Determination of the Effects of Silver Nano-Particle Packaging Materials on Storability of Tomatoes

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ORIGINAL RESEARCH

Abstract- The need to extend the shelf-life of tomatoes has arisen due to the issue of post-harvest losses. This has prompted an exploration into active packaging materials. This study aimed to evaluate the effect of silver nanoparticle packaging material on tomatoes. Freshly cleaned tomatoes were stored at room temperature using two types of packaging materials, namely Styrofoam and High-Density Plastic (HDP). These packaging materials were then either covered with nylon film infused with silver nanoparticles or with regular nylon film. The tomatoes were left in storage for a period of 9 days, during which changes in fruit mass, moisture content, firmness and the number of damaged tomatoes were carefully assessed. After 9 days, the weight of tomatoes infused with nanoparticles was 142g to 96g compared to the normal condition of 150g to 40g for HDP and 166g to 86g compared to the normal condition of 114g to 64g for Styrofoam. Overall, the results of the study demonstrated that post-harvest preservation of tomatoes using the investigated techniques of Silver Nanoparticle under two packaging materials extended days of firmness, and reduced mould concentrations count by 50% thereby reducing the number of losses by 65-70%. The results obtained provided highly useful information in the field of post-harvest storage and preservation.

Keyword- silver nanoparticles, Styrofoam, high-density plastic, tomatoes, preservation

1 Introduction

Tomatoes are one of the most produced and extensively consumed crops in the world, after potatoes. It is a highly beneficial fruit that is perishable; that is, it has a short shelf life and can decay quickly. Studies showed that the annual production of fresh tomatoes is roughly equal to 75% for the fresh market and 25% for processing on a global scale (Muhammad et al., 2012; Olayemi et al., 2012). Tomatoes contain carotenoids, which could provide around 80% of lycopene and are recommended for daily intake. Due to the study nutritional importance of these fresh fruits, they have been recognized as a significant source of some vitamins and antioxidants and as a vital component of the human diet, helping to maintain good health and welfare (Li et al., 2018). However, tomatoes contain high water content which is crucial for the growth of microorganisms such as bacteria, yeast, and moulds to thrive, produce energy, and reproduce and are susceptible to spoilage.

Fruit spoilage is a main contributor to food wastage in the world with an estimated 30% of fruit produce rendered unfit for consumption due to early deterioration (Lapointe & Nguyen, 2019). According to a study published in the (Economic & Affairs, 2022), post-harvest losses of tomatoes in Nigeria range from 20 to 80%, depending on the region. One of the major reasons for the loss of tomato fruits is poor post-harvest handling of the produce. Lack of proper storage facilities and poor transportation and distribution channels across the nation are major factors that cause these huge losses and spoilage (Thomas, 2001).

Nano-packaging technology involves the use of nanoscale materials and structures to enhance the properties of food packaging materials. This can include improved strength, barrier properties, and antimicrobial activity. This system has revolutionized the packaging industry by providing new materials and technologies that offer improved performance, enhanced safety, and reduced environmental impact (He & Hwang, 2016). However, little discovery has been made using Nano-packaging technology as a means of fruit (tomatoes) technique preservation.

This study aims to evaluate the effect of silver nanoparticle packaging materials on the physicochemical properties (such as moisture content, pH, and weight loss) of Tomatoes and to evaluate the effect of silver nanoparticle packaging materials on the sensory attributes (such as colour, firmness, and texture) of Tomatoes.

2 Materials and Methods

The freshly harvested tomatoes from the market were grouped into five different aspects based on different packaging conditions for proper study and recording of each labelled specimen

2.1 Tomatoes Under Normal Packaging Condition

A few fresh harvested tomatoes that were at the red stage of maturity were cleaned, let to air dry, and then sealed inside Styrofoam, a disposable packaging material, and kept at room temperature, where the rate of spoiling, firmness, and weight loss were evaluated and examined.

2.2 Tomatoes Coated With Silver Nanoparticle

Tomatoes were harvested at the red stage of maturity and used as raw material. Tomatoes were washed and placed in different labelled containers (Styrofoam or polystyrene foam). Hereafter, sterile water was used to rinsed the fruits three times and left them to air-dry. The container was covered with nylon film based on different

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conditions, treated with silver nanoparticle solutions, and placed inside a controlled environment for proper study and recording. In the preliminary experiment, the silver nanoparticle (AgNP) of the 5g solution was prepared in a beaker by dissolving the AgNP in 1000 ml of distilled water (deionized water) inside a glass container. Nylon film was soaked for 30 minutes to allow the solution to penetrate the film and then dried at 45 –50°C for 25–30 minutes to change the nanostructure of the treated nylon films. The samples were labelled as presented in Table 1. The tomato fruit was scooped carefully in good conditions, drained, dried naturally and then stored at 28±2°C and 35-45% relative humidity (RH). Shown in Figure 1. is the 5g of silver nanoparticle in a solution used in this experiment.

$$AgNO_3 + Sugar\ solution = AgNP\ solution\ (Siver\ Nanoparticles)$$

Fig. 1: 5g of silver nanoparticle in solution of 100ml of distilled water

2.3 Analytical Methods

Daily, the external quality parameters such as mass, size, and firmness of each specimen of the tomato fruits were evaluated. Table 1 and Table 2 shows the sample specimen placed inside packaging materials like Styrofoam and High Density Polyethene Plastic content. Figure 2 shows tomatoes inside High Density Polyethene Plastic content.

Fig. 2: High-Density Polyethene Plastic Specimen

Table 1. Sample specimen for Styrofoam

Specimen Labelled	Styrofoam content
A	Not treated and not perforated nylon film
B	Not treated and perforated nylon film
C	Treated (silver nanoparticle solution) and perforated nylon film
D	Treated (silver nanoparticle solution) and not perforated nylon film
E	Uncovered.

Table 2. Sample specimen for High-Density Polyethene Plastic content

Specimen Labelled	High-Density Polyethene Plastic content
A	Uncovered (common condition)
B	Not treated with nanoparticles and fully covered with nylon film
C	Not treated with nanoparticles and covered with perforated nylon film
D	Treated (silver nanoparticle solution) and fully covered with nylon film
E	Treated (silver nanoparticle solution) and covered with perforated nylon film

2.4 Changes in Fruit Mass

Tomato fruits were meticulously weighed using a weighing machine prior to the treatment, serving as the initial fruit weight, in order to calculate the physiological weight loss. Every day, the weight loss and fruit mass were documented. The final weight of the samples was determined by weighing the tomato fruits on the ninth day of the experiment. The following formula was used to compute the physiological loss in mass.

$$Percentage\ Weight\ loss\ (\%) = \frac{initial\ fruit\ weight\ (g) - final\ fruit\ weight\ (g)}{initial\ fruit\ weight\ (g)} \times 100$$

$$PW_L\ \% = \frac{W_o - W_i}{W_o} \times 100 \quad \ldots (1)$$

The percentage weight loss (PW_L) on each of the specimens was been calculated using equation 1.

2.5 Firmness and Size

To manually assess the firmness of tomato fruits, one would gently press the fruit with one's fingertips. To observe the firmness changes, a daily measurement of a specific tomato fruit sample was made. Changes in the size of tomato fruits were measured every day with a 150 mm Vernier calliper. The tomato fruits were marked and labelled to measure at the same part to obtain more accurate data on the size changes. Tomato fruits were marked and labelled to measure at the same part to obtain more accurate data on the size changes (Meiramkulova et al., 2023).

2.6 Moisture Content

After weighing Styrofoam and High-Density Polyethene Plastic Specimen, the digital sensitive balance used was reset to zero. The initial moisture content of the samples was determined by weighing them and silver Nano packaging-soaked nylon foil dried at 105°C for 2 h, moving them, allowing them to cool, and then weighing each sample and expressing them as kg water/kg dry solids. The samples were then transferred and allowed to cool. Then, the samples were weighed. The tomato per cent moisture contents were estimated as in Equation 2.

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$$Weight\ loss\ Percentage\ (\%) = \frac{initial\ weight\ of\ tomato\ (g) - final\ weight\ of\ tomato (g)}{initial\ weight\ of\ tomato\ (g)} \times 100$$

$$Weight\ Loss\ \% = \frac{W_o - W_i}{W_o} \times 100 \qquad \ldots (2)$$

where W_o is the initial sample's weight, and W_i is the final sample's weight following daily changes.

Using the formula indicated for Percentage Weight Loss, (W_L%) for the calculations of Percentage Weight Loss, (W_L%) of a specimen of samples in Styrofoam and High-Density Polyethene Plastic to determine changes in weight loss over the 9 days of experiment in the laboratory. The data obtained from the recorded laboratory results were further subjected to ANOVA with the degree of freedom between the 2 groups.

3 Results and Discussion

The laboratory condition for the experiment conducted at, a temperature of 28±2°C and relative humidity between 40-60%, ensuring free of contaminants and particulates with good ventilation. Firmness and colour changes were mostly physical and notable changes in the appearance of the tomatoes, despite being placed in the same conditions. The tomato surface experiences respiration at different stages, which causes the deformation. The firmness of stored tomatoes was significantly affected by storage time and temperature. Shown in Figure 3 shows stages of physical changes for Specimen A, Specimen C and Specimen E of the experiment.

Fig 3: Stages of physical changes

It is noteworthy that tomato fruits are among the most delicate fruits that continue to change even after they are harvested. It ripens quickly, depending on the temperature and humidity of its surroundings, which eventually results in soft, low-quality fruit. An overripe tomato needs to be picked at the proper time because it is more prone to cause injury than a ripe or pink one. Tomatoes ripen more after harvest and can get overripe very quickly. As climacteric fruits, tomatoes breathe most during the ripening stage. Tomatoes normally have a 2-3week shelf life because they are a climacteric and perishable product. The sequence of interrelated events that occur between the time of harvest and the distribution of the produce to the customer is referred to as the post-harvest (post-production) and marketing process. The outcomes of the weight loss monitoring in grams are summarized in Table 3 and Table 4.

3.1 High-Density Polyethene Plastic Laboratory Result

Results of the data were collected daily for 9 days under good ventilation and storage conditions. Weight change was recorded based on damages in tomatoes per day. Table 3 shows number of damaged tomatoes per day in High Density Polyethene Plastic

Table 3. Number of damaged tomatoes per day for High Density Polyethene Plastic

Specimen	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9
A	0	0	0	0	1	1	2	2	2
B	0	0	0	1	2	2	5	5	5
C	0	0	0	0	1	1	2	2	2
D	0	0	0	0	2	2	2	2	2
E	0	0	0	0	1	1	2	2	2

3.2 Styrofoam Laboratory Result

Results of the data were collected daily for 9 days under good ventilation and storage conditions. Weight change was recorded based on damages in tomatoes per day. Table 4 shows number of damaged tomatoes per day in Styrofoam

Table 4. Number of damaged tomatoes per day for Styrofoam

Specimen	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9
A	0	0	0	1	1	1	2	2	2
B	0	0	0	0	1	2	3	3	5
C	0	0	0	0	1	2	3	3	3
D	0	0	0	0	1	2	2	2	2
E	0	0	0	0	0	0	1	2	2

In summary, the percentage weight loss (W_L) for each specimen is shown in Tables 5 and 6 and its graph in Figures 4 and 5.

Table 5. Percentage of weight loss for each specimen for High-Density Polyethene Plastic

Specimen	Percentage Weight Loss, (W_L%)
A	73.3
B	100
C	32.72
D	44.22
E	32.39

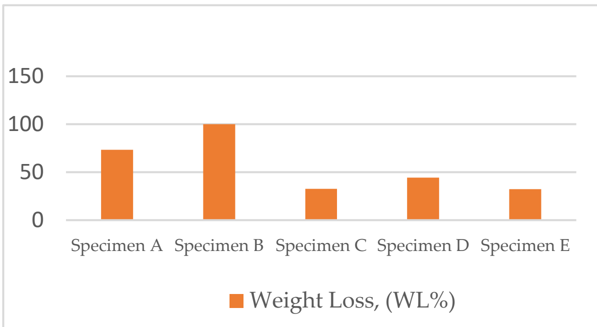

Fig. 5: Daily recorded damages in High-Density Polyethene Plastic

Table 6. Percentage of weight loss for each specimen of Styrofoam

Specimen	Percentage Weight Loss, (W_L%)
A	43.85
B	100
C	67.19
D	57.97
E	48.19

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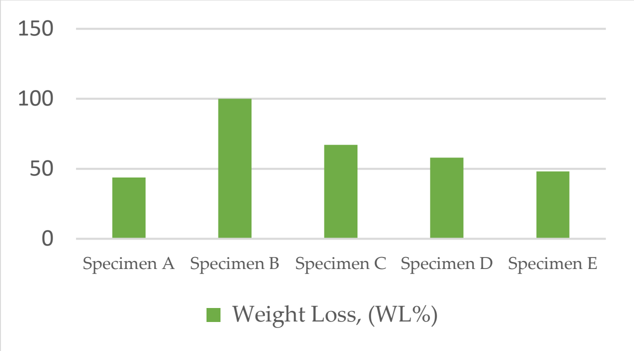

Fig 5: Daily recorded damages in Styrofoam

Furthermore, most part of the tomato fruit is water, according to the Food and Agriculture Organization of the United Nations, and once picked, it can no longer replenish lost water (Zhiguo et al., 2011). Water evaporates at high temperatures and low relative humidity, reducing the number of kilogrammes of weight that can be marketed. The weight evaluating datasets were subjected to an ANOVA analysis, yielding a p-value of 1.02×10^{-6}. The obtained p-value is less than 0.05 (alpha value), indicating that the differences between the analysed parameters' impacts on the datasets were statistically significant. It is also significant to note that ANOVA is an essential tool in many research fields and a widely utilised technique for analysing univariate data. It determines and measures the impact of different experimental parameters and the outcome that can be observed. Assessing these effects for each factor and any potential interactions is the first step in an ANOVA.

The ANOVA results showed that the *pvalue* obtained from the High-Density Polyethene Plastic and Styrofoam calculation under the same condition option at was less than 0.005, hence the results are considered high and statistically significant. The *p value* demonstrated that there were statistically significant variations between the results obtained laboratory values for each sample of specimen. Silver nanoparticle lowers the growth counts of microbes in the packaging materials covered with the chemical thereby reducing the transpiration in the packaging materials. Due to the texture of Styrofoam, the tomato's firmness was reduced thereby decreasing the damage of the tomatoes. Comparing to other notable laboratory work done with nanoparticles materials or nanocomposite, this researched work proves that Styrofoam coated with nanoparticle could be used to extend the shelf-life of tomatoes for its marketability

Fadeyibi et al. (2022), researched and carried out research on the synthesis, characterization, and suitability of a nanocomposite film that includes cocoyam starch and banana peels for packaging locust beans to improve their shelf life and prevent deterioration. According to the results, weight loss improves by about 3% when the temperature rose to less than 250°C. This result showed film was a better packaging material than the LDPE since it recorded lower counts of microbes throughout the storage. Mahajan (2018) researched on the effect of different packaging materials on the postharvest quality of pomegranate fruit. They found that polyethylene bags and low-density polyethylene (LDPE) bags were the best packaging materials for maintaining fruit quality during storage. Javanmard (2018), researched the effect of different packaging materials (LDPE, HDPE, and paper) and storage temperatures (5°C and 10°C) on the quality of apple fruits. They found that LDPE and HDPE packaging materials maintained the quality of apples better than paper packaging, and the lower storage temperature (5°C) resulted in better quality of apples in terms of firmness, acidity, and colour.

However, this research shows the effect of packaging material (silver Nano-particles) on tomatoes was carried out, using two different textural packaging materials such as Styrofoam and high-density polyethene plastic with some of the samples coated with infused AgNPs film nylon or perforated film nylon to study the effects of the rate of transpiration on the fruits. It was observed that the texture of the structure or composition of the container used affects the rate of transpiration thereby affecting the firmness and weight of the tomatoes. The colour changes were quite rapid on the high-density polyethene plastic thereby leading to quick damage on the tomatoes. The silver nanoparticle has been observed to affect the physico-chemical properties of fruits due to the packaging materials used (weight loss and moisture content) but not the pH properties of the fruit. Also, the silver nanoparticle has been observed to affect the sensory attributes (such as colour, firmness and texture) of the tomatoes.

The use of silver nanoparticle solution AgNPs for coating the material makes this study unique and has been researched under proper observed conditions not to have health implications for its usage. However, further laboratory tests could have been carried out to observe the type of microbes' growth on each sample because of the materials used or infused. Silver nanoparticles increase in cost daily due to the high demand for the chemical and its beneficial effect on fruit research recently. Also, a very small quantity is needed for research work.

4 Conclusion

In the study of the effect of silver nanoparticles on tomatoes, by comparing tomato fruits exposed to two different Nano-packaging techniques to control samples, under the same conditions in the laboratory has drawn observations on the maintenance of its essential qualities in the tomato fruits in terms of lycopene content, ascorbic acid, firmness and size, fruit mass, and moisture content. Packaging materials have a huge effect on the shelf life of tomatoes due to the transpiration action between tomatoes and their environment. Silver nanoparticles create a tight covering thereby limiting the rate of transpiration between the fruit and its environment. Silver nanoparticles also limit the microbial activities around and within the fruit thereby maintaining the firmness and colour of the fruit. The sensory attributes of tomatoes gradually changed with a sample infused with

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silver nanoparticles. The physiochemical properties of the tomatoes were observed and the changes depend solely on the packaging container used for preservation.

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