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STUDY ON THE MICROBIAL SPOILAGE OF TOMATO (*Lycopersicon esculentum*): A REVIEW

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***Abstract*:** Tomatoes contain a lot of water, making them more prone to deterioration due to the action of numerous microbes. This makes storage and shipping difficult for this vegetable. Tomatoes are a common vegetable that is eaten fresh in salads, garnished on other foods, and cooked to provide flavours to a variety of dishes. As a result, it is a common food component in both Asian and European countries. Furthermore, tomatoes are high in vitamins, particularly vitamin A, as it contains the precursor -carotene, which is critical for vision. It is also a good supplier of minerals, making it an important food component. Bacteria, the fungus was shown to be the source of spoiling in the majority of the samples. This review paper aims to study various microorganism which are involved in spoilage of tomatoes. This can help in creative different majors for preventing spoilage of tomato. Also, these fungi are the source of highly potent mycotoxins, which can cause serious food poisoning and even death review, the results can be dangerous. We have made an effort to list all of the tomato-related causes that have been researched in this review.

***Keywords*:** Spoilage, Tomato fruit, Fungal deterioration, Bacterial spoilage, good agricultural practises (GAP)

I. INTRODUCTION

It's possible to eat tomatoes both raw and cooked, making them a popular fruit. *Lycopersicum Esculentum* is a plant in the *Solanaceae* family with the botanical name *Lycopersicum Esculentum.* Vitamin A and vitamin C are abundant, as are carbohydrates, proteins, lipids, fibers, and potassium. It contains a lot of lycopene, which provides a lot of health benefits. It includes a considerable volume of water, making it more prone to deterioration due to bacterial action. Tomatoes have a lower sugar concentration than other fruits, making them less sweet (André, *et al.*, 2017).

Food deterioration refers to a variety of changes in food that make it less appealing or even harmful to consumers. Changes in fragrance, taste, appearance, or texture may accompany these changes (Akinmusire, 2011).

Vitamins B, C, and E are abundant in this fruit. Carbohydrates like fructose and glucose, as well as trace minerals like iron, copper, zinc, and dietary fibre, are all essential nutrients for human health. Due to their high-water content, tomatoes are more susceptible to microbial degradation (Obunkwu *et al*, 2018). Tomatoes are very important for their dietary needs, and they can be consumed in a variety of ways. They can be cooked as a vegetable, used as an ingredient in a variety of recipes and sauces, used to make stew, fruit juices, and eaten raw in salads (Onuorah and Orji, 2015). Tomato rotting refers to when the quality of tomatoes deteriorates due to a combination of biological and physical reasons. The fruits' taste, smell, look, or texture may alter as a result of these modifications. In 2015, Onuorah and Orji. According to estimates, nearly a third of the produce is wasted before it reaches the consumer (Mbajiuka and Emmanuel, 2014). This loss has been linked to a variety of reasons, including physical (mechanical breakage, bruising) and microbiological (fungi and bacteria) damages (Onuorah and Orji, 2015).

Tomatoes are prone to deterioration during storage, shipping, and waiting to be processed. The microbial degradation of tomato fruits lowers the market value and nutritional quality of the product. Contaminations with mycotoxins, which form aflatoxins in humans after inhalation or ingestion, render tomato fruits unfit for consumption, resulting in food poisoning (Bello *et al.*, 2016). Some research has been done to discover bacteria and fungi that are linked to tomato rotting. *Bacillus subtilis, Klebsiellaaerogenes, Pseudomonas* *aeruginosa, Salmonella typhi, Proteus mirabilis,* and *Staphylococcus aureus* were isolated from spoiled tomatoes in Benin City by Wogu and Ofuase in 2014. In Lagos State, Nigeria, a similar study found significant amounts of *Staphylococcus spp, Bacillus spp, and Escherichia coli* (Ogundipe *et al*., 2012). *Rhizopussp* have been linked to tomato rotting, according to Akinmusire (2011).

Food deterioration refers to various changes that render food poisonous and less edible for customers. These changes may be related to changes in the food's appearance, texture, flavour, or odour. Tomato (*Solanum lycopersicum L*.) is the third most cultivated and world widely grown vegetable crop. Worldwide, household consumption is rapidly rising. The tomato is a fruit with a berry-like endocarp and delicious flesh. It naturally contains high levels of protein, dietary fibre, vitamins, and minerals. It naturally contains high levels of protein, dietary fibre, vitamins, and minerals. The tomato fruit serves as food, medicine, a dietary supplement, a flavouring agent, a detoxifier, and a system cleanser (Couey, 1982).

Pre- and postharvest illnesses, inappropriate handling, and other circumstances can have an impact on the nutritional value and quality of newly produced tomato fruits (Kader, 1986). Fungi are the most important and prevalent pathogens that infect a wide range of host plants, causing destruction and economic loss in tomato either in the field, storage or transportation (Sommer, 1985). The anticipated total loss in Nigeria as a result of these restrictions is almost 60%. (Kutama *et al*., 2007). Also, Opadokun (1987) submitted that 21% of tomato harvested in Nigeria was lost to rot in the field and additional 20% to poor storage system, transportation and marketing. This significant loss has encouraged researchers to look for easy, practical, and affordable ways to manage pre- and postharvest illnesses and perhaps other difficulties in tomato production (Wilson and Wisniewski, 1989).

When handling and managing tomatoes after harvest, temperature is a crucial component in determining their quality. A compromise respectively temperatures low enough to halt ripening activities but inflict cellular injury and those high enough to prevent chilling injury but not stop further ripening has led to the development of storage temperatures for subtropical fruits like tomatoes (Couey, 1982). Most tomato cultivars may be refrigerated for only two weeks because the compromise temperature is only 12° C, which does not prevent ripening (Hobson, 1981). Fruit ripening has been found to be inhibited by temperatures higher than 35°C (Biggs *et al*., 1988; Klein and Lurie, 1992).

Wogu and Ofuase (2014) discovered Aspergillus sp., Penicillium sp., Fusarium sp., and Saccharomyces sp. from deteriorated tomato fruits. Mbajiuka and Emmanuel (2014) retrieved *Saccharomyces cerevisiae*, *Aspergillius* spp., and *Penicillium* spp. from rotten tomatoes. According to Ghosh, fungi rather than bacteria were discovered to be more accountable for the degradation of tomatoes (2009). Any modification to food that makes it unfit for human eating is referred to as spoilage. Because of their high moisture content, tomatoes are vulnerable to microbial degradation.

Products made from tomatoes have some nutritional advantages for human health, which gives them some distinctive qualities. To avoid blood clots, tomato juice may be consumed. The anti-clotting properties of tomato juice are available in around one cup daily. Red raw tomatoes have the following nutritional value for-100 g; Energy 20Kcal-80 KJ; Carbohydrates- 4g; Sugar-2.6g; Dietary fiber-1g; Fat-0.2g; Proteins-1g; Vitamin C (13mg)-22% and Water 95g.Natural Lycopene, a red fat-soluble pigment often found in tomatoes, is another ingredient that contributes to the food's nutritional worth. Products made from tomatoes also contain essential vitamins and minerals like potassium, vitamin C, and fibre.

By properly isolating and categorizing these organisms in tomatoes, producers and consumers can secure their produce (tomatoes) and recognise spoiled tomatoes that have been infected by fungi and bacteria. This would drastically minimise the number of tomatoes that deteriorate. One of the most well-liked and commonly grown plants in the world, particularly in Africa, is the tomato. It is the second-most important vegetable on the world in terms of the amount of essential nutrients it adds to the diet (Osemwegie, *et al*., 2010).

II. MICROBIAL SPOILAGE OF VEGETABLES

In India, the consumption of vegetables has increased significantly during the past few decades. Approximately 20 percent of the veggies grown each year are thought to be lost to decay. Fresh-cut veggies are defined as "any fresh vegetable or any combo of fresh vegetables that has been mechanically transformed out of its pure source but remains in a fresh state." Fresh-cut fruits and vegetables are a rapidly growing category of minimally or lightly processed, value-added produce items that offer consumers ready-to-eat stuff that is one of many practical, wholesome, and fresh-tasting options (Aminu *et al*., 2021).

In 2010, a USDA-Economic Research Service research found that 18.9 billion pounds of fresh fruits and vegetables were lost each year due to spoiling, accounting for 19.6% of all edible food losses in the United States (Kantor LS *et.al.*,2010). The amount of money lost due to microbiological spoilage was not disclosed. The majority of microorganisms seen on whole fruit or vegetable surfaces are soil dwellers, members of a wide and diversified community of microbes that are important for maintaining a dynamic ecological balance in most agricultural systems.

Soil particles, airborne spores, and irrigation water are all vectors for spreading these microorganisms. Most bacteria and fungi that land on a developing crop plant is either wholly harmless to the plant's health or, in many cases, operate as a natural biological barrier against infestation by the microbes that cause crop damage. This section focuses on the even smaller fraction of bacteria and fungi that cause rotting in the edible portion of the crop plant.

Spoilage microorganisms can be introduced to the crop on the seed, during field growth, harvesting and postharvest processing, or storage and distribution. The same soil-borne spoilage bacteria that are found on produce are also found on harvesting equipment, packinghouse handling equipment, storage facility handling equipment, and food contact surfaces throughout the distribution chain. As a result, early intervention techniques such as good agricultural practises (GAP) during crop development and harvesting will drastically minimise loss due to spoiling at all future points in the food-to-fork continuum (Eckert JW and Ogawa JM. 1988).

FDA released the Guide to Minimize Microbial Food Safety Hazards for Fresh Vegetables in 1998, proposing GAPs for producers, packers, and shippers to address common microbiological hazards associated with their operations. Furthermore, FDA collaborated with the produce sector to create commodity-specific food safety recommendations for sprouts, lettuce and leafy greens, melons, and tomatoes, which included metrics for soil and water amendments, as well as neighbouring land use. FDA published a draught final version of its "guide" (FDA. 2008). in March 2007. Fresh-cut produce's food safety and shelf life should be much improved as a result of this.

III. CHARACTERISTICS OF VEGETABLE SPOILAGE MICROORGANISMS

Staphylococcus aureus, Escherichia coli, Coliform bacteria and *Salmonella sp*. were the most frequent food-borne bacterial pathogens found in fresh vegetables (Tournas VH. 2005). When cultivated in lactose broth at 35°C, coliforms are facultative anaerobic, Gram-negative, non-spore producing rods that ferment lactose with gas production within 48 hours. They are widespread occupants of animal and human stomachs, and they are a commonly utilised bacterial indicator of food and water hygienic quality, as well as a microbial pollution indicator.

Many vegetables provide virtually optimal circumstances for many sorts of bacteria to survive and flourish. Internal tissues are nutrient-dense, and many, particularly vegetables, have a pH that is close to neutral. The polysaccharides cellulose, hemicellulose, and pectin make up the majority of their structure. Starch is the most common storing polymer. Spoilage bacteria take advantage of the host by employing extracellular lytic enzymes to breakdown these polymers, releasing water and other intracellular contents for use as nutrition. Extracellular pectinases and hemicellulases, which are essential components in fungal deterioration, are abundant in fungi (Miedes E and Lorences E P. 2004).

Some spoilage microorganisms can colonise and cause lesions on healthy plant tissue that has not been harmed (Tortora G. 1995). Microorganisms that cause spotting can also infiltrate plant tissues during fruit development, either by the calyx (flower end) or along the stem, or through numerous specialised water and gas exchange mechanisms in leafy materials. The spoilage microorganism must, however, overcome many natural protective barriers in order to establish itself. The outer protective epidermis of vegetables is normally covered by a natural waxy cuticle layer containing the polymer chitin. A complex array of epiphytic microbes colonises the outermost fruit surface, posing a further competitive barrier to the rotting organism.

The bacteria *Escherichia coli* is linked to faecal contamination and can be found in the intestines of humans and warm-blooded animals. With outbreaks occurring from food and water polluted by human or animal faeces or sewage, the existence of these bacteria poses a major hazard to public health. The sickness is caused by the intake of preformed enterotoxins produced in foods by Staphylococcus aureus, which is the third most prevalent cause of proven food poisoning in the globe (Andrews JH and Harris RF. 2000). Several Gram-positive bacteria, most notably lactic acid bacteria, have been linked to deterioration of fresh-cut fruits and vegetables packaged in a modified environment with 2% O_2 and >10% CO_2 and stored at 7°C or higher, regardless of the produce.

Lactic acid bacteria are Gram-positive rods and cocci that are normally non-motile and do not generate spores. They are unable to produce ATP via creating a proton gradient because they lack the ability to synthesis cytochromes and porphyrins (components of respiratory chains). Lactic bacteria can only get ATP from sugar fermentation. Lactic acid bacteria can grow under anaerobic settings since they do not need oxygen in their energy production, but they can also flourish in the presence of oxygen.

The luminous *Pseudomonas species*, of which *Pseudomonas marginalis* is an example, are the most common and critical spoiling germs of refrigerated fresh-cut vegetables. A Gram-negative rod and strict aerobe, *Pseudomonas sp*. Depending on RNA homology, these species can be grouped into four groups and nine groups based on cellular fatty acid content. Pseudomonas is found on both animal and plant products and is widely spread in nature. They can use a wide range of organic molecules and can oxidise glucose and maltose to create acids. Some *Pseudomonas species* produce water soluble fluorescent pigments called pyoverdine or fluorescein, which can be seen in damaged foods under UV light.

Soft rot is a type of decay that causes fluid transparency in diseased leafy plant parts as well as watery disintegration of non-leafy plant elements. "Soft-rot Erwinia" causes infection and degradation at wound sites, and once established, can soon lead to the product's entire disintegration. Pectin lyase, polygalacturonase, pectin methyl esterase, and pectate lyase are four pectin-degrading extracellular enzymes found in soft-rot Erwinia. Pectate lyase is the enzyme responsible for the most extensive degradation of these enzymes. *E. carotovora* expresses four different extracellular pectate lyase isozymes, providing built-in redundancy for this ostensibly critical pathogenicity factor (Barras F .1994).

Soft-rot Erwinia are only active at temperatures of 20°C or higher, emphasising the importance of maintaining a continuous cold chain from harvest to retail to effectively manage this pervasive spoilage bacterium. The *fluorescent Pseudomonads* (*Pseudomonas fluorescens* and *Pseudomonas viridiflava*) are another type of soft-rotting bacteria that may decompose plant tissue at temperatures as low as 4°C. One of the reasons for the high prevalence of these bacteria on rotting vegetables at wholesale and retail markets (Liao, 2005) is most likely because of this.

The fruits of tomatoes are popular throughout the world and are used in all kind of stews, soups and also eaten raw in salads. Ripe tomato fruits have high nutritive values, being a good source of vitamin A, B, C and minerals (Kimaru and Sinha, 2010). Because of the importance of tomato as food, it has been bred to improve productivity, fruit quality, and resistance to biotic and abiotic stresses (Haydar *et al*., 2011). The tomato has been extensively used as both food and as research material. It is a major vegetable crop that has achieved tremendous popularity over the last century and it is grown in outdoor fields, greenhouses and net houses (Bihn and Gravini, 2016)

A growing infestation of spoilage bacteria can damage a significant amount of a stored lot of fruits if they undergo inappropriate pre-harvest fungicide application, poor washing, or inadequate culling. Apples, pears, and a variety of other pectin-rich fruits are pathogens of *Penicillium expansum* and *Botrytis cinerea* (Miedes E and Lorences E P.2004). Botrytis cinerea is a particularly clever and selective plant pathogen, with numerous cutinases and lipases capable of destroying pectin-rich plants (Van Kan JAL. 2006).

IV. MICROORGANISMS ASSOCIATED WITH SPOILAGE OF TOMATOES

Previously, study was conducted at Venkataramapuram, Tirupati's local market (A.P). In his research, he used the serial dilution approach to generate different sample solutions in different concentrations. After being injected with several specialised media for the identification of organisms, he conducted research and discovered a specific organism *Bacillus substilis, Aspergillus niger* (Chandu, A.N., *et.al.*,2016).

In his prior research, he produced specialised media potato dextrose agar for the identification organism, and in his investigation, he discovered the unique organism *Aspergillus fiavus, Penicillium Waksmani, Botryodiplodia theobromae, Fusarium Oxysporum, Colletrichum asianum.* (Kator, L., *et.al.*,2018)

Previous research was conducted in Kebbi State's Alerio Local Government Area. He made potato dextrose agar and nutritional agar in his lab. To isolate the fungus and bacteria, they used the spread plate and streak plate methods. During his research, he discovered this unique organism *Candida* species, *Penicillium digitatum, Aspergillus niger, Alternaria, Mucor* species *Trichoderma* species *Saccharomyces cerevisiae.* (Aminu Naka, J.N., *et.al.*,2021)

In Benin City, serious research was conducted in four markets: Oba, New Benin, Santana, and Vegetable. He created sample solution in consentration up to 10 in serial dilution for this study. He also inoculated numerous specialised media for the identification of organisms, and through his research, he discovered this particular organism *Bacillus subtiles, B. cereus, B. Aureus, Escherichia coli, Klebsiella aerogenes, Pseudomonas aeruginosa, Salmonella typhi, Proteus mirabilis* and *Staphylococus aureus. (*Wogu, M.D.&Ofuase, O, *et.al.*,2014)

Previous research was conducted in the Nigerian city of Awka, in the state of Anambra. They employed the corplate method, in which a serially dilute sample was dispensed into a conical flask containing strial sabouraud dextrose agar and chloranphenicol was added to suppress bacterial growth. After inoculating several biochemical media in search of an identification organism, he studied and discovered this unique organism *Aspergillus niger, Rhizopus stolonifer, Fusarium Oxysporum, Saccharomyces cerevisiae, Alternaria alternate, Penicillum digitatum, Geotrichum candidum* (Samuel O.& Orji, M.U.2015)

V. TECHNIQUES FOR LOCATING AND SEPARATING SPOILAGE MICROORGANISMS

A sliced fruit or vegetable may contain a variety of microorganisms, such as fungi, Gram-positive bacteria, and Gram-negative bacteria (yeasts and molds). Some viruses have been discovered to be plant pathogens of whole produce, and it is likely that they cause fresh-cut root or tuber vegetables to lose quality. While parasites can pose a threat to food safety, they have no impact on the sensory characteristics or deterioration of whole or freshly cut fruits or vegetables. The best ways to identify and isolate spoilage microorganisms from fresh fruits and vegetables mostly depend on whether the item of interest already has a visible lesion or not. It is logical to assume that any spoilage bacteria present will be found at or close to the sample's outer surfaces if there are no obvious indicators of disease. In this instance, the goal of sample preparation is to remove as many viable germs from the sample surface as possible in order to isolate and detect them later. Microorganisms can be released using a variety of techniques, but they all commonly start by diluting the sample by a proportion of sterile diluent to a 1:10 concentration in a sterile Whirlpak R or Stomacher R bag. Although sterile, deionized water is an option, it is not advised since osmotic shock may disrupt some of the overall microbial population. Butterfield's buffer, 1 percent buffered peptone water, and phosphate-buffered saline are all examples of buffers. Eight appropriate diluents that can be easily made in the lab or bought pre-formulated are acceptable for this purpose (Francis GA and O'Beirne D, 1999).

By puncturing the sample in a Stomacher for up to 2 minutes, pulping it in a sterile commercial food blender for up to 60 seconds, or vigorously shaking it on a forearm mixer for up to 30 minutes, the bacteria can be physically moved. In fact, when sample preparation must be done outside of a lab, surface microorganisms can be dislodged by hand shaking the sample pouch for up to 2 minutes, but less effectively and even with lower yields than the aforementioned procedures. These mechanical techniques all have benefits and drawbacks. The Stomacher method, supposedly offering a high percentage of retrieval of viable microorganisms from the sample, is quick, avoids physical contact with the diluted sample, and is arguably the method used in the food industry the most (Wu VCH *et al*., 2003).

By preparing the sample with minimal maceration, a comparatively recent piece of equipment called the Pulsifier gives the same benefit as the wristaction shaker. There were apparently no changes in viable recovery between the two techniques during a study of total viable bacterial cell and coliform bacteria, recovered from samples of 30 different fresh vegetables using the Stomacher and the Pulsifier, respectively (Viswanathan *et al*., 2001). Regardless of how the sample was first prepared, the following stage relies on whether the researcher wants to try and quantify a particular disease (or pathogens) or just do a qualitative study. If there isn't a pathogen-specific selective medium, quantitative recovery could be challenging. It is usually required in this situation to scatter the plate straight onto a variety of nutritionally distinct media and then pick out the colonies that closely resemble the microorganism of interest. However, if an appropriate selective medium is available, serial dilution, spread-plating (0.1 ml), and incubation come next following sample preparation. When compared to the corresponding temperature range of the environmental flora the researcher wants to suppress, the incubation duration and temperature greatly rely on the range of temperature of the pathogen of interest.

There is a wealth of literature describing routine diagnosis of bacterial and fungal illnesses in fresh vegetables and fruits. Depending on the fruit or vegetable affected, many spoilage microorganisms produce extremely unique lesions. Because of this, early diagnoses are frequently made based on the physical appearance of the lesion in the field or at the packing facility. A two-volume text set titled "A Color Atlas of Post-Harvest Diseases and Disorders of Fruits and Vegetables" offers a thorough analysis of the biology, epidemiology, and outward manifestation of numerous fruit and vegetable spoilage germs (Snowdon and A. L., 1990). A number of photomicrographs of the reported pathogens are also included, showing how they appear as single cells, mycelia, and fruiting bodies.

"Basic Plant Pathology Methods" is a very thorough reference book that covers methods for enriching, isolating, and identifying the majority of plant pathogens as well as information on how to isolate pathogens from soil and other strata, manipulate and handle pure cultures in the lab, use various staining techniques for microscopy, as well as biological control assays, fungicide efficacy assays, and histological procedures (Dhingra *et al*., 2017).

Baby carrots have reportedly yielded 48 strains of pectinolytic bacteria from the genera *Pseudomonas*, *Erwinia*, *Bacillus*, *Xanthomonas*, and *Flavobacterium* as well as lactic acid bacteria and yeasts (Liao *et al*., 2007). Gram negative rods made up the majority of the bacteria isolated from "Nam Dokmai" mango cubes, with *Enterobacteriaceae*, including the belonging to the genus *Klebsiella* and *Pantoea*, accounting for about 60% of the total (Poubol *et al*., 2005). Additionally, *Pantoea agglomerans*, also known as *Erwinia herbicola* and *Enterobacter agglomerans*, and *Burkholderia cepacia*, also known as *Pseudomonas cepacia*, were frequently isolated plant pathogens bacteria that cause rot in vegetables. *Curtobacterium* was the most prevalent genus of Gram-positive bacteria. *Enterobacter* sp., *Escherichia coli*, *Pseudomonas* sp., and *Micrococcus* sp. were the *predominate microflora* on sliced watermelon, making them one of the most prevalent types of spoilage microbes associated with cut melon. Endive leaves developed soft rot after being injected with either high P. *marginalis* cell counts or filtrated P. *marginalis* cultures separated from spoiled chopped up fennel (Ukuku *et al*., 2006). Fresh vegetables' microbiological quality was evaluated during a collection effort from various regions, and the results ranged from 4.3 to 10.4 log. Aerobic bacteria, coliforms, and Escherichia coli, Staphylococcus aureus range from 1.0 to 8.77 log10 CFU g^{-1}, 2.0 to 0.71 log10 CFU g^{-1}, and 1.47 to 8.77 log10 CFU g^{-1}, respectively. As measured by the amounts of coliforms, *Escherichia coli*, and *Staphylococcus aureus*, lettuce samples had a markedly increased microbial load than parsley samples obtained from various Bekaa Valley locations. On samples from Malva, that either *Escherichia coli* or indeed *Staphylococcus aureus* had been found. In comparison to other Bekaa Valley locations, Barelias had the highest microbial loads, including coliform, *Escherichia coli*, and *Staphylococcus aureus*. Furthermore, *Staphylococcus aureus* and *Escherichia coli* were found significantly more frequently in lettuce samples (51.5 percent vs. 13.8 percent) and lettuce samples (42.30 percent vs. 13.80 percent), respectively (38 percent) (Halabab *et al*., 2011).

VI. PREVENTION AND CONTROL OF MICROBIAL SPOILAGE

To control germs on fresh-cut food, a variety of thermal and non-thermal treatments have been developed. Hot water, heat steam, and hot sanitising solution are all examples of thermal processing used to treat fresh-cut vegetables. In the fresh-cut produce industry, thermal processing is a relatively recent technology. Physical and chemical processing technologies are two types of non-thermal processing. High pressure, irradiation, pulsed electric fields, pulsed white light, ultrasound, and ultraviolet radiation are examples of physical technology. Some of these approaches are not economically viable due to their high cost (high pressure and pulsed electric fields), lack of consumer acceptance (irradiation), or the need for process confirmation of efficacy (UV and pulsed white light) (Ohlsson T and Bengtsson N 2002).

Based on the physical condition of the chemical utilised, chemical methods can be separated into gas-phase sanitation and liquid-phase sanitation. Ozone and chlorine dioxide are examples of gas-phase sanitation. One of the challenges in implementing gas-phase technologies is that the treatment of produce necessitates the use of a unique in-line closed system. Employee safety may be jeopardised by these applications. Chlorinated water is the most extensively utilised chemical treatment in the fresh-cut produce business. Raw material quality, processing technology, good manufacturing practises (GMP), packing, and temperature management are all essential factors in preventing microbial spoilage in addition to these active control techniques. The use of high-quality raw materials can lower the risk of surface contamination while also enhancing the plant's self-defence mechanism. Current techniques of prevention and treatment make it difficult to sanitise diseased or damaged products, and they can contaminate products with low quantities of microorganisms. Yeast populations were observed to be substantially greater on cut honeydew melons with soft tissue during storage than on firm honeydew melons (Zhuang H *et al.* 2003). The increase in respiration just prior to full ripening in climacteric fruits is well known to coincide with a significant decline in fruit resistance to pathogens.

Damaged cells have higher respiration rates, which leads to cellular senescence or death, as well as a higher vulnerability to fungal colonisation. The vulnerability of fresh-cut fruits and vegetables to microbial deterioration is also influenced by processing processes such as peeling, cutting, washing, and dewatering. Fresh-cut processing (peeling, abrasion, or cutting) removes natural epidermal barriers to microbial attack and exposes interior nutritive fruit cells. Surface moisture accumulates as a result of these processing stages, and tissue is exposed to microbial pollutants. In comparison to undipped samples, dipping cut lettuce in 100 ppm chlorine water dramatically increases Listeria innocua levels (Francis GA and O'Beirne D, 1999).

When compared to hand peeling, an abrasive peeling method for carrot slicing produces substantially more lactic acid bacteria (Barry-Ryan C and O'Beirne D. 2000). When compared to hand peeling and fine abrasion peeling, coarse abrasion resulted in considerably more total mesophilic aerobic bacteria during storage. Washing vegetables with sanitised water can reduce microbial contamination, especially when the microbial load on the cut surface is modest. Several methods are used in packaging to reduce microbial deterioration. MAP is one of the most important extrinsic variables that influences microbial deterioration of fresh-cut food, as previously indicated. Several new modified environment packaging solutions have evolved in recent years with the goal of actively delivering antimicrobial chemicals into the packages to limit bacteria development.

Appropriate cold chain temperature control is another key technology for minimising microbial deterioration. Cold chain management starts with raw product cooling in the field and continues through processing and retailing to the restaurant or consumer's table. Unfortunately, there are frequent gaps in the cold chain, which have a compounding effect on a product's optimal shelf life. Poor performance of fresh-cut produce in retail outlets has been linked to faulty cold chain temperature control, according to sales representatives in the fresh-cut industry. GMPs, processing conditions, antimicrobial treatments, forms of antibacterial packaging, and harsh temperatures all reduce the shelf life of fresh-cut fruit, regardless of raw material quality.

CONCLUSION

In this investigation, several taxa of bacteria and fungi were identified as being linked to tomato fruit deterioration. As a result, relevant health professionals should make aggressive efforts to restrict or prohibit the exhibition and sale of damaged tomato fruits at local markets. The general public should also be made aware of the potential health concerns linked with the ingestion of relatively less expensive but spoiled ripe tomato fruits, as these could be agents in food-borne bacterial and fungal infections.

REFERENCES:

1. André, S., Vallaeys, T., &Planchon, S. (2017). Spore-forming bacteria responsible for food spoilage. Research in Microbiology, *168*(4), 379-387.
2. Akinmusire, O. (2011). Fungal species associated with the spoilage of some edible fruits in Maiduguri. Advances in Environmental Biology, 5 (1), 157-161.
3. Andrews JH and Harris RF. The ecology and biogeography of microorganisms on plant surfaces. Annual Review Phytopathology. 2000; 38: 145–180.
4. Aminu Naka, J. N., Kalgo, A. S., & Patrick, R. J. (2021). Fungal and Bacterial Species Associated with the Deterioration of Fresh Tomato Fruits (Lycopersium esculentum M.) Sold in Aliero Market, Kebbi State. *Int. J. Sci. Res. in Biological Sciences Vol*, *8*(2)., M
5. Barry-Ryan C and O'Beirne D. Effects of peeling methods on the quality of ready-to-use carrot slices. Journal of Food Science Technology. 2000; 35: 243–254.
6. Barras F, Van Gijsegem F and Chatterjee AK. Extracellular enzymes and pathogenesis of soft-rot erwinia. Annual Review Phytopathology. 1994; 32: 201–234.
7. Chandu, A. N., Kulkarni, S. V., & Gupta, A. K. Isolation, Screening and Characterization of Microorganism from Detoriated Tomato (Lycopersiconesculentum).
8. Eckert JW and Ogawa JM. The chemical control of postharvest diseases: deciduous fruits, berries, vegetables and root/tuber crops. Annual Review Phytopathology. 1988; 26: 433–469.
9. Francis GA and O'Beirne D. The microbiological safety of minimally processed vegetables. International Journal of Food Science and Technology. 1999; 34: 1–22.
10. FDA. Guide to minimize microbial food safety hazards of fresh-cut fruits and vegetables. February 4, 2008.
11. Jeanroy A, Ward K. How to Prepare Canned Tomatoes. 2012. Accessed on 20thOctober, 2012.
12. Kantor LS, Lipton K, Manchester A et al. Estimating and addressing America's food losses. Food Review. 2010; Jan-Apr: 2–12.
13. Kator, L., Iheanacho, A. C., & Aloho, K. P. (2018). Isolation, identification and pathogenicity of fungal organisms causing postharvest spoilage of tomato fruits during storage. *Annual Research & Review in Biology*, 1-7.
14. Liao CH. Bacterial soft rot. In G. M. Sapers, J. R. Gorney, & A. E. Yousef (Eds.), Microbiology of fruits and vegetables. Boca Raton, Fl: CRC Press. 2005, 117–134
15. Halablab, M. A., Sheet, I. H., & Holail, H. M. (2011). Microbiological quality of raw vegetables grown in Bekaa Valley, Lebanon.
16. Miedes E and Lorences E P. Apple (Malusdomestica) and tomato (lycopersicum) fruits cell-wall hemicelluloses and xyloglucan degradation during Penicilliumexpansum infection. Journal of Agricultural and Food Chemistry. 2004; 52: 7957–7963.
17. Onuorah, S., & Orji, M.U. (2015). Fungi associated with the spoilage of post-harvest Tomato fruits sold in major markets in Akwa, Nigeria. Universal Journal of Microbiology Research , 3 (2), 11-16.
18. Ogundipe, F., Bamidele, F., Adebayo-Oyetoro, A., Ogundipe, O., &Tajudeen, O. (2012). Incidence of bacteria with potencial public health implications in raw Tomato sold in Lagos State, Nigeria. Nigerian Food Journal , 30 (2), 106-113.
19. Osemwegie, O.O., Oghenekaro, A.O., and Owolo, L.O (2010). Effect of pulverized Ganoderma spp., on SclerotiumrolfsiiSacc and Post-harvest tomato fruit preservation. J. Appl. Sci Res. 6, 1794-1800
20. Ohlsson T and Bengtsson N. Minimally processing technologies in the food industry. New York Washington, DC: CRC Press, Boca Raton Boston. 2002.
21. Samuel, O., & Orji, M. U. (2015). Fungi associated with the spoilage of postharvest tomato fruits sold in major markets in Awka, Nigeria. *Universal Journal of Microbiology Research*, *3*(2), 11-16.
22. Tortora G. Microbiology. The Benjamin Publishing Co. Inc., New York, USA. 1995, 274-278.

23. Tournas VH. Moulds and yeasts in fresh and minimally processed vegetables and sprouts. International Journal of Food Microbiology. 2005; 99: 71–77.
24. Van Kan JAL. Licensed to kill: the lifestyle of a necrotrophic plant pathogen. Trends in Plant Science. 2006; 11: 247–253.
25. Wogu, M.D.&Ofuase, O. (2014). Microorganisms responcible for the spoiilage of tomato fruits,sold in markets in benin city, Southern Nigeria. School of Academics and Journal of Bioscience, 2 (7), 459-466.
26. Viswanathan, P., & Kaur, R. (2001). Prevalence and growth of pathogens on salad vegetables, fruits and sprouts. *International Journal of Hygiene and Environmental Health*, *203*(3), 205-213.
27. Zhuang H, Barth MM and Hankinson TR. Microbial safety, quality, and sensory aspects of fresh-cut fruits and vegetables. In J. S. Novak, G. M. Sapers, & V. K. Juneja (Eds.), Microbial safety of minimally processed foods. Boca Raton, Fl: CRC Press. 2003, 255–278.
28. Bello, O. B., Olawuyi, O. J., Azeez, A. H., Adebisi, O. S., & Owoade, T. A. (2016). Microorganisms causing post-harvest tomato (*Solanum lycopersicum L*.) fruit decay in Nigeria. *Scientia*, *13*(2), 93-96.
29. Ukuku, D. O., & Sapers, G. M. (2006). Microbiological safety issues of fresh melons. *Microbiology of fruits and vegetables*, 231-251.
30. Etebu, E., Nwauzoma, A. B., & Bawo, D. D. S. (2013). Postharvest spoilage of tomato (*Lycopersicon esculentum Mill*.) and control strategies in Nigeria. *Journal of Biology, Agriculture and Healthcare*, *3*(10), 51-61.
31. Abubakar, M., Singh, D., Hamisu, A., Keta, J. N., & Ahmad, A. J. (2019). Identification and Assessment of the Effects of Pathogenic Fungi Associated with The Spoilage of Tomato Fruits in Jega Local Government Area, Kebbi State, Nigeria. *Journal of Innovative Research in Life Sciences*, *1*(2), 47-54.
32. Snowdon, A. L. (1990). *A colour atlas of post-harvest diseases and disorders of fruits and vegetables. Volume 1: General introduction and fruits*. Wolfe Scientific Ltd.
33. Tadesse, T. N., Ibrahim, A. M., & Abtew, W. G. (2015). Degradation and formation of fruit color in tomato (Solanum lycopersicum L.) in response to storage temperature. *American Journal of Food Technology*, *10*(4), 147-157.
34. Ajayi, A. O. (2013). Nature of tomatoes microflora under storage. *American Journal of Experimental Agriculture*, *3*(1), 89.
35. Dhingra, O. D., & Sinclair, J. B. (2017). *Basic plant pathology methods*. CRC press.
36. Liao, C. H., & Wells, J. M. (1987). Diversity of pectolytic, fluorescent pseudomonads causing soft rots of fresh vegetables at produce markets. *Phytopathology*, *77*(5), 673-677.
37. Poubol, J., & Izumi, H. (2005). Shelf life and microbial quality of fresh-cut mango cubes stored in high CO2 atmospheres. *Journal of food science*, *70*(1), M69-M74.
38. Wu, v. c., jitareerat, p., & fung, d. y. (2003). comparison of the pulsifier and the stomacher for recovering microorganisms in vegetables 1. *Journal of Rapid Methods & Automation in Microbiology*, *11*(2), 145-152.