomato are Blossom end rot, fruit cracking, Catfaced fruit, Sun scald and Blotchy ripening (Dorais, *et al*, 2001; Foster, 1937; Olson, 2004; Peet, 2009; Imas, 1999).

Control of postharvest diseases and losses of tomato

Post harvest decay of fruits result in substantial economic losses around the world (Hongyin *et al*, 2011). Synthetic fungicide treatment has been the main method of controlling post harvest diseases (Bolkan, *et al*, 1990; Holliday 1980; Eckert and Ogawa 1998). However, there is increasing international concern over the indiscriminate use of synthetic fungicides because of the possible harmful effects on human health (Norman, 1998) and emergence of pathogen resistance to fungicides (Holmes 1999). Therefore new alternatives for controlling postharvest diseases which have low residues and little or no toxicity to non-target organisms are in urgent demand. Control of postharvest diseases and losses has to commence on pre harvest process on the farm for it to be effective. A great many alternative strategies have been employed to control postharvest disease and losses which include: biological control, bioactive compounds, heat treatment, (Sharma, 2009; Mari, *et al.*, 2007), irradiation, fumigation, waxing, disinfection and physical treatment (Wilson, *et al,* 1991; Ron, *et al*, 1998). For purpose of this review they are herein categorized into three broad methods – Biological, chemical and physical methods.

Biological control: Biologically-based strategies have been studied with a view to effectively manage tomato losses occasioned by postharvest diseases and spoilage. *Bacillus subtilis, Saccaromyces cerevisae, Candida tanuis* and *Trichoderma virens* are some bacteria and fungi that have been found useful in the implementation of alternative management strategies in the control of postharvest tomato diseases. *Bacillus subtilis*, for example has been proven to greatly increase yield and highly effective in the control of postharvest tomato disease (Abd-Allah, 1995; Abd-Allah, et al, 2007). To achieve this feat, the bacterial cells are introduced into tomato seedlings through the roots prior to transplantation from the nursery to the field (Abd-Allah, 1995; Abd-Allah, et al, 2007). The suggested modes of action of *Bacillus subtilis* on tomato roots that results to increase in yield and subsequent delay in postharvest losses are varied and diverse. The application of *B. subtilis* has been reported to induce systemic physiological change in plant metabolism that enhanced the crop's anabolic processes (Abd-Allah and Ezzat, 2005; Abd-Allah et al, 2006). Furthermore, application of *B. subtilis* have been reported to improve the yield of tomato (Abd-Allah and Ezzat, 2005) because when introduced into the roots of tomato seedlings *B. subtilis* induces systematic resistance of plant vigor index through stimulated beneficial rhizobacteria in the rhizosphere of host plant, hence promoting plant nutrient (Abd-Allah and Didamony, 2007). The application of *B. subtilis* before harvest protects tomato fruits against postharvest decay fungi and improves its quality (Abd-Allah, 2007, Abd-Allah et al 2003; Leibinger, *et al*, 1997).

Studies have shown that the yeast *Saccharomyces cerevisiae* and dimorphic fungus *Candida tanuis* are able to greatly inhibit the growth of several fungi known to cause decay among postharvest tomato fruits. Specifically, these fungi were reported to inhibit the growth of *Botrytis cinerea, Rhizopus stolonifer and Alternaria altenata* in an *in vitro* study (Abd-Allah et al 2009). The inhibitory effect of these fungi on postharvest spoilage fungi were further enhanced when applied in combination with peppermint oil (Abd-Allah, *et al* 2009). The synergy between peppermint oil and *S. cerevisiae* has been shown to control gray mold, soft rot, Rhizopus rot, black rot, of postharvest tomato (Abd-Allah, *et al* 2009).

Similarly, many soilborne fungal diseases have been successfully controlled by the use of antagonistic microorganisms (John, *et al,* 2010). Experiments have shown that seeds sown in soil mixed with *T. virens* enhanced the growth of tomato and suppressed the incidence of Fusarium wilt of tomato. Treatment of tomato seeds sown in soil with *T. virens* followed by inoculation of *F. oxysporum f sp. Lycopersici* enhanced induction of defense-related enzymes such as peroxidase, polyphenol oxidase and phenyalanine ammonia lyase, which effectively controlled *Fusarium* wilt of tomato (Wei, *et al,* 1996; John, *et al,* 2010).

Chemical control: Various types of chemicals have been studied and used to control postharvest spoilage of tomato fruits. Some of these include bioactive compounds such as Potassium bicarbonate, Sodium metabisulphite, Calcium chloride, Nitrous oxide etc (Enrique & Eduardo 2006; Lai *et al.*, 2011; Okolie and Sanni, 2012). Bioactive compounds such as Potassium bicarbonate **(**$KHCO_3$**)** have been reported to effectively control mycelia growth of *Botrytis cinera* and *Alternaria altenata* for two weeks at a concentration of 1-2%, and in so doing maintained tomato fruit quality (Enrique & Eduardo 2006). The trade off, however, was that the firmness of the fruits dipped in 1-2% Potassium bicarbonate was significantly compromised in the process (Enrique & Eduardo 2006). Most researchers in Nigeria who have ventured into the use of chemicals to control postharvest losses of tomato in storage have had their attention focused on plant extracts. This is because the use of synthetic chemicals is no longer in vogue owing to their hazardous effect on environmental and human health. Natural plant products have often being considered as important and alternative sources of agricultural chemicals (Cardellina, 1988; Gulter, 1998), and most have been used in the control of insect pest (Emosairue and Ukeh, 1998), plant diseases, (Tawari and Nayak, 1991; Amadioha, 1998; Amadioha and Obi, 1999) and as bird repellent (Mason and Mathew, 1996; Nelson *et al*, 1997). Some of the plant extracts that have been studied in Nigeria with a view to managing postharvest losses of tomato include garlic (*Allium sativum*), ginger (*Zingiber officinale*), (Chuku *et al.,* 2010), *Tridax procumbens, Venonia amygdalina*, *chromolaena odorata, Azadirachta* *indica* (Ijato *et al.,* 2011), *Ocimum gratissimum* (Etebu and Enaregha, in Preparation). The quest for plant extracts in the control of postharvest spoilage of tomato fruits stems from the perceived belief that plant products are usually broad spectrum, effective, economical and most importantly environmentally safe (Ramazani *et al.,* 2002; Chuku, 2006).

Physical methods: A couple of physical means have been adopted over the years in the control and/or management of postharvest tomato fruits in storage. Postharvest disease and losses may be controlled by low and high temperature, modified atmospheres, correct humidity, good sanitation and proper handling of produce to avoid mechanical and physiological damage during storage and transportation (Ron *et al.,* 1998). Some of the physical means adopted so far in Nigeria include heat treatment, waxing and coating.

Heat treatment: This is the process where fruits are passed through hot dip for up to 4minites at 49^{o}C and above to kill fungal spores. The choice of hot dipping has been popular because it could control surface infection as well as infection that have penetrated the skin, and leaves no chemical residues on the produce. The downside of this form of treatment, however, is that it could cause physiological damage and aberrant ripening of fruits (Ron, *et al*, 1998). Dipping tomato in hot water of about 50°C has been reported to delay ripening of tomato fruits, reduce chilling injury and controls postharvest diseases initiated by microorganisms (Akbudak *et al.,* 2007). Although reports on this form of treatment in Nigeria are scarce, Okolie and Sanni (2012) working recently on whole tomatoes in Nigeria showed that hot water dip treatment extended the quality of whole tomatoes in storage. Another form of heat treatment engaged in preservation of tomato in Nigeria is drying. Traditionally, tomatoes are sliced and dried in the open air and exposed to the sunlight. This could sometimes be time consuming depending on the variety of tomato, the humidity in the air during the drying process, the thickness of the slices or pieces, and the efficiency of the dehydrator or oven (Kaur *et al*., 1999). Sun drying is a common method used to preserve and extend the shelf life of fruits in Nigeria (Ofor and Ibeawuchi, 2010; Etebu and Bawo, 2012). Sun drying is popular among locals because of its simplicity and the small capital requirement (Latapi and Barret, 2006; Berinyuy et al., 2012).

Waxing and coating: This is the application of wax to prevent produces that shrivel rapidly and reduces consumer acceptability during storage, transportation and marketing. In addition to reducing water loss, waxes are also applied to improve the appearance of produce. The rate of water loss can be reduced by 30-50% under commercial condition, particularly if the stem scar and other injuries are coated with wax. It also prevents entry of microbes into the produce (Ron, *et al,* 1998; Mehrotra and Ashok 1980). A work in Nigeria focused on the use of Shea butter coating as a means to controlling postharvest spoilage of tomato fruits (Okolie and Sanni, 2012).

Social and institutional constraints in postharvest disease management

Several social and institutional factors have been pointed by a couple of researchers as part of the bane militating against the effective management and control of postharvest spoilage and losses of tomato in Nigeria. Some of these factors borders on policies, education, services, resources and transportation.

Ofor and Ibeawuchi (2010) opines that clear-cut government policies are required to facilitate and encourage utilization and administration of human, economic, technical, and scientific resources to prevent deterioration of commodities. According to them such clear cut government policies are clearly lacking. In the same vein, the number of institutions established to cater for training and research in the agricultural sector has been described as grossly inadequate. This inadequacy is has been said to be responsible for the dearth of scientific and technical knowledge associated with preservation, processing, packaging, transporting, and distribution of food products (Ofor and Ibeawuchi, 2010).

Lack of relevant services arising from inefficient commercialization systems, and absent or ineffective government agencies in the production and marketing of commodities, as well as a lack of credit facilities that address the need of the country and the participants have also been fingered as one of the social and commercial factors that has greatly hindered the effective management of agricultural production in the country (Adebisi-Adelani, *et al.* 2011). Adebisi-Adelani and associates (2011) further reiterates that the non-availability of credit facilities needed to improve tomato production ranked as one of the most important problems. The unavailability of credit sources, they explain, is largely because farmers do not have collateral needed by loan granting institutions in the country. Even when farmers are able to meet the need requirement, they still have to contend with the high interest rates charged by the financial institutions. Furthermore, management and coordinated approach to prevention and reduction of postharvest losses of tomato, like any other human endeavour, would require human, economic, and technical resources necessary for developing programs (Ofor and Ibeawuchi, 2010; Adebisi-Adelani, *et al.* 2011).

Conclusion

The quality and nutritional value of tomato fruit is affected by pathological, physiological and mechanical damages during transportation from the field to the consumer. Species of *Alternaria, Fusarium, Penicilliun, Aspergillus, Geotrichum, Phytophthora* as well as *Botrytis* have been reported as common pathogens implicated with postharvest diseases of tomato fruits; responsible for as much as 10-30% reduction in the yield of major tomato crops. To this end, several pre harvest and postharvest technologies have been used to control their decay. These technologies are broadly categorized as biological, chemical and physical methods. The use of bioactive compounds, heat treatment and plant extracts are preferred to the use of systemic fungicides because the latter has been shown to pose harmful effects on human lives and the environment.

Other measures that can be adopted to reduce loss in tomato are: reduction in mechanical damages during harvest which can be an entry point of secondary microorganism and increase in loss of moisture content of fruits; provision of good storage facilities to store the produce that are harvested before they are been taken to market; provision of good road network especially those linking farms to markets to reduce transit losses; improved sanitary conditions in rural markets were bulk of the fruits is sold; training initiatives on post harvest handling of perishable products such as tomato should be encourage; adoption and feedback mechanism be explored periodically for sustainability. Finally, minimizing post harvest diseases and losses of food that has already been produced is more sustainable and environmentally sound than increasing production areas to compensate for these losses.

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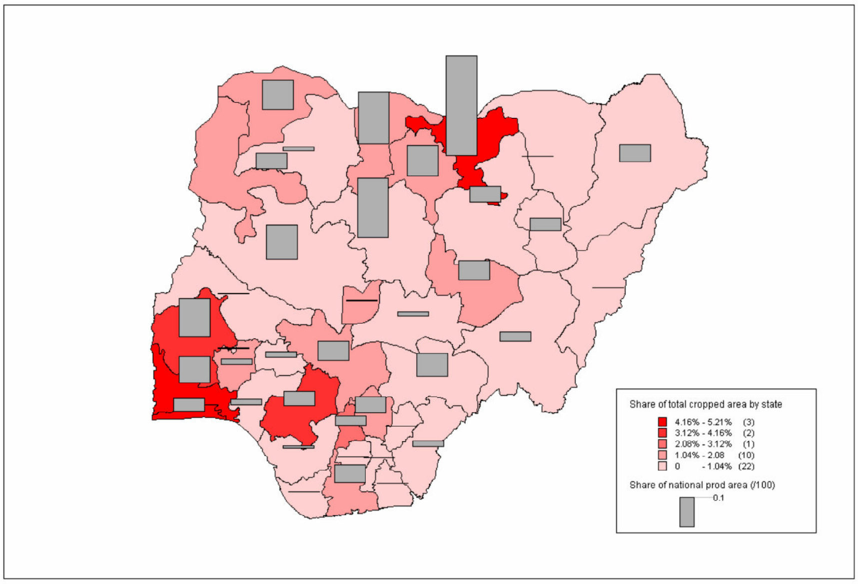

Fig. 1: Map Showing the Production Areas for Fresh Tomato across Nigeria (Source: AMINU and Musa, 2003)

Fig. 2: Transportation and sale of tomato fruits in Yenagoa, Bayelsa State, Nigeria