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Tomato Post-Harvest Losses and Mitigation Measures: A Review

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Abstract: Tomato is the most highly produced and consumed fruit/ vegetable in Nigeria; with annual production estimates of over 162 million tons due to which Nigeria was ranked second largest producer of tomatoes in Africa. Tomato, being a fruity vegetable, has a large quantity of moisture at harvest; thus, it continues to undergo physiological processes (i.e. respiration, ripening and senescence) even after harvest; making it highly vulnerable to deterioration. Postharvest losses account for between 30 and 50% of the tomatoes produced in Nigeria. This paper discusses the various factors/agents responsible for the higher percentages of postharvest losses in tomatoes and proffers solutions. Poor cultural, harvesting and handling practices, coupled with the wrong choice of packaging materials, the absence of cold storage facilities, inadequately maintained roads and the use of vehicles with inappropriate suspension systems were revealed as the major contributors of postharvest losses in tomatoes. It was also revealed that considerable percentage of postharvest losses can be prevented by applying pre- and postharvest mitigation measures; firstly, by cultivating improved cultivars of tomato, and by not applying too much nitrogen fertilizers during cultivation; due to its detrimental effects on the shelf life of tomato. Secondly, shelf life can be extended by carefully harvesting tomato at mature green maturity stage and ensuring that the crop is harvested at early morning hours before the ambient temperature reaches 24°C. Dipping tomato fruits in calcium chloride, CaCl₂ followed by storing it in a refrigerator, evaporative cooler; or passively modified atmosphere with proper temperature management yield promising results; in addition, proper choice of packaging materials and use of vehicles with proper suspension systems will minimize mechanical injury, thus, extending the shelf life of tomatoes.

Keywords: Mechanical injury, bruise, rates of physiological processes, shelf life, tomato

I. INTRODUCTION

Tomato is renowned for its beneficial, nutritional and medicinal composition. The most important of which are vitamin-C, magnesium and an anti-oxidant, lycopene that is effective in the prevention/minimization of the growth of cancer-cell [1]. An increase in tomato production has been documented in Nigeria, Africa and globally ([2], [3]). Earlier studies revealed Nigeria as the second largest producer of tomato in Africa (next only to Egypt) with an estimated harvest of 1.56 and 1.8 million metric tons of tomato in the years 2011 and 2015 respectively [4]. A wide range of tomato varieties are produced in Nigeria e.g. *Rukuta*, *mai-chibiya*, *Ibadan* and *Ogbomoso* (local varieties) and *Roma VF*, *Leventis*, *Ronita*, *DT97/162A*, *DT97/215A*, *Tropical* and *UB82B* (improved varieties [5]. However, in 2013 alone, Nigeria imported about 151 million USD worth of processed tomato and tomato-products, giving it a remarkable position among the largest tomato importers globally, despite its position among world tomato producers, principally due to its inability to pacify the factors of postharvest deterioration ([6], [7]).

The higher moisture content of tomato (80 – 90%) is responsible for its higher physiological rates (respiration, maturity, ripening, and senescence), increased vulnerability to mechanical injury, and ethylene generation [8]. Consequently, it is the most vulnerable horticultural material to mechanical injury; yet, more researches were devoted to other fruits/vegetables such as apples, strawberry, peaches, mangoes and potatoes [9]. The estimate of tomato postharvest losses resulting from varying causes differed amongst researchers, however, between 30 and 50 per cent were commonly documented ([10], [11]), although postharvest losses up to 60% was documented for tomatoes in Kaura area of Kano state (one of the eight, highest tomato-producing states in Nigeria) [4].

II CAUSES OF POSTHARVEST DETERIORATION AND THEIR MITIGATION MEASURES

Generally, postharvest deterioration results from any or a combination of the following variables: harvesting at the wrong maturity stage and period, use of improper equipment for harvest and handling, poor ride-quality of roads. Other variables are the use of inappropriate transportation modes/wrong suspension systems, delayed transportation, inadequate storage facility ([12], [13], [14], [15]). Conversely, a wide range of pre-harvest factors play vital roles in determining the postharvest quality and shelf life of tomatoes, the most notable of which are cultural practices (e.g. the type and quantity of fertilizer used, cultivar used and the quality of water used for tomato production). Yet, the relative influences of the aforementioned postharvest factors vary depending on the level of technological advancement in a given country.

Consequently, tomato deterioration was reviewed under the following sub-headings: mechanical injuries resulting from impact-loads and transport vibration, environmental factors (temperature & relative humidity), maturity at harvest (intensity & duration), and processing technology. Additionally, regardless of the cause of deterioration in fruits and vegetables, the following parameters: total soluble solids (TSS), ethylene/CO₂ generation, firmness value, colour retention, physiological weight loss and shelf life have been employed commonly as quality parameters for evaluating the extent of postharvest deterioration in fruits and vegetables ([16],[17],[18]).

i. Environmental Temperature

Low temperatures have been associated with prolonging the shelf life and preserving the postharvest quality of horticultural materials. The suitable temperature range for safe storage of fruits/vegetables varies with the product in question, besides, even within the same cultivar, significant effects of maturity stage and the presence or absence of chemical treatment on both shelf life and postharvest quality have also been documented ([19], [20]). The spoilage effects of temperature may be encountered either via – i) field heat, which is the difference between the recommended safe storage temperature for a particular fruit and the ambient temperature, ii) storage temperature or both. Delay in the extraction of field heat results in increases materials' sensitivity to ethylene, to mechanical injuries, in addition to increasing its respiration rate and ripening process.

As a remedy to the effects of field heat, precooling is often suggested. It involves the extraction of the field heat prior storage of the harvested materials and the suitability of any precooling method depend on the characteristics and volume of the materials to be precooled, its commercial value, and availability of labour and electrical energy [21]. Techniques such as room cooling, ice water cooling, hydro-cooling, vacuum cooling are employed in the extraction of field heat depending on the characteristics and volume of the horticultural material. Reference [22] recommend room cooling, ice- water and hydro-cooling methods as being suitable for tomato, yet, Reference [23] suggests that up to 16 hours of precooling delay is allowed for tomatoes but did not specify the tomato cultivar or the climatic environment under which such duration is allowable. Similarly, it is worthy to note that precooling measure for tomatoes is challenged by the erratic-nature or total absence of electrical energy in tomato producing areas, and by the low commercial value associated with tomato [24].

The temperature of the storage environment plays an important role in determining the rate of physiological process and subsequently the vulnerability of horticultural materials to mechanical injury. Customarily, farmers thought that by storing harvested materials under shades, in wetted jute sacks or earthen pots, the shelf life of the stored materials could be enhanced considerably. However, in tropical environments and depending on the month within which fruits/vegetables are harvested, even the shade temperatures may be in excess of what was recommended for safe storage of tomatoes (7 to 10°C for ripe, 13 to 16°C) [25]. Whereas storing tomato in low-temperature areas such as Bwade, Gembu and Jos in Adamawa, Taraba and Plateau states of Nigeria may be challenged by symptoms of chilling injury such as abnormal ripening, pitting, internal discolouration, increased respiratory activity, ethylene production, and increased liability to decay. The aforementioned effects equally shorten its shelf life besides worsening of qualities ([26], [27]), but the severity of such effects varies depending on cultivar, and the maturity stage at harvest [19]. Other measures adopted for the enhancement of tomato shelf life (though not on a commercial scale) are the evaporative cooling techniques (passive & active), chemical and hot water treatments [8].

ii. Mechanical injuries

Mechanical injuries in horticultural materials are in the form of bruise (external/internal), cuts, bursts, cracks etc., which result due to application of excessive loads to agricultural materials during harvesting, handling and transportation especially during loading or off-loading of cargos, and at storage points ([28], [29], [30], [31]). These injuries also result due to the use of wrong packaging materials, use of vehicles with unsuitable suspension systems; especially when driven on roads of poor ride quality/at higher speeds. The damage potential of road vibration is influenced by its ride-quality and travel speed [15]. Roads in developing countries are poorly maintained and truck drivers rarely obey traffic regulations [30].

While an estimate of tomato deterioration resulting from road and suspension systems is not readily available in this part of the world, Reference [28] studied tomato handling and transportation systems in eight

tomato-producing states in Nigeria. Their findings revealed that about 50% of tomato handlers use 911 model of Mercedes Benz lorry, 15% use articulated trucks and another 15% use canter trucks with load capacities of 7.5, 4.5 and 7.5 tons respectively. Similar studies revealed that handlers employ motorcycles and bicycles for moving of tomatoes from production areas to urban centres ([3], [4]). Reference [15] investigated the effects of road type (asphalt, concrete and asphalt), travel speed (20, 40, and 80 km/hr) for two and six tons capacity trucks with leaf spring on the severity of damage to tangerine fruits. Conversely, found that lower payload capacity resulted in higher fruits damage. Injuries to harvested materials may be mitigated by placing transported materials close to the centre of gravity of trucks, harvesting horticultural materials at the most appropriate maturity stages (e.g. mature green for tomato), and use of appropriate suspension systems (e.g. air-ride systems). Other measures are loading trucks in order to the appropriate capacity to dampen the suspension system and by driving at the recommended speeds ([39], [32], [29]).

iii. Road profile

Road profile is a measure of the deviation of road surface/pavement from an imaginary planar surface, which is also a measure of the ride quality of roads. It may be used for evaluating the damage potential of roads on agricultural materials or transported cargo, however, earlier studies employed road profile data for judging the suitability or otherwise of constructed pavements, for specifying profile limits of newly constructed roads, serviceability and for the development of passenger comfort criteria ([31], [32]). Reference [29] conducted a similar study for speed range between 0 and 90km/hr but for arterial, secondary, tertiary roads and highways. It is worthy of note that regardless of the truck type or its load capacity, higher truck speed resulted in higher vibration intensity, while, vehicle speed declined with the deterioration in road quality.



Plate I, Laterite road surface [15]

Earlier researches equally employed laboratory simulation for investigating the influence of both the impact and vibration parameters on the damage potential of varying impact and vibration levels ([35], [36]). Nevertheless, such tests were mainly based on test profiles developed from roads sampled in developed countries that are not in any way representative of developing countries such as Nigeria; thus, such simulations are less relevant for minimizing postharvest losses of horticultural materials transported of African roads.

iv. Packaging materials

Packaging materials are very vital for minimizing damage to horticultural materials resulting from impact and transport vibration. It is also employed for atmospheric modification of the storage environment, Reference [37] found that by use of double corrugated, instead of a single-layered box; damage to apple could be reduced from 55.6 to 40%. Similarly, Reference [15] found a significant influence of packaging materials in minimizing vibration damage on apricot fruit, besides the influence of packaging materials in injury minimization, fruits depth in a container and the tightness of fill equally influence the damage potential in a given packaged material. In Nigeria, fruits and vegetable handlers employ traditional baskets, jute sacks, wooden boxes and a plastic bucket for handling tomato and other related fruits ([28], [38]).



Plate II, Vehicles and Packaging materials used tomato handling in Nigeria [38]

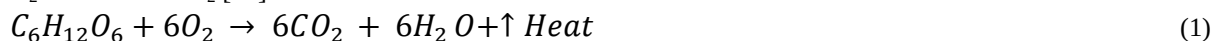


Plate III, Tomato handling in Nigeria [28]



Plate IV, Tomato Handling in Ghana [3]

However, without any modification, such baskets and boxes have sharp edges, which inflict cuts or bruises on the surfaces of the handled materials thereby creating entry points for bacteria and their consequent effect. To achieve the best protection from impact/vibration effects, Reference [39] recommended using packaging materials with transmissibility value of 1.0. The use of a modified atmosphere for shelf life enhancement dates back to the seventeenth century when Jacques Berard (a French Scientist) recognized that harvested fruits utilize O_2 and release CO_2 [40].



For atmosphere modification generally, the following packaging materials are often used: polymeric films, paper, box, glass bottles, metallic cans, besides, the polymeric films.

However, for horticultural materials, polymeric films such as low high density polyethylene, polypropylene, polyvinyl chloride, polyester, polyethylene terephthalate, polyvinylidene chloride and ethylene vinyl alcohol. The efficacy of polymeric films and the factors, which affect their performances, have been investigated ([41], [42], [43]). Reference [43] investigated a MAP with low-density polyethylene with a thickness of $37.5\mu m$ with 0.2 and 4 perforations of 1 mm diameter on French beans stored at $5^\circ C$ with a relative humidity of 95% for 21 days. Rahman *et al.* (2010) evaluated the effect of the colour of polymeric film (white, yellow, blue, black and the control), and perforation on the shelf life of tomato stored at $10^\circ C$. While Reference [44] compared the efficacy of polyethylene ($20\mu m$ and $50\mu m$), polypropylene, and polyvinyl chloride on the postharvest qualities of tomato at pink maturity stage. Their findings revealed that even though atmosphere modification preserves quality and shelf life of horticultural materials, a completely impervious/unperforated packaging material causes anaerobic respiration, off-flavour and poor ripening quality of fruits [43]. In addition, black coloured polyethylene performs significantly best in preserving all postharvest qualities, except for the shelf life of the studied beans [41]. However, whereas unwrapping of tomatoes allows for fruits over-ripping within 30 days of storage, tomatoes sealed in propylene (PP) remained very firm after 60 days of storage, besides it had the lowest weight loss and highest soluble solids [44].

v. **Maturity stage**

Postharvest physiologists recognize maturity stages at which tomatoes may be harvested as mature green, pink, yellow maturity stages. Earlier findings have associated maturity stages with varying levels of physiological rates and vulnerability to mechanical injury; more so, harvesting fruits at the appropriate maturity stage enhance the shelf life of horticultural materials ([18], [45]). Similarly, Reference [46] found that by harvesting tomato at the mature green stage rather than at the later maturity stages, the physical injury could be reduced by about 10.31%. Reference [47], who conducted a comparative study on the quality and shelf life of tomato harvested at the breaker, yellow and pink maturity stages recorded the least weight loss at yellow maturity stage and the highest firmness value at breaker stage. Nevertheless, they found the lowest values of juice content, total soluble solids, fruit and disease incidence at the pink stage. In contrast to most findings, however, Reference [48] found that though tomato at mature green stage produces less ethylene, yet it is more prone to impact damage than at the pink to red maturity stages.

Correspondingly, Reference [18] opined that fruit colour is a suitable indicator of maturity stage, but such an approach is limited to single cultivar as same colour may mean different maturity stages in different cultivars. Besides, tomato harvested at an immature stage is associated with poor ripening quality, taste and comparably lower nutritional value. However, it is worthy to note that most tomato farmers are challenged by their inability to distinguish between immature fruit and a mature green tomato [49]. On the other hand, the presence of injury on tomato increases its rate of ethylene generation, which commonly associated, with the degradation of chlorophyll and yellowing of green tissues in plants, inducement of abscission in leaves, flowers and fruits in plants and softening of fruits [26].

Consistently, the ethylene concentration as low as 1 ppm (1 μ l) is adequate to initiate the aforementioned adverse effects [10]. Most recently, researchers ([10], [50], [17]) have made several attempts to subdue the effects by employing low/freezing- temperatures, chemical and bio-additives and extracts such as neem, Aloe Vera, moringa leaf-powder, sodium chloride, methyl-cyclo-propane, chitosan etc. However, not a single study has conducted a comparative evaluation of the aforementioned bio/chemical additives in minimizing the rates of ethylene generated from fruits and vegetables.

vi. **Fruit processing**

Fruit processing is one of the measures to be employed for minimizing postharvest deterioration in agricultural materials. It involves the conversion of raw tomatoes into puree, ketchup, juice, powder etc. In the underdeveloped world and depending on the distance between the production and processing centres, fruit processing may be the best measure against postharvest losses. However, the quality of a processed tomato depends strongly on the quality of the tomato that was used as raw materials [51]. In Nigeria, as it is in other tropical countries, there exists a great potential for sun drying of agricultural commodities, yet, the tomato may be grown under either rain-fed or irrigated conditions. For the tomato grown under the later condition, sun-drying becomes a challenge especially when harvested in months with high relative humidity (>80%); additionally, power supply could not be relied upon either due to erratic nature or due to the cost of electricity in developing countries and the correspondingly low values of tomato during the harvest/glut season. Alternatively, researchers have ventured deep into the redesign and evaluation of passive evaporative coolers with the view to minimizing the cost incurred in preserving qualities of fresh tomato, yet, such development is still confined to the laboratory, as the said technology is hitherto not adopted for commercial application in Nigeria.

III-RECOMMENDATIONS

- (a) There is the need to substantiate the efficacy of ethylene inhibitors and wood ash on the postharvest quality and shelf life of local cultivars of tomato available in Nigeria, especially as each relates to minimizing the effects of transport impact and vibration on tomato.
- (b) Considering the fact that road characteristics and maintenance culture vary from one country or location to the other, there is the need to ascertain the extent of damage due to vibration and impact resulting from transportation of fruits and vegetables on Nigerian roads using the most commonly used cargo transport vehicles.

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