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Extending the shelf life of tomato and onion in Nigeria: A review

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Abstract
Purpose: Onions and tomatoes storage is widely practiced worldwide in accordance to their cultural and economical practice. In Nigeria, method of storages adopted mostly depends on the traditional knowledge. This method is risky as in some cases, large percentage of the produce gets rotten before they take the produces to the market. Sprouting, desiccation and microbial spoilage are often observed in storage and it compels to choose advanced techniques like modified ventilated structures, modified atmospheric (MA) and controlled atmospheric (CA) storage. The CA and MA storage reduce the application of chemicals for sprout inhibition by manipulating the gas composition to extend the storage period of the onions and tomatoes. In order to reduce the postharvest loss of these commodity, various researches have been carried out on the best methods to be employed. These techniques aimed to extending shelf life and preserving the freshness and quality of the product from the time of harvest to final consumption. Technologies such as cold storage, waxing and chlorine treatment, have been employed all in a bid to extend postharvest shelf life and quality.

Keywords: onions, tomatoes, modified atmosphere, controlled atmosphere, cold storage

1. Introduction
The word tomato is a modification of word 'tomati' literally means the swelling fruit. Other names reported by historians are tomatl, tumatle and tomatas. Tomato (*Lycopersicon esculentum Mill.*) is herbaceous plant belonging to family solanaceae., domesticated between Mexico and West coast of South America and following its introduction to Spain in 16th century, widely dispersed throughout African continent. It is one of the popular vegetables worldwide and plays a vital role in human diet. Tomato fruits are consumed whole, in salads, in soups, as juice, ketchup, paste and puree (Adedeji *et al*., 2005). Tomatoes are rich source of vitamins, minerals, sugars, essential amino acids, iron, fibre and phosphorus (Ayendiji *et al*., 2011). Tomato fruits also contain high amount of lycopene, a caretonoid with anti-oxidant properties and beneficial in reducing diseases like cancer (Basu & Imrhan, 2007) [18] and cardiovascular diseases (Freeman & Reimers, 2010) [38]. Nigeria is second largest producer of tomato fruits in Africa and 13th largest in world (FAOSTAT, 2012). The estimated total postharvest loss of tomatoes in Nigeria is about 60% according to Kutama *et al*. (2007) [48] which translates to huge economic loss.

Onion is one of the most important commercial condiments which grown and consumed all over the world. Its consumption is due to the presence of bioactive chemical components of different nutritional and health benefits. Polyphenols, fructo polysaccharides, and many other health promoting compounds determine to a large extent the majority of research on onion (Kumar *et al*., 2015) [47]. Nigeria occupies 6th position in the World's onion producing countries; producing over 618,000 tonnes in year 2007 (Sulumbe *et al*., 2015) [64]. Its utilization is mainly as flavoring and taste-enhancer with very attractive sensorial appeal when used as spice and condiments in foods (Bhattacharjee, 2013) [20]. Onion is rich in sulfur-containing polyphenol compounds responsible for the strong astringency flavour (Corzo-Martinez *et al*., 2007) [29, 51]. The overall nutritional compositions, morphological make coupled with low cost of production, make onion an integral part of many African and Asian cuisines. Onion is also a vital source of minerals and micronutrients such as calcium and potassium as well as non-essential heavy metal such as selenium, depending on the area of cultivation. In addition to the array of nutrients compositions, onion is well endowed with some important bioactive functional constituents conferring its antioxidative, antiplatelet, antithrombic, antiasthmatic and antibiotic capacities. Flavonoids, specifically quercetin represents the most prevalent phytochemical in onion with its attendant health promoting effects (Caridi *et al*., 2007) [26]. The objectives of this review is to extend the shelf life of fresh tomato and onion produce in Nigeria.

1.1Tomato
Nigeria is the second largest producer of tomato fruits in Africa and 13th in the world (FAOSTAT, 2012). It is said to have originated from the regions of Central and South America (De-Lennoy, 2001) [32]. According to FAOSTAT, (2012), Nigeria is the largest producer of the crop in sub-Saharan African, with an estimated production of approximately 1.5 million tonnes. It is a popular part of the Nigerian diet and is widely consumed fresh and cooked. Tomato is rich in fibre, folates, antioxidants, phenols, flavonoids etc. (Rao, 2006) [56]. These inherent nutritional properties make it very important as a part of the diet.

Epidemiological and clinical studies shown that the consumption of this vegetable can help in the prevention and management of some diseases such as some forms of cancers, degenerative eye defects and also the risk of developing some cardiovascular diseases (Basu and Imrhan, 2006) [17]. Despite the high production and nutritional benefits, it has a short postharvest life resulting in high losses (Shankara *et al*., 2005). It is estimated that about 50%

of the harvested fruit is lost before it reaches the final consumer (Mashav, 2010) [52]. In Nigeria, Kutuma *et al*, (2007) reported a loss of about 60%, also, Kutuma *et al.*, (2007) reported the postharvest loses of tomato in Nigeria, Rwanda and India. High perishability of the crop, results in a decrease in its quality by the time it eventually gets to the hands of the consumers. This occurs when proper postharvest practices are not employed. Postharvest losses have serious economic impacts, such as direct financial losses of the part of growers and as well as for marketers. It also indicates a waste of productive agricultural resources such as land, water, labour, managerial skills and other inputs that have been channelled towards the production of the crop. In most developing countries, postharvest losses of food crops have been faulted as a major cause of food insecurity and food shortage.

In a country such as Nigeria, where most farmers and marketers are ignorant of the best postharvest methods to employ, spoilage of the tomatoes is a popular scenario. Postharvest technologies like chemical treatments, packaging and storage positively influence the level of postharvest losses and the quality of produce. Postharvest treatments such as application of chlorine solutions are known to reduce enzymatic activity and decay by pathogens thereby extending the storage life of the produce (Islam *et al*. 2012) [44]. Modified atmosphere packaging (MAP) using polymeric films like polyethylene is a simple and inexpensive method to extend shelf life of fresh tomatoes. In modified atmosphere packaging tomato has been shown to delay ripening. During storage of tomato fruits, regulation of ripening and prevention of microbial attack is an important consideration. An improvement in tomato postharvest handling, packaging and storage is really desirable. Government can increase the production of tomato by providing facilities and modern equipment to farmers which can lead to the availability of tomato for exporting to African countries thereby contributing to GDP (Arah, 2015) [11]. To reduce postharvest loss of this commodity, various researches have been carried out on the best methods to employ. These techniques are aimed at extending shelf life and preserving the freshness and quality of the product from the time of harvest to final consumption. Technologies such as Controlled Atmosphere Storage, passive, active Modified Atmosphere Packaging, cold storage, waxing, and chlorine treatment, have been employed all in a bid to extend postharvest shelf life and quality (Anthon & Barrett, 2012). Some of these techniques are used individually or combined. However, it has been observed that even with the application some of these technologies, some challenges still exist such as the case of chilling injury in cold storage below 10ºC (Cantwell *et al.*, 2009) [25], and inhibition of sugar development of in harvested fruits due to cold storage.

2. Nutritional profile of tomato

Tomato is a nutritious vegetable crop that is low in calories. It has been reported that one medium-sized tomato has only 35 calories (Gao *et al.,* 2010) [40]. The tomato is rich in micronutrients and minerals. These vitamins are all important in the normal metabolic activities of the body. It is also a rich source of bioactive compounds in the form of antioxidants (lycopene, β-carotene, α-carotene etc.); flavonoids; polyphenols etc. (Dewanto *et al.*, 2002; Slimestad, 2008) [31, 66].

Tomato also is the source of antioxidant lycopene in human diet with lycopene constituting an estimated 90% of the total carotenoid contents (Frusciante, *et al.*, 2007; Raffo *et al.,* 2006) [39, 55]. This vegetable crop also represents a relevant source of soluble and insoluble fibres (Frusciante, *et al.*, 2007; Raffo *et al.*, 2006) [39, 55].

2.1.1 Health benefits

Epidemiological and clinical studies have shown that the increased consumption of tomatoes was able to prevent the occurrence of some certain forms of diseases. This is due to its abundance in phytochemical compounds such as carotenoids, phenols, flavonoids etc. (Dewanto *et al.*, 2002) [31]. These compounds have been reported to be able to play important roles in human body (Eldahshan and Singab, 2013) [33]. The health benefit of tomato has been mostly attributed to its lycopene content (Arnao *et al.,* 2001) [12]. Although there is said to be a synergetic contribution by other antioxidants notwithstanding, there is need for more research on the mechanism of this process.

Lycopene which is the major antioxidant in tomato has been studied to possess great antioxidant potentials. It has been reported by Arnao *et al.*, (2001) [12] that the antioxidant capacity of lycopene is 1.16 times higher than β-carotene and 2.9 times higher than antioxidative capacity of L-ascorbic acid Beta-carotene as an antioxidant has proven to be protective against many types of cancers, especially cancer of the lungs and studies have shown it may help to protect the eyes from the damage that can lead to cataracts and also in the protection of phagocytic cells from oxidative damage. Tomato is also rich in flavonols, which are highly concentrated in tomato skin as conjugated forms of quercetin and kampferol. These bioactive compounds contribute to the health benefits of tomato.

2.1.2 Postharvest quality indices

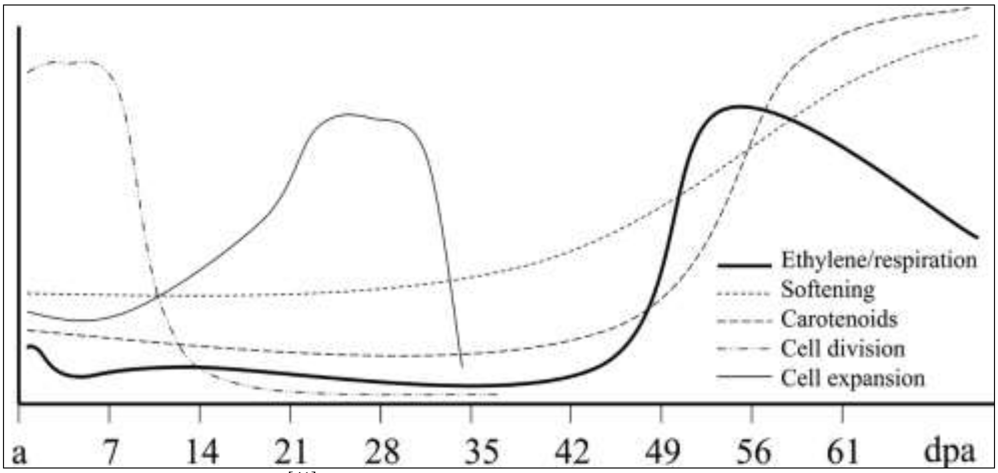
Tomato is a climacteric fruit and its ripening process is induced by ethylene which affects physical, chemical, and physiological properties of the fruit (Alexander and Grierson 2002) [5]. At the onset of ripening there is an increase in the synthesis of ethylene which causes changes in skin colour, sugar content, organic acid metabolism, and tissue generally. At harvest fruit begins to respire and this results in a series of biochemical and physiological changes which involves the oxidative breakdown of organic reserves in the fruit.

Tomato quality is measured based on sugar content, titratable acid (TA) content, colour, firmness, total soluble solid (TSS), and ripening index (TSS/TA) (Majidi *et al*., 2014) [50]. Tomato contains organic acids such as citric acid (which is the main organic acid), malic acid, and glutamic acid. In most cases the amounts of this acid is dependent on level of maturity and type of tomato cultivar. A decrease in titratable (TA) and rise in pH indicates maturity as well as reduction in the citric acid content (De-Lennoy *et al*., 2001 Anthon, *et al*., 2011) [32]. High quality tomato is judged from the intensity of its red colour and the prominence of its flavour. The flavour influenced by sugar content to acid ratio of tomato (Siddiqui, *et al*., 2015) [59]. The main sugars found in tomato are glucose and fructose, which are usually present at equimolar ratios (Beckles, 2012) [19]. The sweetness of tomato becomes more intense when the sugar content is maximum, at which stage the red colour is most pronounced. The red colour is as a result of increase in the amount of lycopene (Giovannoni, 2004) [41]. Fruit firmness (texture) is also greatly influenced by ripening, which results in a progressive softening of the fruit flesh. The developmental changes as a result of ripening is illustrated in figure 1.

2.1.3 Tomato production in nigeria

The tomatoes is cultivated through all tropical, subtropical and temperate regions of the world, there are different cultivars of the crop available in the market. In sub-Saharan Africa, Nigeria is the highest producer of the fruit with an estimated annual production of 1.5million metric tons (FAOSTAT 2012). Tomato is grown in most parts of the country, the best area being the Savannah agro-ecological zone, where diseases and pests affecting tomatoes are less common. The major producing areas lie between latitude 7.5ºN and 13ºN and within a temperature range of 25ºC-34ºC. It is grown in the south-western part of Nigeria under raining season condition and in the northern part under irrigated conditions (Ayandiji *et al.*, 2011) [13]. Despite being the highest producers of this food commodity, records of postharvest losses of this commodity is high. This is as a result of poor postharvest handling of the produce. The lack of adequate storage facilities, poor transportation and marketing channels are major factors that contribute to the losses (Siddiqui, *et al*., 2015) [59]. Also ignorance of the farmer in the packaging method (packing rotten and fresh fruits together) ignorant of the farmers to process their produce and lack of modern storage facilities, result in incidences of losses (Siddiqui, *et al.*, 2015) [59].

In addition, during the transportation of the produce to the market, problems such as bad roads and poor road networks, use of dilapidated vehicles, and the use of baskets; results in reduction in product quality. Farmers are forced to sell at ridiculously low prices which is a loss on their part. There is the need for government intervention in these areas. This can be achieved when the basic infrastructures such as good roads, adequate storage facilities and the likes are provided. Also the need to educate the farmers on various means of processing for value addition and how to utilize locally made resources to adequately store their produce (Siddiqui, *et al*., 2015) [59].



Source: Giovannoni, (2004) [41]

Fig 1: Developmental and Ripening Changes in Tomato Fruit

3. Postharvest preservation of fresh tomatoes

An increase in ethylene synthesis induces ripening in tomato which culminates into different changes in the fruit such as a colour changes from green to red as chloroplasts are transformed into chloroplasts, chlorophyll is degraded and carotenoids accumulate; fruit softening and textural changes occur as the fruit cell wall is modified and partially disassembled by enzymes and the ripe flavour develops as specific volatiles increase and the sugar-acid balance alters. A lot of research has gone into understanding the role of different intrinsic and extrinsic factors in the ripening process in climacteric fruits such as tomatoes (Giovannoni, 2004; Alexander and Grierson, 2002) [41, 5]. Also importantly the roles of oxygen-carbon dioxide balance has also been studied, this is important since they play significant roles in the respiration and ripening of fruits (Kader and Ben-Yehoshua, 2000) [45].

3.1 Major areas of focus in preserving freshness of tomatoes

In a bid to meet consumer demand for fresh products with extended shelf life, postharvest technologists have been able to focus on influencing the development of some specific quality characteristics. This is done to slow down the ripening and senescence of the tomato. Also in the area of inhibiting the action of enzymes involved in the breakdown of the fruit cell wall. The following are major areas of focus in postharvest preservation of tomatoes:

3.1.1 Maturity

Tomatoes are usually harvested at physiological maturity and allowed to ripen off the plant. The various stages of maturity can range from immature green to full red stage (Cantwell and Kasmire, 2002) [24]. Table 1 illustrates the stages and classes of physiological maturity in tomatoes.

3.1.2 Ethylene

The need to inhibit or slow down the rate of ethylene production is also very important in extending the postharvest life of fruits (Sammi amd Masud, 2007) [58].

3.1.3 Temperature

Due to respiration in plants and their fruits, there is a production of heat.at harvest there is a need to bring down this temperature, neglecting to do so may result in undesirable results such as a very fast process of ripening to senescence.

3.1.4 Oxygen-carbon dioxide balance
In order to slow down the rate of fruit ripening, the oxygen to carbon dioxide ratio is regulated. This is important since the ratio of these gases exert a great influence on the rate of fruit ripening (Kader and Ben-Yehoshua, 2000) [45].

3.1.5 Pathogens and spoilage organisms
Ripening of fruits means production of some desirable nutrients which could enhance the proliferation of pathogenic or spoilage microorganisms, if proper postharvest measures are not put in place. The problems of pathogens and spoilage organisms are a major source of concern in postharvest food losses. Important to note is that before applying the above principles, some important point of harvest factors need to be considered. Factors such as time of harvest (considering the level of maturity), reduction of mechanical damage as much as possible, the condition of water used for cooling of the harvested produce and sanitation of the packing house.

Table 1: stages and classes of physiological maturity in tomato

Stage of Maturity	Description
Immature	Seed cut by sharp knife on slicing the fruit; no jelly-like material in any of the locules; fruit is more than 10days from the breaker stage.
Mature-green A	Seed fully developed and not cutting on slicing fruit; jelly-like material in at least one locule; fruit is 6-10days from breaker stage; minimum harvest at maturity.
Mature-green B	Jelly-like materials well developed in locules but fruit still fully green; fruit is 2-5days from breaker stage.
Mature-green C	Internal red coloration at the blossom end; but no external colour change; fruit is 1-2days from breaker stage.
Breaker colour	First external pink or yellow colour at the blossom end.
Turning colour	More than 10% but not more than 30% of the surface in the aggregate; shows a definite colour from green to tannish-yellow, red or a combination thereof.
Pink colour	More than 30% but not more than 60% of the, in the aggregate shows pink or red colour.
ht red colour	More than 60% of the surface; in the aggregate shows pinkish-red or red, but less than 90% of the surface shows red colour.
Red colour	More than 90% of the surface, in the aggregate, shows red colour.
Full red	Fruit has fully developed red colour; fruit is more aromatic then red stage.

Source: Cantwell and Kasmire, (2002) [24].

4. Techniques used in postharvest preservation of fresh tomatoes
Fruits remain alive after harvest, the climacteric burst of ethylene makes fruits palatable and therefore promotes senescence. The aims of postharvest tech nology is to manage the concentration and timing of the synthesis of ethylene so that the tomato quality is still at an optimal level by the time it reaches the consumer.

4.1 Storage temperature
In order to maintain the optimum quality and extend the shelf life of tomato it can be stored at the ranged of 10ºC – 15ºC. Tomatoes stored at 10ºC above the optimum temperature results in a deterioration of the fruit quality. Temperature storage below 10ºC can result in chilling injuries consequently affecting the tomato quality. The severity of chilling injury is more pronounced in green tomatoes than compare to the red tomato, this is dependent on the storage time and temperature (Cantwell *et al*., 2009) [25]. The normal development of sugars and volatiles is inhibited in cold storage, this however is dependent on the stage of maturity.

4.1.2 Modified and controlled atmosphere storage
Ethylene related deterioration is inhibited or reduced when harvested fruits are stored in modified or controlled atmosphere. The use of controlled atmosphere and modified atmosphere entails the deliberate manipulation of the composition of the gaseous composition of the environment to optimize the product quality. In controlled atmosphere the gas constituents are more precise and stable while in modified atmosphere the air composition changes continuously (Majidi *et al*., 2014) [50]. Carbon dioxide is increased and oxygen is reduced in CA and MA. The effectiveness of this method is dependent on the fruit variety, maturity and initial quality, storage temperature, and the composition and duration of exposure to MA or CA (Brecht *et al.*, 2003) [21].

4.1.3 Co$_2$, o$_2$ and nitrogen ratio
Optimal atmosphere modification for oxygen-carbon dioxide ratio to inhibit senescence in tomato is 3–5%(v/v) while oxygen for Mature Green and ripe fruit is 1-3% (v/v) and 1–5%(v/v) for carbon dioxide of Mature Green and Ripe fruit respectively with nitrogen supplementation between (94–96% v/v) (Cantwell *et al.*, 2009) [25], studies shown that low oxygen levels outside the above stated ranges can cause harm for the fruit by inducing anaerobiosis (Cantwell *et al*., 2009) [25].

4.1.4 Modified atmosphere packaging (map)
It is the use of specialized materials to enclose a product in an altered composition of gases without any other effort to modify the environment. The materials used for MAP allow free diffusion of gases, this helps to maintains an equilibrium between the external atmospheric gas composition and that inside the package due to tissue respiration. Commonly used materials are low density polyethylene (LDPE), polyethylene terephthalate (PET) polypropylene (PP) polyvinyl chloride (PVC) and polystyrene. Modified atmosphere (MA) helps to control ripening, reduce water loss, improve the sanitation of the product, reduce bruising and spread of disease (Cantwell *et al*., 2009) [25]. These advantages may be further enhanced if ethylene scrubbers or other chemicals are included in the packaging (Bailen *et al*., 2006) [15].

4.1.5 1- Methylcyclopropene (1-mcp)
1-MCP is applied to fresh fruits to inhibit ethylene action. It reduces many of the changes associated with ripening such

as respiration rates, cell wall breakdown and color change and is also able to irreversibly bind to ethylene receptors and block ethylene binding (Tassoni *et al*., 2006). The specific effects of 1-MCP depend on the length and intensity of exposure, the sensitivity of the cultivar and stage of fruit development when applied (Martinez-Romero *et al*., 2007) [51].

4.1.6 Ozone

Ozone is a well-known potent antimicrobial agent that can be used to simultaneously reduce pathogen attack and delay senescence. It has been shown to reduce ethylene in cold rooms thereby confirming its potency in reducing fruit aging (Aguayo *et al.*, 2006) [4]. Ozone treatment of sliced tomatoes appeared not to exhibit any negative effects on the TSS (total soluble solid) content (Aguayo *et al*., 2006) [4]. Higher contents of fructose and glucose in ripe fruit 6 days after ozone-enrichment (0.05 or 1.0 µmol mol−1) was observed as compared to the controls (<0.0005 µmol mol−1) and the treated fruits were found to be sweeter as judged by a sensory panel Aguayo *et al*., (2006) [4].

4.1.7 Edible coating

They are materials that are used to coat the surface of a food material and are eaten along with the product. These coatings exhibits positive effects on managing senescence in fruits. Edible coatings comprise of natural compounds such as carbohydrates: starch and alginate; proteins: whey and casein from milk and zeins and gluten from maize and wheat seeds respectively; and lipids: beeswax, carnauba and candelilla wax and fatty acids, and their derivatives (Zapata *et al*., 2008) [71].

Ali *et al*., (2010) [6], studied the effect of the coating gum Arabic on mature green fruits of tomato cultivar ‘moneymaker’ stored at 20ºC for 20days. The taste of the coated fruit was judged by panelists to be better than that of the control. Another study found that coated mature Green tomatoes stored at either 5ºC or 12ºC tolerated chilling injury better than the controls however low temperature reduced TSS (Zapata *et al*., 2008) [71].

4.1.8 Irradiation

It is classified as non-ionizing. Ionizing radiation is high frequency and causes loss of ions from the material with which it comes into contact. Radiation can also minimize the colonization of fruit with pathogens due to contamination, insect infestation, postharvest disease, as well as delay ripening (Allende *et al*., 2006; Bruhn *et al*., 2009). The three most commonly used are UV-C, X-ray and gamma-rays. Ultra violet ray is non-ionizing and is frequently used for postharvest management of fruit. Most experiments were done with UV-C but UV-B has been investigated (Charles and Arul, 2007) [27].

4.1.9 Combined effect of these techniques on tomato pres ervation

Fagundes *et al*., (2015), studied the combinations of active Modified atmosphere package and cold storage on the postharvest quality of cherry tomatoes. The produce was stored in bi-oriented polypropylene/low density polyethylene BOPP/LDPE bags (with a gas composition of 5% O2+ 5% CO_2) at (5ºC). The combined effect of these two techniques was effective in delaying maturity of the fruit and extending the shelf life for up to 25days, while maintaining the quality of the tomatoes.

The effects of 1-methylcyclopropene (1-MCP), modified atmosphere packaging and their combination were investigated on storage and quality maintenance of tomatoes at pink and red stages of ripening. The fruits were stored at 12ºC with 90% relative humidity for 21 days. Parameters related to fruit ripening, such as skin color, lycopene, TA and SSC/TA were evaluated. The overall results indicated that the combination of 1,000 nL/L 1-MCP and modified atmosphere package was the most effective treatment in delaying fruit ripening at the two stages (Zapata *et al*., 2008) [71].

Choi *et al*., (2014), reported that the combined application of ultraviolet-C (UV-C) irradiation, modified atmosphere packaging (MAP), and cold storage temperature on the microbial quality of cherry tomatoes. UV-C irradiation at 2kJ/m^2 was able to inactivate *Salmonella enterica* serovar Typhimurium. After 9 days of storage, the overall quality of the fruits was still maintained.

Different packaging systems developed by Sammi and Masud, (2007) [58] were evaluated for their suitability to extend storage life and improve the quality of tomato fruits. Freshly harvested mature green tomatoes were packed in polyethylene packaging with or without treating with calcium chloride, boric acid and potassium permanganate. The storage life and quality of the fruits was maintained for up to 96days of storage.The shelf life of tomato was extended for up to 17days as a result of treatments with chlorine with the combinations of MAP and two storage conditions (ambient condition: Temperature 20-25°C & relative humidity 70-90% and refrigerator: 4-5°C & relative humidity 60-65%). With various studies that has been done and those still being carried out, these techniques can be successfully applied as hurdles in extending the postharvest shelf life of fresh tomatoes and also simultaneously preserving quality (organoleptic, nutritional and microbial).

5. Onion

Onion (*Allium cepa*) is one of the most important commercial condiment vegetable grown and consumed all over the world (Farooqi and Kumar, 2003) [36]. It is the oldest cultivated crop, and the pungent edible bulb belongs to the lily family considered as a food of exceptional value for flavouring and seasoning (Farooqi and Kumar, 2003) [36]. Onions are perennials, with the fleshy bulb growing below the ground. Onions it serves as a dual purpose of being a food and as a medicine. The green stems and leaves are hollow and can reach 3 ft (1m) in height. The plants bear small flowers that are usually white or purple. It has a superficial root system and very short flattened stem at the base of the plant, which increases in diameter as growth continues. The leaves of the plant are long, linear, hollow and cylindrical. Thickening of the leaf bases forms a bulb, when the plant reaches a certain stage of growth (Farooqi and Kumar, 2003) [36]. Epidemiological and clinical studies has shown that the nutritional consumption of this vegetable can help in the prevention and management of some diseases such as cancer, diabetes, peroxynitrite induced diseases, osteoporosis, cardiovascular diseases, tooth disorders, urinary infections, sexual debility, cholera, ear and skin disorder, cough and anemia e.t.c. (Nath *et al.*, 2010) [53].

Despite the high production rate in Nigeria and its nutritional benefits, it has a short postharvest life resulting in high losses. It is estimated that loss of total onion crop in developing countries is high and can reach 20-95%. Post-harvest losses of 16-35% have been reported. Exact data on the nature and extent of these losses at each step in the postharvest chain is not readily available in literature. However losses of over 9% have been reported for Spring onion between wholesale and retail (Amuttirantana & Passornsiri, 2000). Postharvest losses have serious economic impacts, such as direct financial losses on the part of the growers and also the marketers. It also indicates a waste of productive agricultural resources such as land, water, labour, managerial skills and other inputs that have been channelled towards the production of the crop. In most developing countries, postharvest losses of food crops have been faulted as a major cause of food insecurity and food shortage (Amuttirantana & Passornsiri, 2000). In order to reduce the postharvest losses of this commodity, various researches have been carried out on the best methods to employ. These techniques are aimed to extending the shelf life and preserving the freshness and quality of food product from the time of harvest to final consumption. Technologies such as Controlled Atmosphere Storage (CAS), passive and active Modified Atmosphere Packaging (MAP), cold storage, have been employed all in a bid to extend the postharvest shelf life and quality of the products. (Anthon and Barrett, 2012).

Despite the achievements in production technology, the post-harvest losses during storage still pose a great problem. Onion is a seasonal crop and bulbs are usually stored until the harvest of next season crop or for longer period due to seasonal glut in the market. Significant losses in quality and quantity of onion occur during storage. Storage of onion bulbs has, therefore, become a serious problem in the tropical countries. The post-harvest losses, viz., sprouting, rotting and physiological loss in weight pose a great problem. Keeping this in view, efforts are made to review all possible methods of onion storage and in this way it could be possible to quest for exact needed facility to reduce the rate of deterioration.

This paper deals with two sections, application of spray che micals or growth hormones prior to harvest and the effect of storage structures; methods on storability of onions. Applic ation of preharvest and spray chemicals for onion storage: Maleic hydrazide (MH, l,2 dihydropyridazine 3 6 dione), a c hemical as preharvest spray considerably prolongs the shelf life of onions. The effectiveness of maleic hydrazide depends on its translocation into the inner meristem or growth points where it could act upon, and thereby inhibit sprouting. The chemical is applied to the crop, usually 2 to 3 weeks before harvest when enough green foliage is present to facilitate its absorption and translocation. Bufler, (2009) [23] reported that maleic hydrazide application does not result in good sprout control when storage is at higher ambient temperatures. Maleic hydrazide does not have universal clearance and so as an alternate Pedeliski, used of ethephon (2-chloroethyl phosphoric acid) as pre-harvest spray to keep the bulbs dormant for longer period. Bufler, (2009) [23] found that Copra onion variety held in continuous ethylene (10.6 ml-1) had reduced sprout growth compared with those held in air. Adamicki, (2004) [1] reported that the application of ethephon to onion plants 2 weeks prior to harvest was found to reduce sprout incidence by 5% after 32 weeks of storage at 0°C; however, no significant reduction in rooting was observed. Onions treated with ethylene and 1MCP in combination afte r curing for 24hour had reduced sprout growth as compared with the control after 25 weeks harvest. Sprout growth follo wing storage beyond 25 weeks was only reduced through co ntinuous ethylene treatment. Unlike ethephon treatment, con tinuous ethylene exposure has been found to increase shelf life after 14 days at 20°C. Among the physiological factors which affect storage of bulbs, sprouting is the most obvious manifestation of deterioration. Sprouting does not start immediately after harvest and there is usually a time lag, the dormant period, which may last several weeks before growth resumes. The dormancy period depends on variety, climatic conditions during growth, harvest maturity, mechanical damage, microbial infections and the storage environment particularly the temperature. Sprouting of onions is devastating at temperature in between 5 - 15°C and gets most vulnerable when accompanied with relative humidity above 85%. Practices of onion storage: In Nigeria, different storage methods are practiced by the farmers but the most common one which is adapted by the farmers is ambient temperature storage this method involves storage of fresh onion in ventilated room space carpeted with wooden particles or rice chaff to preserve the onions for about four to eight weeks before taking to the market. The onion crop is harvested when the bulb is matured and leaves are green.

5.1 World production of onion

Onions is a crop that lends itself well to small –scale and part-time farming operations. Multiple markets exist for growers with small acreages and the various colour and types of mature bulbs (red, yellow, and white) allow growers to find their market niche. According to FAO, (2012) 60 million tons of dry onions are produced annually, with the crop being grown across 7.4 million acres in over 134 different countries. This represents a doubling of world production over the last ten years. Biggest producers are China, India and United States; accounting for about half of the worlds dry onion production. Other countries, with annual production figures above 1.1 million tons, are Brazil, Iran, Japan, Pakistan, Turkey and Russia. The current average world yield stands at 7.6 tons per acre (t/ac) but highest average yields of 17 – 26 tons per acre (t/ac) are found in Korea, Japan, Europe and the USA. Leading growers can produce crops that exceed 44 tons per acre (t/ac). The average annual onion consumption is over 13 lb of onions per person across the world. The highest consumers of onions are Libyans with an average per capita consumption around 66 lb/year. Between 15-18% of onions are processed for used in food items such as soups, relishes and sauces (FAO, 2012).

The term dry onion is used to distinguish them from green onions, which are pulled while the tops are still green and usually before large bulbs has formed. Many field operations, such as land preparation, planting and harvesting, can be custom hired, and most of the equipment for planting and harvesting can be used for other crops. The common onion (*Allium cepa*), is a member of the Amaryllidaceous family, originated in mid- Asia in what is now northwestern India, Afghanistan, Tajikistan and Uzbekistan. It was reported in the sixteenth century that onions were among the most common vegetables used at that time. They occurred in red and white varieties and were sweet, strong or intermediate in flavour. The onion was introduced by the Spanish in to the West indies soon after their discovery from there, onions were spread to all parts of the Americans and were grown by the earliest Colonist and soon afterward by native Americans. Relatives of onion include garlic, leek, chives, Welsh onion, and shallots. Most of the onions harvested in the United States are sold as fresh produce in 2010; the United States produced more than 150,000 acres of onions with a yield/harvest of almost 900 million tons (FAO, 2012).

5.2 Production of onion

Onion (*Allium cepa)* cultivation in Nigeria is confined to the Semi-Arid, Northern Guinea and Savanna zones. The bulk of onion production is from the dry season cropping system particularly under irrigation in the Northern States. In this light, the greater part of onion production in Nigeria is undertaken in the northern part of the country specifically in Kaduna, Kano, Jigawa, Katsina, Sokoto, Plateau and Bauchi States. The natural features of these regions, especially the presence of flood prone plains and river basins and above all the development of very large irrigated lands, create a condition that greatly favour the development of this crop (Ojo *et al*., 2009). In comparison with other fresh vegetables, onions are relatively high in food value of antioxidant and phytochemicals (Hussaini *et al*., 2000) [43]. The crop is the second only to tomatoes in importance among the vegetables in Nigeria and fifth in the world market (Hussaini *et al*., 2000) [43].

The trace metals enter the food chain from soil through mineralization by crops or environmental contamination as the application of agricultural inputs, such as pesticides, fertilizers, herbicides or use of polluted river (from industrial effluents) for irrigation (Cramer, 2000) [30]. Apart from its nutritional value, the common onion is one of the most outstanding higher plants recommended by United States Environmental Protection Agency (USEPA) and the American Society for Testing and Materials (ASTM) in 1982 and 1994 respectively for use as an excellent and alternative first–tier indicator for safety evaluation of cytogenetic and mutagenic effects of drinking water and environmental pollutants (Cramer, 2000) [30]. The use of *A. cepa* for root length inhibition and chromosome aberration bioassay as a sensitive, cost effective and valid indicator of toxicity test for the routine monitoring of water pollution is due to the important activation enzymes of the root tip cells (Fiskesjö *et al*., 2011) [37]. These shown good correlation with other test systems involved in genotoxicity (Fiskesjö *et al*., 2011) [37].

5.3 Chemical composition and nutritive values of onion

Onion has been described as the dynamite of natural foods (Rune, 2007). The outstanding characteristic of onion is its pungency, which is due to the volatile oil known as allyl-propyl disulfide. Onions contains vitamin B, vitamin C and traces of iron and calcium. Onions when compared with other fresh vegetable are relatively high in food energy, intermediate in protein content and rich in calcium and riboflavin (Rune, 2007). There is substantial disparity in composition between different varieties and it also varies with phase of mellowness and the length of storage. Onion has been accepted as an important source of valuable phytonutrients such as flavonoids, fructo-oligosaccharides (FOS) and thio-sulphinates and other sulfur compounds. According to Rune (2007), a mature onion contains about (86.6% moisture), (1.2% protein), (0.1% fat), (0.6% fiber), (0.4% minerals), and (11.1% carbohydrate) principally in the form of sugars per 100 g of edible portion. Apart from calcium and riboflavin as a mineral and vitamin, it also contains phosphorus, iron, carotene, thiamine, and niacin in small quantities (Rune, 2007).

5.4 Health benefits of onion

Epidemiological and clinical researches have shown that the increased consumption of onion could prevent the occurrence of some certain diseases (Silaste *et al*., 2007) [67]. This is due to its abundant phytochemical compounds such as carotenoids, phenols and flavonoids etc. (Dewanto *et al*., 2002) [31]. Studies have also shown that Onion is an excellent source of strong antioxidant which is full of anticancer compounds. It has been used particularly to inhibit stomach and intestinal cancers, thins the blood, lowers cholesterol, raises good-type HDL cholesterol and wards off blood clots. Also, the leaves of onions are aphrodisiac, anti-spasmodic, anti-helminthic, alterative, carminative, digestive, diuretic, emollient, expectorant, mild laxative, stimulant and tonic (Bakhru, 2011) [16]. Onion possesses pain-killing property (Bakhru, 2011) [16]. It has been reported that onions may help in the treatment of eye defect when its juice is mixed with honey (Bakhru, 2011) [16]. It is a valuable medicine for suppressing pain resulting from piles through its daily use as an ointment (Bakhru, 2011) [16].

Onions are known to contain anthocyanin and flavonoids. The mechanisms of action include free radical scavenging, chelation of transition metal ions, and inhibition of oxidases such as lipoxygenase (Udayan and Venkatesh, 2005) [69]. The anti-oxidative effects in onion such as inhibition of lipid peroxidation and lowering of low-density lipoprotein (LDL) cholesterol level have been allied with condensed risk of neurodegenerative disorders, several cancers, cataract formation, ulcer development and cardiovascular diseases. 3-mercapto-2-methylpantan-1-ol (3-MP), onion inhibits peroxy-nitrite-induced cytotoxicity, intracellular tyrosine nitration and intracellular reactive oxygen species. According to Bakhru (2011) [16], Onions are anti-coagulant food having a truly wonderful ability to counteract the detrimental clot-promoting effects of eating fatty acids. It also acts as an effective remedy for cholera. Onion ground with pepper mixture allays thirst, vomiting, diarrhea and restlessness when consumed by a cholera patient. Research studies have proved that the onions affect the liver's metabolism of glucose or release of insulin or prevent insulin's destruction. Onion is a mucus clearing vegetable and also, used to prevent cold, cough, bronchitis and influenza (Bakhru, 2011) [16].

Presence of essential oils like catechol, protocatechnic acid, thiocyanate, thiopropionol aldehyde and other micronutrients in onion avoid the peril of developing heart diseases and stroke. Studies have shown that intake of raw onion helps in healing tooth disorders and also the juice can be consumed, applied for curing ear infections, skin disorders, rheumatic diseases, urinary infections and bleeding piles. The aphrodisiac properties of onion increases libido and strengthens reproductive organs of sexual importance (Bakhru, 2011) [16]. Other pharmacological activities of onion include inhibition of carcinomas, immune-suppression and neuro-protective effects. It is highly effective against pathogenic gram-positive bacteria and dermatophytic fungi and also promotes beneficial microorganisms (Nath *et al*., 2010) [53].

5.5 Postharvest storage and preservation practices of onion

Storage and preservation of onion can be done either in cool (0 °C, 65 - 70% RH) or warm (22 °C; 65-70% RH) conditions and has been reported to keep well up to 6 - 7 months for cool and about 6 weeks for warm conditions. Onions can be frozen, washed, chopped to desired sizes, blanched for 3 minutes and then put in ice water before freezing. Drained onions can be blanched and spread on trays before placing in a freezer. Once the onions are frozen, it can be transfered into a freezer bag.

5.5.1 Traditional techniques of onion storage

The age-long methods of onion preservation by farmers in the northern part of Nigeria where the onions mostly produced, the farmers used ventilated room space carpeted with wooden particles or rice chaff to preserve the onions for about four to eight weeks before taking to the market (Nath *et al*., 2010) [53]. This method is risky as in some cases, large percentage of the produce gets rotten before they take the onions to the market.

5.5.2 Low temperature storage

To maintain optimum quality and extend the shelf life, onions can be stored 3 to 4 weeks at 0 °C (32 °F) with 95-98% relative humidity (Adamicki, 2014) [2]. The storage life of onion decreased to 1 week if the temperature is 5 °C (41 °F), and rapid yellowing and decay of leaves occurs at higher temperatures (Adamicki, 2014) [2]. Pungent dry onions can be stored for 6 to 9 month at 0 °C (32 °F) with 65-75% relative humidity (Adamicki, 2014) [2]. Adamicki, (2014) [2] reported that the high relative humidity induces the root growth, while high temperature induces sprouting. A combination of high temperature and high relative humidity leads to increases in onion rotting and decreases quality of the onion bulb. Storage below the freezing point of -1 to -2 °C (28 to 30 °F) is recommended in Europe (Adamicki, 2014) [2]. But mild type or sweet onions can be kept for 1 to 3 month; they are stored in common storage with cool, circulating ambient air or in refrigerated cold rooms. The Onions grown from the seed stores better than those grown from the sets or transplants (Adamicki, 2014) [2]. After harvesting, onion bulbs can enter into a state of rest for 4 to 6 weeks, depending on the cultivar and weather conditions during growing of onions bulbs.

Maleic hydroxide is a sprouting inhibitor, which is often used to prevent root growth and sprouting during long-term storage of onion bulb. It is applied for 2 weeks before harvesting of onions. Onions that can be intended for storage should be dried well and cured in the field, under sheds, or in storage. After curing and drying the onions for 2 weeks in field, it can be transferred to storage rooms for final drying and curing. Forced-air ventilation can be applied at 25-27 °C (77 to 81 °F) by using outside or heated air (Adamicki, 2014) [2].

Onions can be dried and stored on the floor surface area, it is reported that drying of onions can be regarded as completed when the neck of the onion is tight; the outer scale dry and starts to make a rustling noise when touched and when the skin colour is uniform. It is reported that weight of the onions can be reduced by 3 to 5% during drying and storage (Adamicki, 2014) [2]. Losses due to neck rot can be reduced by rapid drying immediately after harvesting the onions.

5.5.3 Modified and controlled atmosphere storage

Ethylene related deterioration is inhibited or reduced when harvested fruits are stored in modified or controlled atmosphere. The use of controlled atmosphere (CA) or modified atmosphere (MA) entails the deliberate manipulation of the composition of the gaseous composition of the environment to optimize the product quality. In controlled atmosphere (CA) the gas constituents are more precise and stable while with modified atmosphere (MA) the air composition changes continuously (Majidi *et al*., 2014) [50]. Carbon dioxide is increased and oxygen is reduced in CA and MA. The effectiveness of this method is dependent on the fruit variety, maturity and initial quality, storage temperature, and the composition and duration of exposure to MA or CA (Brecht *et al*., 2003) [21]. Onions can be stored for 6 to 8 weeks in 2% O_2 and 5% CO_2 at 0 °C (32 °F). They can tolerate 1% O_2 and up to 5% CO_2, but off flavour may be develop if they are stored at >5 °C (41 °F) (Suslow and Cantwell, 2014) [65].

Low O_2 atmospheres reduce respiration and extend shelf life of onions, but increases in CO_2 reduce sprouting and root growth in onions. Controlled atmospheres have been used for storage of pungent onions in some countries like England, Switzerland and Poland (Adamicki, 2014) [2]. An atmosphere of 3% O_2 and 5% CO_2 inhibits rotting, sprouting and disease development (Adamicki & Kepka, 2014; Smittle, 2014) [2, 62]. However, onions stored in 3% O_2 and 10% CO_2 showed physiological disorders; high CO_2 caused injury, but neck rot of onions (*Botrytis* spp.) may be reduced (Sitton *et al*., 2014). After storage of onions for about 226 days in 3% O_2 and 5% CO_2, sprouting of onions at 20 °C (68 °F) may be delayed for 10 days, when compared with air-stored controls (Adamicki & Kepka, 2014) [2]. It is possible to store onions in low O_2 (1 to 2%) and 2% of CO_2 (Adamicki, 2014; Tanaka *et al*., 2014) [2, 68].

5.5.4 Irradiation of onions

It is classified as non-ionizing. Ionizing radiation is high frequency and causes loss of ions from the material with which it comes into contact. Radiation can also minimize the colonization of fruit with pathogens due to contamination, insect infestation, postharvest disease, as well as delay ripening (Allende *et al*., 2006; Bruhn *et al*., 2009). The three most commonly used are UV-C, X-ray and gamma-rays. Ultra violet ray is non-ionizing and is frequently used for postharvest management of fruit. Most irradiation experiments were done with UV-C but UV-B has recently been investigated (Charles & Arul, 2007) [27].

5.5.5 Postharvest quality indices

Onion is regarded as non-climacteric fruit with consistently low endogenous ethylene production during storage (Hussaini *et al*., 2000) [43]. It has the value of distinctive pungent flavour and it's an essential ingredient in cuisine of many regions of the world. It can be eaten raw or in cooked form and also used in salads. Onion can be generally dehydrated and pickled as a processed product. The ratio of raw material to finished processed product depends on the solid content of raw material, maturity of the onion depend on the size, shape of bulb and deterioration of the produce during storage (Hussaini *et al*., 2000) [43]. Onion with high solid content (dry matter) is preferred for dehydration. Kumar *et al*., (2007) [48] found that there is a higher postharvest losses in dry land plots than in the irrigated lands when treatments were applied throughout the entire season of growth. Soil moisture and nitrogen regimes had influence on the production of different grades of onion bulbs.

Many commercial onions are stored before marketed, but cultivars differ in their storage capability. The aim of onion bulb storage is to cover consumer demands and extend the availability of onion and its keeping quality. The main factor which produces deterioration of onion bulbs during storage are the pre and postharvest environmental conditions (Hussaini *et al*., 2000) [43]. Both, water and nutrient management of onion production have significant effects on postharvest behaviour of produce. These pre-harvest inputs influence the storage behaviour of onion bulbs directly or indirectly (Hussaini *et al*., 2000) [43]. For example, bulbs grown under low soil moisture regimes are usually smaller and tend to loose moisture readily during storage. Nitrogen has an adverse effect on storability of onions. The crop grown with higher doses of Nitrogen results in rotten and early sprouting in onions on storage. The amount and frequency of irrigation influence the yield and quality of onions (Kumar *et al.,* 2015) [47].

6.0 Factors influencing effective storage of onions

In a bid to meet consumer demand for fresh products with extended shelf life, postharvest technologists have been able to focus on influencing the development of some specific quality characteristics. This is done to slow down the event of ripening and eventual senescence of the fruit. Also in the area of inhibiting the action of enzymes involved in the breakdown of the fruit cell wall. The following are major areas of focus in postharvest preservation of onion.

6.1.1 Maturity

Onions can be harvested when the necks are reasonably dry and the tops have fallen over. As onions mature, the dry matter content and pungency increases as a result of increase in storage potential.

6.1.2 Ethylene Production and Sensitivity

The need to inhibit or slow down the rate of ethylene production is also very important in extending the postharvest life of fruits (Sammi & Masud, 2007) [58]. Ethylene production in onions is very low which contains < 0.1 μL kg^{-1} h^{-1} at 20 °C (68 °F) (Suslow & Cantwell 2014) [65] and also Sensitivity to ethylene is low, but it has a concentrations of >1,500 μL L^{-1} which encourages the sprouting of onion bulbs (Suslow & Cantwell 2014) [65].

6.1.3 Precooling Conditions

In order to maintain the high quality of onion bulbs, onions should be precooled at < 4 °C (39 °F) within 4 to 6 weeks after harvesting. Hydrocooling, forced-air cooling, and vacuum-cooling are used with crushed ice over the product to maintain the temperature and moisture content. Dry onion bulbs for long-term storage should be precooled at 0 °C (32 °F) immediately after drying. The precooling method affects it's storability of the onion bulbs. Rapid precooling inhibits rotting and sprouting in onion during storage. Natural cooling has a positive effect on storability when the onions have a long rest period and good weather conditions for curing. Gradual cooling at 1 °C (1.8 °F) per day in storage is less effective at inhibiting sprouting and rotting than rapid cooling (Suslow & Cantwell 2014) [65].

6.1.4 Chilling sensitivity

Onions are not sensitive to chilling and can be stored at -2 to -3 °C (28 to 27 °F), since the highest freezing point is -0.8 °C (31.6 °F). However, storage at <-4 °C (25 °F) may cause freezing injury (Suslow & Cantwell 2014) [65].

7. Physiological problems associated with postharvest sto rage of onion

According to Adamicki and Kepta, (2014) [2]; Smittle (2014); Hoftun (2014) [42]; Suslow and Cantwell, (2014) [65] and Solberg *et al*. (2014) [63], onion bulbs are affected by several physiological disorders. They also reported that freezing injury is causes soft, water-soaked, fleshy scales and rapid decay of onion bulb after transferring the onion from cold storage to higher temperature storage which leads to microbial growth. The studies showed that the translucent scales occurs with loss of or changes in carbohydrate content (Adamicki & Kepta, 2014) [2]. Also, studies showed that storage of onions at >7% CO_2 can lead to development of translucent scales (Adamicki and Kepta, 2014) [2]. Late harvesting takes longer time of drying and at high temperatures it will produce the highest incidence of translucent scales (Adamicki & Kepta, 2014) [2]. A watery scale is a thick leathery skin with watery, glassy, fleshy scales. The watery scales may be affected by fungal or bacterial growth. Late harvesting and prolonged field drying can lead to produce having highest occurrence of leathery skin. A scale greening and green coloration of outer scales is caused by exposure to light after curing. Ammonia injury is also indicated by brown-black blotches resulting from leakage of ammonia during storage (Adamicki and Kepta, 2014; Smittle, 2014; Hoftun, 2014; Suslow & Cantwell, 2014; Solberg *et al*., 2014) [2, 42, 65, 63].

7.1.1 Pests and diseases

Onions suffer from a number of pest and diseases. The most serious for the home gardener are likely to be the onion fly, stem and bulb eelworm, white rot, and neck rot. Diseases affecting the foliage include rust and smut, downy mildew, and white tip disease. The bulbs may be affected by splitting, white rot and neck rot.

7.1.2 Pathogens and spoilage organisms

Ripening of fruits means production of some desirable nutrients which could enhance the proliferation of pathogenic or spoilage microorganisms, if proper postharvest measures are not put in place the problems caused by pathogens and spoilage organisms are a major source of concern in postharvest food losses. Important to note is that before applying the above principles, some important point of harvest factors needs to be considered. Factors such as time of harvest (considering the level of maturity), reduction of mechanical damage as much as possible, the condition of water used for cooling of the harvested product and sanitation of the packing house.

7.1.3 Postharvest pathology

Microorganisms attack onions during storage include:

Botrytis neck rot is indicated by watery decay, which begins at the neck and then attacks the entire bulb. A gray fungal mold covers the neck of the bulb and the whole surface of the bulb. (Ryall & Lipton, 2014; Suslow & Cantwell, 2014) [57, 65]. Neck rot can be slowed after harvesting, but it cannot stop, even if stored under optimum conditions (Ryall and Lipton, 2014; Suslow and Cantwell, 2014) [57, 65]. Proper drying of onion in the field and during storage can decrease this postharvest fungal decay disease.

Black mold rot provides a black discoloration and shriveling on the neck and also on the outer scales which is caused by *Aspergillus niger* van Tiegh. Infection usually occurs in the field, but the disease spreads from bulb to bulb. The surface of the bulbs must be dry during and after harvesting to avoid infection. Storage at 0 °C (32 °F) with moderate Relative humidity prevents the spread of the disease (Ryall and Lipton, 2014; Suslow amd Cantwell, 2014) [57, 65].

Blue mold rot also produces watery soft rot on the neck and outer scales, followed by formation of blue to blue-green mold of the fungus *Penicillium* spp. Harvesting of mature bulbs, proper curing, and storage of onions at 0 °C (32 °F) with 60 to 70% RH will minimize the blue mold problems.

Bacterial soft rot, caused by *Erwinia carotovora* Jones, develops water-soaked individual scales, or at the entire onion bulb, which causes foul smelling, viscous, liquid-covered rotted areas (Ryall amd Lipton, 2014; Suslow and Cantwell, 2014). The disease progresses rapidly under warm and humid conditions. Harvesting at full maturity, proper drying, it minimizes the bruising and maintains the optimum storage conditions, and also prevents the bacterial soft rot (Ryall amd Lipton, 2014, Suslow amd Cantwell 2014) [57, 65].

8.0 Utilization of onion

8.1.1 Culinary uses of onion

In Nigeria it is an important component of the daily diet which can be eaten both in raw and cooked state. The onions has a particular flavour that gives dishes a pleasant taste and is often used as a “base” for the preparation of broth, soups, casseroles, risottos, meats tasty sauces, stuffed onions, in salads.

8. 1.2 Onion beverage production

The juice from the red onion cultivar which contained 67.3 g/l of total sugar was smoothly fermented by repeated batch operation using the flocculating yeast. The productivity, the final ethanol concentration and the ethanol yield were about 6.5 g/l, 30.6 g/l and 91.9%, respectively. The onion alcohol produced could be used as a favorable source of onion vinegar or alcohol beverage (Sammi and Masud, 2007) [58]

Conclusion

Since in the postharvest life of these products is not just about the pathogens but about the various biochemical and physiological changes that occurs as a result of ripening, all of which has a direct effect on the storability and shelf life of the product. It is very imperative to slow down these processes as much as possible to ensure that the freshness, nutritional and organoleptic qualities are intact by the time it gates to the final consumers. Research carried out by different scientist on the postharvest technology of tomatoes and onion has been able to prove that application of existing and novel techniques can successfully help to extend the shelf life of fresh tomato and onion produce. Therefore the onus lies on postharvest technologists to study these techniques and develop methods of intellectual people applying them in the preservation of fruits and vegetables. Unfortunately, developing countries such as Nigeria have a long way to go in this area. This is not far-fetch from the dearth of researchers who are actually interested in solving problems. Also the lackadaisical attitude of the government in sponsoring research is of a major concern. The lack of the required infrastructure for the successful application of these technologies is also a major issue.

Conflict of interest

The authors have no conflict of interest to report.

References

1. Adamicki F. Effects of pre-harvest treatments and storage conditions on quality and shelf-life of onions. Acta Horticulture. 2004; 688:26–33. doi:10.5958/0976-0741.2014.00911.8
2. Adamicki F, Kepka A. Storage of onions in controlled atmosphere. Acta Horticulture. 2014; 38:53-75. doi:10.5958/0976-0741.2014.00911.8
3. Adedeji OK, Taiwo C, Akanbi, Ajani R. Physico-chemical properties of four Tomato cultivators grown in Nigeria. Journal of Food Processing and Preservation. 2006; 30(1):79-86.
4. Aguayo E, Escalona VH, Artes F. Effect of cyclic exposure to ozone gas on physicochemical, sensorial and microbial quality of whole and sliced tomatoes. Postharvest Biology Technology. 2006; 39:169–177. (January, 2016).
5. Alexander L, Grierson D. Ethylene biosynthesis d action in tomato: a model for climacteric fruit ripening. Journal of Experimental Botany Volume 53, no. 377, Fruit Development and Ripening Special Issue. 2002; 53(377):2039-2055. dOI: 10.1093/jxb/erf072.
6. Ali A, Maqbool M, Ramachandran S, Alderson PG. Gum arabic as a novel edible coating for enhancing shelf-life and improving postharvest quality of tomato (Solanum lycopersicum L.) fruit. Postharvest Biology and Technology. 2010; 58:42–47.
7. Allende A, Tomas Barberan FA, Gil MI. Minimal processing for healthy traditional foods. Trends in Food Science and Technology. 2006; 17:513-519.
8. Amuttiratana D, Passornsiri W. In Bhatti, M.H., Ch. Hafeez, A., Jaggar, M., Farooq. Postharvest losses of vegetables. A report on workshop held between 17 And 22 October at the Pakistan Agricultural Research Council, Islamabad, Pakistan. FAO Regional Co-operation for vegetable research and development RAS/89/41, 2000.
9. Anthon GE, Barrett DM. Pectin methyl esterase activity and other factors affecting pH and titritable acidity in processing tomatoes. Food Chemistry. 2000; 132:915-920. doi: 10.11648/j.ijfsb.20180303.14
10. Anthon GE, Le Strange M, Barrett DM.. Changes in pH, acids, sugars and other quality parameters during extended vine holding of ripe processing tomatoes. Journal of the Science of Food and Agriculture. 2011; 91:1175-1181.
11. Arah IK, Amaglo H, Kumah EK, Oferi H. Preharvest and Postharvest Factors affecting the Quality and Shelf life of Harvested Tomatoes: A mini Review.

International Journal of Agronomy. 2015; 6:215. doi 10.1155/2015/478041
12. Arnao MB, Cano A, Acosta M. The hydrophilic and lipophilic contribution to total antioxidant activity. Food Chemistry. 2001; 73:239-244.
13. Ayandiji A, Adeniyi OR, Omidiji D. Determinant Postharvest Losses among Tomato Farmers in Imeko-Afon Local Government Area of Ogun State, Nigeria. Global Journal of Science. Front. Res. 2011; 5:23-27.
14. Ayandiji AOR, Adeniyi OD. Determination of Postharvest losses among Tomato Farmers in Imeko-Afon Local Government Area of Ogun State, Nigeria. Global Journal of Science. Front. Res. 2011; 11(5):22-28.
15. Bailen G, Guillen F, Castillo S, Serrano M, Valero D, Martinez Romero D. Use of activated carbon inside Modified Atmosphere Packages to maintain tomato fruit Quality during cold storage. Journal of Agricultural and Food Chemistry. 2006; 54(6):2229-2235. doi: 10.1021/jf0528761.
16. Bakhru HK. Indian Spices and Condiments as Natural Healers. Jaico publishing House, 2011.
17. Basu A, Imrhan V. Tomatoes versus Lycopene in Oxidative Stress and Carcinogenesis: Conclusions from Clinical Trials. European Journal of Clinical Nutrition. 2006; 61:295-303. doi:10.1038/sj.ejcn.1602510.
18. Basu A, Imrhan V. Tomatoes' Versus Lycopene in Oxidative Stress and Carcinogenesis: Conclusions from Clinical Trials. European Journal of Clinical Nutrition. 2007; 61(3):295-303.
19. Beckles DM. Factors affecting the postharvest soluble solids and sugar content of tomato (Solanum lycopersicum L.) fruit. Postharvest Biology and Technology. 2012; 63:129-140.
20. Bhattacharjee S. Analysis of the Proximate Composition and Energy Values of Two Varieties of Onion (*Allium Cepa* L.) Bulbs of Different Origin: A Comparative Study. International Journal of Nutrition and Food Sciences. 2013; 2(5):246-253. DOI: 10.5897/JSPPR2018.0263
21. Brecht JK, Chau KV, Fonseca SC, Oliveira FAR, Silva FM, Nunes MCN *et al*. Maintaining optimal atmosphere conditions for fruits and vegetables throughout the postharvest handling chain. Postharvest Biology and Technology. 2003; 27:87-101.
22. Bruhn CM, Gorny JR, Kader AA, Mitcham EJ. In: California, U.O. (Ed.), Produce Irradia-tion: Recommendations for Maintaining Produce Postharvest Quality, Safety & Marketability. Postharvest Technology Research Information Center, Davis http://postharvest.ucdavis.edu/datastorefiles/2341208.pdf, 2009.
23. Bufler G. Exogenous ethylene inhibits sprout growth in onion bulbs. Ann Bot London. 2009; 103:23-28.
24. Cantwell MI, Kasmire IF. Postharvest Handling System; Fruits/Vegetables. In Kader Adel A. (ed.). Postharvest Technology of Horticultural Crops. Third Edition, University of California, Publication 3311, 2002, 407-422.
25. Cantwell MI, Nie X, Hong G. Impact of Storage Conditions on Grape Tomato Quality 6th ISHS Postharvest Symposium, Intl Soc. Hort. Sci., Antalya, Turkey, 2009.
26. Caridi D, Trenerry VC, Rochfort S, Duong S, Laughter D, Jones R. Quantifying quercetin glucosides in onion (*Allium Cepa* L.) varieties using capillary zone electrophoresis and high performance liquid chromatography. Journal of Food Chemistry. 2007; 105:691-699. DOI: 10.5897/JSPPR2018.0263
27. Charles MT, Arul J. UV treatment of fresh fruits and vegetables for improved quality: a status report. Stewart Postharvest Review. 2007; 3:1-8.
28. Choi DS, Park SH, Choi SR, Kim JS, Chun HH. The combined effects of ultraviolet-C irradiation and modified atmosphere packaging for inactivating Salmonella enterica serovar Typhimurium and extending the shelf life of cherry tomatoes during cold storage. Food packaging and shelf life. 2014; 3:19-30. http://www.elsevier.com/locate/fpsl. Critical Review in Food Science and Nutrition 48, 496–511.
29. Corzo Martinez M, Corzo N, Villamiel M. Biological properties of onions and garlic. Journal of Trends in Food Science and Technology. 2007; 18:609-625. DOI : 10.5897/JSPPR2018.0263
30. Cramer CS. Breeding and Genetics of Fusarium basal rot resistance in onion. Euphytica. 2000; 115:159-16.
31. Dewanto V, Wu X, Adom KK, Liu RH. Thermal Processing Enhances the Nutritional Value of Tomatoes by Increasing Total Antioxidant Activity. Journal of Agricultural and Food Chemistry. 2002; 50:3010-3014.
32. De Lennoy G. Tomato. In Reamaekers, R. H. (Ed). Crop Production in Tropical Africa. Directorate general for International Co-operation. Brussels, Belgium, 2001, 467-475.
33. Eldahshan OA, Singab ANB. Carotenoids. Journal of Pharmacognosy and Phytochemistry. 2013; 2(1):225-234. ISSN 2278- 4136.
34. Fagunde C, Moraesa K, Pérez Gago MB, Palou L, Maraschinc M, Monteiro AR. Effect of active modified atmosphere and cold storage on the postharvest quality of cherry tomatoes. Postharvest Biology and Technology. 2015; 109:73-81.
35. FAOSTAT. Data Food and Agricultural Organization of the United Nations, 2015. (http://faostat.

fao.org/site/567/default.aspx#ancor),

36. Farooqi AA, Kumar N. Growth regulators on sprout inhibition and storage quality of carrots and onions. Plant Physiology, 25: 539-549.Journal of Advance Pharmaceutical Residual. 2003; 1(2):94-100.doi: 10.11648/j.ijfsb.20180303.14
37. Fiskesjö G. The Allium test in waste water monitoring. Environmental Toxicology and Water Quality. 2011; 8:291-298.
38. Freeman BB, Reimers K. Tomato Consumption and Health: Emerging Benefits. American Jounal of Lifestyle and Medecine, 2010, 1-11.
39. Frusciante L, Carli P, Ercolano MR, Pernice R, Di Matteo A, Fogliano V *et al*. Antioxidant Nutritional Quality of Tomatoes, 2007. doi: 10.1002/mnfr.200600158.
40. Gao G, Bergefurd B, Precheur B. Growing Tomatoes in the Home Garden". Ohio State University Extension Bulletin 1624. Fact sheet Agriculture and Natural Resources, 2010.
41. Giovannoni J. Genetic Regulation of Fruit Development and Ripening. The Plant Cell, 2004. www.plantcell.org.
42. Hoftun H. Internal atmosphere and watery scales in onion bulbs (Allium cepa L.). Acta Horticulture. 2014; 343:135-140. doi:10.5958/0976-0741.2014.00911.8
43. Hussaini MA, Amans EB, Ramalan AA. Yield, bulb size distribution and storability of onion (*Allium cepa* L.) under different levels of N fertilization and irrigation regime. Tropical Agriculture. 2000; 77:145-152.
44. Islam MP, Morimoto T, Hatou KK. Storage Behavior of Tomato inside a Zero Energy Cool Chamber. Agricultural Engineering International Journal. 2012; 14(4):209-217.
45. Kader AA, Ben Yehoshua S. Effects of super atmospheric oxygen levels on postharvest physiology and quality of fresh fruits and vegetables. Postharvest Biology and Technology. 2000; 20:1-13.
46. Karmarkar DV, Joshi MB. Investigations on the storage of onions. Indian Journal of Agricultural Sciences. 2014; 11:82-89. doi:10.5958/0976-0741.2014.00911.8
47. Kumar VP, Prashanth KVH, Venkatesh YP. Structural analyses and immunomodulatory properties of fructo-oligosaccharides from onion (Allium cepa). 2015; 117:115-122. DOI: 10.5897/JSPPR2018.0263
48. Kutama AS, Aliyu BS, Mohammed I. Fungal Pathogens Associated with Tomato Wicker Storage Baskets. World Journal of Science. 2007; 2(2):38-39.
49. Kumar S, Imtiyaz M, Kumar A, Singh R. Response of onion (*Allium cepa* L.) to Different levels of irrigation water. Agricultural Water Management. 2007; 88:161-166.
50. Majidi H, Minaei S, Almassi M, Mostofi Y. Tomato Quality in Controlled Atmosphere Storage, Modified Atmosphere Packaging and Cold Storage. Journal of Food Science and Technology. 2014; 51(9):2155-2161 dOI 10.1007/s13197-012-0721-0.
51. Martinez Romero D, Bailen G, Serrano M, Guillen F, Valverde JM, Zapata P, *et al*. Tools to maintain postharvest fruit and vegetable Quality through the inhibition of ethylene action: a review. Critical reviews in Food Science and Nutrition. 2007; 47:543-560.
52. Mashav. Use of alginate or zein as edible coatings to delay postharvest ripening process and to maintain tomato (Solanum lycopersicon Mill) quality. J. Sci. Food Agric. 2010; 88:1287-1293.
53. Nath KVN, Rao KNV, Banji D, Sandhya S, Sudhakar K, Saikumar P, *et al*.. Onion (*Allium cepa*) – Ethno medicinal and therapeutic properties. Journal of Advance Pharmaceticals Residue. 2010; 1(2)**:**94-100. doi: 10.11648/j.ijfsb.20180303.14
54. Ojo MA, Mohammed US, Adeniji B, Ojo AO. Profitability and technical efficiency in irrigated onion production under Middle Rima valley irrigation project in Goronyo, Sokoto State Nigeria. Continental Journal of Agricultural Science. 2009; 3:7-14.
55. Raffo A, La Malfa G, Fogliano V, Maiani G, Quaglia G. Seasonal variations in antioxidant components of cherry tomatoes (Lycopersicon esculentum cv. Naomi F1). Journal Food Composition and Analysis. 2006; 19(1):11-19.
56. Rao AV. Diet and Chronic Diseases: Role of Phytonutrients. In: Tomatoes, Lycopene and Human Health; Preventing Chronic Diseases. Caledonian Science Press., Scotland, 2006, 15-17
57. Ryall AL, Lipton WJ. Handling, Transportation, and Storage of Fruits and Vegetables, 2nd ed., vol. 1. AVI, Westport CT, 2014.
58. Sammi S, Masud T. Effect of different packaging systems on the quality of tomato (Lycopersicon esculentum var. Rio Grande) fruits during storage. International Journal of Food Science and Technology. 2007; 44(5):918-926. Dio: 10.1111/j.1365-2621.2007.01649x.
59. Siddiqui MW, Ayala Zavala JF, Dhua RS. Genotypic variation in tomatoes affecting processing and antioxidant properties. Critical Reviews in Food Science and Nutrition, 2015. http://dx.Doi.org/10.1080/10408398.2012.710278.
60. Shankar N, Joep VLJ, Marja G, Martin H, Barbara VD. Cultivation of Tomato Production, Processing and Marketing. Agrodok 17, Agromida Foundation and CTA Wageningin, 2005.
61. Sitton JW, Fellman JK, Patterson ME. Effects of low-oxygen and high-carbon dioxide on postharvest quality, storage and decay of "Walla Walla" sweet onions. *In* M.E. Saltveit, ed., 7th International Controlled Atmosphere Research Conference, July 13-18, 1997, University of California, Davis. 2014; 4:20-25. University of California, Davis, CA. doi:10.5958/0976-0741.2014.00911.8
62. Smittle DA. Evaluation methods for 'Granes' onions. Journal of American Soccer Horticultural Science. 2014; 113:877-880. doi:10.5958/0976 0741.2014.00911.8

63. Solberg SO. Effects of harvesting and drying methods on internal atmosphere, outer scale appearance, and storage of bulb onions. Journal of Vegetable Crop Production. 2014; 42:23-35. doi:10.5958/0976-0741.2014.00911.8
64. Sulumbe IM, Shettima BG, John TB. An analysis of the marketing of onion in Monguno local government area of Borno State, Nigeria. Journal of Marketing and Consumer Research. 2015; 13:9-14. DOI: 10.5897/JSPPR2018.0263
65. Suslow T, Cantwell M. Onions: dry. Recommendations for maintaining postharvest quality, 2014. *At* http://postharvest.ucdavis.edu/produce_information.
66. Slimestad R, Fossen T, Verheul MJ. Flavonoids of Tomatoes. Journal of Agricultural and Food Chemistry. 2008; 56:2436-2441.
67. Silaste ML, Alfthan G, Aro A, Kesaniemi YA, Horkko S. Tomato juice decreases ldl cholesterol levels and increases ldl resistance to oxidation. Br J nutr. 2007; 98:1251-8.
68. Tanaka KY, Matsuo, Egashira J. Controlled atmosphere storage for onions. *In* T. Kozai, ed., Proceedings of the International Symposium on Plant Products in Closed Ecosystems, Narita, Japan. 1996-2014, 669-674. Acta Horticulture Leuven, Belgium. doi:10.5958/0976-0741.2014.00911.8
69. Udayan PS, Venkatesh S. Onion (Allium cepa) – Ethnomedicinal and therapeutic properties. Journal of Natural Rem. 2005; 5(1):35-40.
70. Vibhakara HSJ, Gupta DKD, Jayaraman KS, Mohan MS. Development of a High-Moisture Shelf-Stable Grated Carrot Product Using Hurdle Technology. Journal of Food Process and Perseveration. 2006; 30:134:144. Doi:10.1111/j.1745- 4549.2006.00055.x.
71. Zapata PJ, Guillen F, Martinez Romero D, Castillo S, Valero D, *et al*. Use of alginate or zein as edible coatings to delay postharvest ripening process and to maintain tomato (Solanum lycopersicon Mill) quality. Journal of Food Agriculture. 2008; 88:1287–1293.s