Extending Storage Life And Maintaining The Quality Of Tomato Fruits By Using Postharvest Exogenous Edible Coating Of Aloe Vera Gel, Starch, And Casein

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Abstract

Tomato (***Solanum Lycopersicum* Mill**.) is considered one of the most grown horticultural crops having a short storage life due to its climacteric nature of ripening, susceptibility to postharvest microbial decay, mechanical damage, and high rate of losses during handling operations. Therefore, the present study was conducted to investigate the effect of some postharvest exogenous edible coating treatments immersed in four different solutions of Aloe Vera Gel (10%), Starch (2%) plus Citric Acid (1%), Casein 2.5 % and control (distilled water) on reducing the decay, maintaining quality and extending storability during storage for 28 days at 8 ± 1°C and 95% RH. The obtained results revealed that the tomato dipping in a solution of Aloe Vera Gel (10 %) , Starch (2%) and Casein (2.5%) was the best treatment for reducing weight loss, decay, shriveling, also maintaining a general appearance, ascorbic acid, TSS, and increasing titratable acidity, total phenolic and the peroxidase activity compounds as compared with uncoated fruits. The tomato fruits dipping in Aloe Vera Gel (10%), and Starch (2%) were highly effective in preserving and maintaining the lycopene content and gave the lowest value of polyphenol oxidase activity at the end of storage time of tomato fruits at the end of storage time 28 days at 8 ± 1o°C and 95% RH.

Keywords: Tomato, Aloe Vera Gel, Starch, Citric Acid, Casein, Storability, TSS, Total Phenolic, Peroxidase Activity, Lycopene Content, and Polyphenol Oxidase Activity.

INTRODUCTION

Tomato (***Solanum Lycopersicum*** Mill.) is a very popular fruit around the world due to its exceptional health benefits. Besides its appreciable contents of lycopene, beta-carotene, magnesium, niacin, iron, phosphorus, potassium, riboflavin, sodium, and thiamine. Egypt ranks 5th worldwide in tomato production 6731220 tons.

2020 FAO. Numerous studies support the idea that those who consume a lot of tomatoes have a lower chance of developing cancer **(Famurewa and Raji, 2011; Srivalli *et al.*,2016).** Tomatoes are an important vegetable because of their great taste, attractive color, and nutritional value. Tomatoes are an excellent source of vitamin C, vitamin A, minerals, and antioxidants **(Masood *et al.*,2015)**.

The postharvest period of tomato as a climacteric fruit is relatively short because many processes lead to a loss of quality and storability, including high respiration rates, transpiration, postharvest diseases, acceleration of the ripening process, and senescence **(Zapata *et al.*, 2008 and Chrysargyris *et al.*, 2016).** The quality of tomatoes is constantly changing after harvest. Fruit quality aspects include firmness, flavor, color, nutritional value, shelf life, and resistance to pathogens **(Chrysargyris *et al.*, 2016).** Tomato quality deteriorates rapidly after harvest and, in some cases, during or after transportation and marketing **(Chrysargyris *et al.*, 2016).**

Synthetic-plastic polymer, synthetic wax-based packaging or coatings, and chemical preservatives have been abundantly used for preserving fruits after harvest. However, these synthetic inputs are non-degradable and extremely risky to consumers and the environment **(Kumar *et al.*,2022).**

In recent years, Edible coatings seem extremely promising and are currently one of the most studied approaches to maintaining fruit quality and post-harvest life. **(Arnon-Rips *et al.*, 2016).** Edible coatings can protect fruits effectively from mechanical and microbial damage, prevent the migration of favorable volatiles, delay fruit senescence processes and provide an esthetic appearance. **(Bourtoom, 2008 and Arnon-Rips *et al.*, 2016).** These coatings meet the desire of consumers for safe and healthful foods since they are made of biodegradable and biocompatible materials, and in many circumstances, they may provide an alternative to synthetic packaging and antimicrobial ingredients. **(Arnon-Rips *et al.*, 2016).**

Aloe vera plant is a tropical or subtropical plant that contains nutrients and active compounds including sugars, vitamins, anthraquinones, minerals, enzymes, salicylic acid, lignin, and amino acids **(Bora *et al.*,2016).** Aloe vera gel is considered one of the best edible films due to its hygroscopic properties, antimicrobial action, and biochemical attributes **(Bora *et al.*,2016)** Aloe vera gel reduces the activity of cell-wall degradation enzymes and respiration rate, thus preventing the deterioration of harvested tomato fruits **(Bora *et al.*,2016).** Also, The Aloe vera gel could be considered a promising postharvest treatment to preserve fruit quality during cold storage **(Sempere-Ferre *et al.*, 2022).**

caseinates have been proposed as natural materials for edible coatings because proteins have some advantageous properties, such as their ability to form networks, plasticity, and elasticity **(Pereda *et al.*,2008).** in addition to a good barrier to oxygen, carbon dioxide, and aromas **(Caprioli *et al.*, 2009)**. It is recognized that oxygen plays an important role in fruit degradation, as it is involved in many undesirable reactions including microorganisms' growth, enzymatic browning, vitamin loss, and lipid oxidation **(Caprioli *et al.*, 2009).** the use of caseinates might be considered a good alternative to get high protection to oxygen and retarding senescence while the storage period of fruits. **(Arrieta *et al.*, 2014).**

Edible coatings of starch have similar physical properties to synthetic polymers, such as being transparent, odorless, tasteless, semipermeable to CO2, and resistant to the passage of O2 **(Ambarsari *et al.*,2018).** Starch-based coatings proven to extend the storage life of fruits, decrease weight loss, and maintain fruit quality during storage period **(Cheng *et al.*,2016).**

According to some studies, the effectiveness of starch as an edible coating should be mixed with antimicrobial compounds. One of the chemical compounds that could be used as an antimicrobial agent in edible coatings is citric acid. Citric acid is generally recognized as a safe chemical preservative that can act as an antimicrobial agent. The addition of citric acid in edible coatings inhibits the browning reaction and reduces losses because this acid acts as an antimicrobial agent. Compared to other organic acids, citric acid is relatively cheap and easy to obtain **(Ambarsari *et al.* 2018).**

In this study, the aim is to investigate the effect of the edible coating of aloe vera gel, starch with citric acid, and casein on the extension of storage life, reducing decay and maintaining quality attributes of tomato fruits (***Solanum Lycopersicum* Mill. CV. Cal)** during storage time at the optimum condition (8° ±1 C 90-95% RH).

MATERIALS AND METHODS

Tomato Fruits were purchased from a private farm, in the March and April 2021 season, respectively. Tomato fruits are collected in the stage of turning and show a clear transition to the greenish-yellow, pink, red, or a mixture of these colors in an area of 20-30% of the fruit surface. The tomatoes were selected free from physiological defects and fungal diseases and of almost uniform size. the fruits were washed with a sodium hypochlorite solution (0.05%) for 5 minutes, before applying the coating treatments, then rinsed with distilled water, and air-dried at room temperature 20-25 °C **(Chrysargyris et al.,2016).**

Preparation of edible coating solution:

1- Preparation of starch and citric acid solution: The starch (2% Weight (W)/Volume (V)) was mixed with citric acid (1% W / V) and then 10% glycerol was added as a plasticizer and then all the materials were mixed with distilled water and boiled at 80-90 ° C for 15 minutes with constant shaking and the solution was left Up to room temperature (approx. 25 ° C) **(Ambarsari et al., 2017).**

2- Preparation of Casein: The solution was prepared by dissolving the calcium caseins in distilled water and stirring well to become a homogeneous solution and then heating the solution at 80 ° C for 30 minutes after that cooling the solution at room temperature and the solution PH was adjusted to 6.5 and the solution is prepared immediately before treatment **(Brault et al. 1997).**

3- Preparation of Aloe Vera gel: The leaves were washed with distilled water and 2% sodium hypochlorite to disinfect the leaves, the outer cortex of the leaves was separated, and the colorless hydro parenchyma layer was mixed in the blender, then filtered to get rid of the fibers. The solution is homogenized for 15 minutes at 15,000 rpm after being heated at 140 ° C for 15 minutes on the hot plate and then cooled at room temperature **(Razali et al., 2017).**

Storage and design Experimental: fruit tomatoes were dipped in the following edible coating before storage at the optimum conditions (8±1°C,90-95%RH). The experimental design A complete randomized design was used with a storage experiment with one factor.

Edible coating treatments:

1- Control (uncoated)
2- Aloe Vera Gel (10%) Dipping for 10 minutes.
3- Starch (2%) and Citric Acid (1%) Dipping for 10 seconds
4- Casein (2.5 %) Dipping for 30 seconds

Physical and Chemical Changes:

Physical changes were estimated every 3 days, while chemical changes were estimated every 7 days during the storage period at (8±1°C,90-95%RH)

Physical measurements:

1 – Weight loss percentage %: To determine the percentage of weight loss, the initial weight was measured at the beginning of the treatment from the first day (zero-day) and then measured weight at regular intervals every three days until the end of the experiment using the digital balance. The percentage of weight loss was calculated using the following formula: Percentage of weight loss= [(initial wt - the secondary wt)/ initial wt] *100.

2- Decay percentage% of fruits: The decayed percentage of fruits was estimated by calculating the number of decayed fruits per sample day and determining the difference between the number of healthy and decayed fruits in each package using the following formula:

Percentage of Fruit Decay = <u>number of healthy fruit- number of decay fruit</u> *100
Number of healthy fruits

3- Wrinkling (shriveling): The wrinkling (Shriveling) was determined visually using scores described by **Kader et al., 1973)** on a 1 to 5 scale, with reference points of severe, 4= moderately severe, 3=moderate, 2=slight and1=none**.**

4- General appearance of quality: The general appearance of quality was estimated using the visual score as follows: 1= Unmarketable, 3 = Poor, 5=Fair,7= good,9 =Excellent. This scale depends on morphological defects such as wilted husks, color changes of fruits, denting, and the presence of physiological defects. **(Kader *et al.*, 1973).**

Chemical changes

1 - Titratable acidity (TA%): Ten grams (g) of the sample was mixed with 30 ml of distilled water in a blender, then filtered through whatman paper, No.1, and then the filtrate of squeezed fruit juice was diluted to 100 ml with distilled water. TA was calculated by titrating 10 ml of the filtrate-diluted tomato juice against 0.1 N NaOH by using phenolphthalein as an indicator. Titratable acidity was expressed as a percentage of citric acid.

2- Ascorbic acid content: The ascorbic acid content of fruit juice was determined by using the 2, 6-dichloroindophenol titrimetric method according to **(A.O.A.C 1990).,** The results were expressed in milligrams of ascorbic acid per 100 ml of fruit juice.

3- Total Soluble Solids (T.S.S): Total soluble solids (TSS) were evaluated using a digital refractometer (Refractometer, OPTIKA HR-110; Italy). On the prism, one or two drops of clear juice were placed. The refractometer was calibrated before use by adding a few drops of distilled water. The prism was washed with distilled water in between each sample. The values obtained were expressed as °Brix **(A.O.A.C 1990).**

4- Lycopene content: Lycopene content was estimated according to **Fish *et al.* (2002).** with some modifications. Briefly, 2 g of tomato fruit tissue was homogenized in a mixture of 5 ml of absolute ethanol, 10 ml of hexane, and 5 ml of acetone containing 0.05% (w/v) BHT. After being kept at room temperature in the dark for 10 minutes, 3 mL of distilled water was added and then centrifuged at 10,000 x g for 20 minutes at 4 °C. The upper phase was used to quantify lycopene by measuring the absorbance at 503nm using the molar extinction coefficient of lycopene in hexane (17,200M-1 cm-1). The results were the mean ± S.E. of the measurements performed in triplicate for each batch and were expressed in mg kg-1 fresh tissue.

5- Total phenolic compounds: Half a gram of the fruit was ground in ten ml of 80% ethanol in dark-colored glass bottles, then 1 ml of the clear extract was taken, 1/2 ml of the Folin-Ciocalteu reagent was added and left for 5 minutes, and then 1 ml of 20% sodium carbonate was added, then the final volume was adjusted to 10 ml with distilled water. After incubation in the dark for an hour, the absorbance at 765 nm was recorded on a spectrophotometer (Chrom Tech CT-2200; Taiwan) and compared with the prepared blank sample. Total phenolic content was expressed as micrograms of gallic acid equivalents per gram of fresh weight (µg GAE / g FW). Gallic acid was used for the calibration curve (**Folin and Ciocalteu (1927).**

6- Enzyme activity:

Preparation of enzyme extract

Fruit tissue of tomato (2 g) was taken from each replicant and homogenized in 8 mL 0.1M Na-phosphate buffer (pH 7.0) which contains 1% polyvinylpyrrolidone (PVP) and 0.1 mM EDTA and then the homogenate was centrifuged at 10,000 rpm for 15 min at 4 °C. The supernatant was used as a crude enzyme extract to estimate the enzyme's activity. Also, Protein content was estimated in the crude extract by the method of **(Bradford, 1976)** using bovine serum albumin as a protein standard.

Assay of peroxides activity (POD) : Peroxidase was estimated According to the method of **(Lebedeva *et al.*, 1977)** 2.8 ml of phosphate buffer solution (pH 5.5, 0.1M) is put into the quartz cuvette, add 100 µL of o-dianisidine at a concentration of 0.5 M, and start the reaction by adding 100 µL crude enzyme of the crude enzyme extract. the absorbance was read at (460 nm) every 30-second interval up to 2 minutes. The peroxidase activity was calculated using the extinction coefficient of o-dianisidine and the enzyme activity was expressed as unit per mg of protein.

Assay of polyphenol oxides activity (PPO) : 2.3 ml of phosphate buffer solution (pH 6.5, 0.1M) is put into the quartz cuvette, add 0.6 ml of catechol at a concentration of 0.1 M, and start the reaction by adding 100 µL crude enzyme of the crude enzyme extract. The enzymatic activity is calculated based on the method **(Oktay *et al.*, 1995),** in which the enzyme unit is expressed by the amount of enzyme that causes an increase in the absorption reading at 420 nm wavelength by 0.001 within a minute (spectrophotometer, Chrom Tech CT-2200; Taiwan). The PPO activity was expressed as a unit.mg-1 protein.

Statistical analysis

Data were arranged and statistically analyzed using Mstatic (M.S.) software (freed 1988). Means were calculated from three replicates, and the Duncan multiple range tests ($p < 0.05$) were used to determine the significant differences between means. As illustrated by (**Snedecor and Cochran1982).**

RESULTS AND DISCUSSION

1- Weight loss: -

The Data represented in **Fig. (1)** Showed that all coating treatments significantly reduced the loss in weight loss percentage as compared with uncoated fruits. Data revealed that coated fruits were the most effective treatment in reducing weight loss percentage. This concern the highest value of weight loss percentage was recorded with untreated control. Generally, the results of the treatments indicate a reduction in water loss by adding edible materials, and the reason for this may be the formation of an insulating layer on the surface of the tomato fruits, which increased the concentration of carbon dioxide around the fruits while reducing the level of oxygen, which helps reduce respiration and vital processes inside tomato fruits.

In this respect, **Parven *et al.* (2020)** reported that the weight loss is considered to be as one of the main attributes in determining the storage life of fruit. The percentage of total weight loss of papaya was increased with increasing duration of storage.

These results are in an agreement with those reported by **Roshandel-hesari *et al.*, (2022)** for casein**, Arefin *et al.*, (2020)** for aloe vera gel, and **Adjouman *et al.*, (2018)** for starch**.** Weight loss occurring in tomato fruits during storage may be due to related to high ethylene production, transpiration, and respiration rate during the ripening of fruits. Transpiration led to the transportation of moisture from the inside of the fruit to the outer skin, followed by evaporation of moisture from the skin surface to the external atmosphere.in addition, respiration involves a series of biochemical changes responsible for the conversion of complex organic substances in cells to simpler substances in the presence of external oxygen with the release of carbon dioxide and water, and the generation of heat thus losing the weight of fruits **Yadav *et al.*, (2022).** Coated tomato fruits with aloe vera gel created a physical barrier that reduced moisture transfer from the inside of the fruit to the outside. Also, this property of aloe vera gel is due to its hygroscopic nature, presence of hydrophobic compounds, and higher polysaccharide content, creating a water barrier between tomato skin and the outside atmosphere. Thereby resulting in a lower weight loss percentage **Firdous *et al.*, (2020).** These results are in accordance with a study conducted by **Yang *et al.*, (2019)** who dipped tomato fruits in corn starch-based coating and found that coated fruits reduced weight loss during storage**.** The effect of starch treatments in decreasing weight loss may be due to starch as edible coatings provide a protective layer and consequently reduce the water loss and rates of respiration in fruit tomatoes **Yang *et al.*, (2019)**. Similar results had been reported by **Beulah *et al.*, (2021**) guava coated with casein led to decrease weight loss during storage. They indicated that the reason might be coated casein formed a layer-like structure up on the fruit surface and acted like a barrier for water drips and helps to control the moisture content in fruits throughout storage.

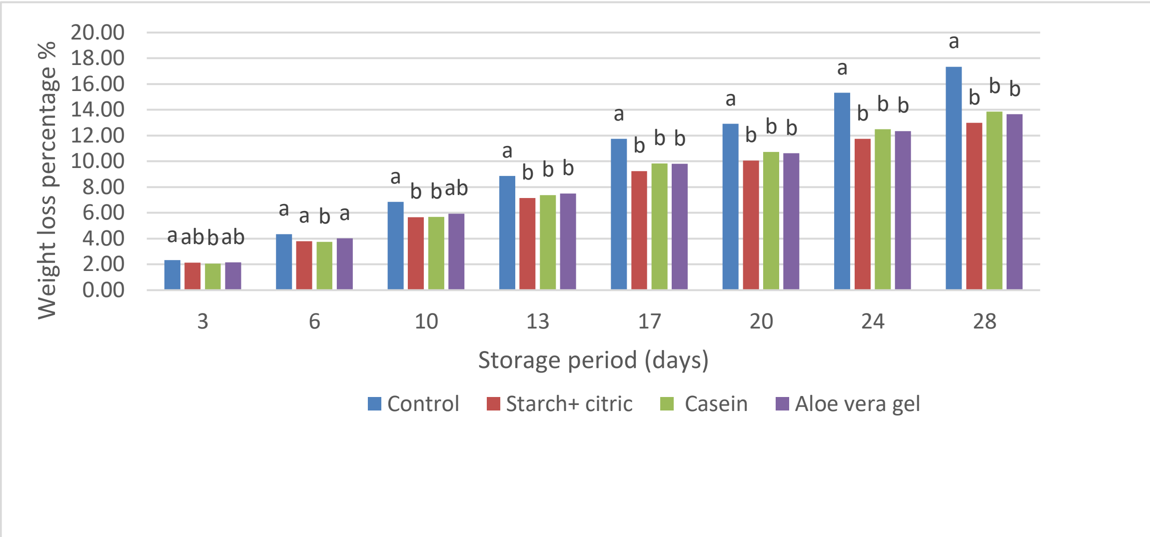

Fig. 1. Effect of edible coating on weight loss % of tomato fruits during storage at (8 °±1C, 90-95% RH). Significant difference (p<0.05) between data is expressed by different letters. Values are the means of three samples (n = 3) per treatment. Values followed by the same letter in each column do not differ significantly (P < 0.05). * Indicate not significance, among controls through storage period.

2- Decay %:

Data in **Fig. (2)** showed that the effect of some postharvest treatments on the decay % of tomato fruits during storage at (8° ± 1°C 90-95%RH). The results indicated that there was a significant decrease in the decay % of tomato fruits noticed at the end of storage time, these findings agree with those of **Chrysargyris *et al.*, (2016)** for aloe vera gel, **Ambarsari *et al.*, (2018)** for starch**,** and **(Beulah et al., 2021**) for casein. Also, Data showed that all coating treatments gave significantly decreased decay percentages as compared with uncoated fruits. Data revealed that all coating treatments were much better in decreasing decay % and thus increasing storage periods. There was no significant difference between edible coatings treatments but There was a significant difference between edible coatings treatments and the control group. The untreated fruits (control) showed the highest decay percentage during the storage time. These results are in agreement with **(Tzortzakis *et al.*, 2019)** who found that tomato fruits coated with aloe vera gel at 10% reduced the decay percentage during storage compared with uncoated fruits. Similar results were reported by **(Ambarsari *et al.*, 2018)** who indicated that tomato fruits coated with starch at 2% incorporated with citric acid at 1% decreased the decay percentage during storage compared with uncoated fruits. in accordance with **(Beulah *et al.*, 2021**) who observed that coated fruit with casein can reduce the decay percentage throughout storage compared to untreated guava fruits. The antifungal activity of Aloe vera gel has been indicated against postharvest fruit pathogens, such as Penicillium digitatum, Penicillium expansum, Botrytis cinerea and Alternaria alternata and was based on the suppression of germination and the inhibition of mycelial growth **(Serrano *et al.*, 2006) and Hassanpour *et al.*, (2015).** In addition, the inhibitory effects of Aloe vera gel have been also found in Aspergillus niger, Cladosporium herbarum, and Fusarium moniliforme **(Ali *et al.*, 1999).** Some individual components found in aloe vera gel, such as saponins, acemannan, and anthraquinones derivatives, are known to have antibiotic activity and could be responsible for their antibacterial activity **(Serrano *et al.*, 2006).**

Ambarsari *et al.*, (2018)coated tomato fruits with starch at 2% incorporated with citric acid at 1% decreasing the decay percentage during storage compared with uncoated fruits. The decrease in decay percentage may be because of the coating on retarding senescence which makes the fruits more susceptible to pathogenic infection as a result of loss of cellular or tissue integrity.

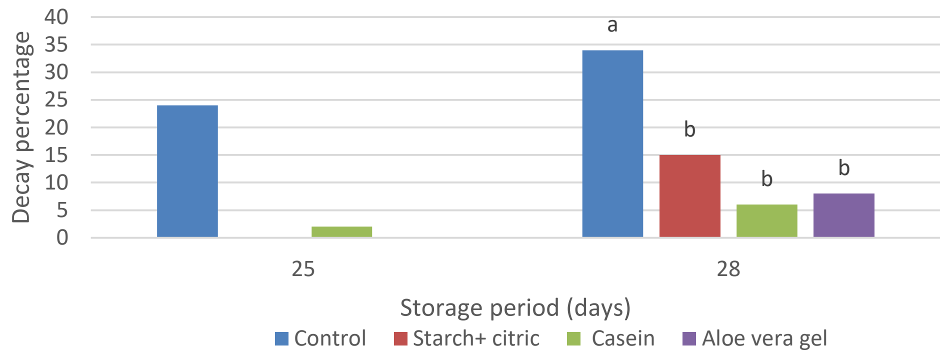

Fig. 2. Effect of edible coatings on decay % of tomato fruits during storage at (8 °±1C, 90-95% RH). Significant difference (p<0.05) between data is expressed by different letters. Values are the means of three samples (n = 3) per treatment. Values followed by the same letter in each column do not differ significantly(P < 0.05). among controls through storage period.

3- Wrinkling (shriveling): -

Data in **Table (1)** included the effect of some postharvest treatments on the wrinkling (score) of tomato fruits during storage at (8° ±1 C 90-95%RH). The Results indicated that the wrinkling of fruit tomatoes significantly increased with time. These findings agree with those of **Firdous *et al.*, (2020)**, **and Roshandel-hesari *et al.*, (2022)** on tomato fruits. Wrinkling of fruit surface is associated with loss in the firmness of fresh fruits and vegetables. wrinkling increased led to anegatively affected the visual quality of tomato fruits during storage. Wrinkling is the deformation of fruit size such as fruits or vegetables throughout storage. Wrinkling occurs due to evaporation and transpiration which significantly lower the water content of fruits. fruits can shrink and lose weight Because of the transfer of moisture from natural pores and respiration **Roshandel-hesari *et al.*, (2022)**.

Results in **Table (1)** indicated that all coating treatments gave significantly reduced wrinkling as compared with uncoated fruits. Data revealed that all coating treatments were much better in reducing wrinkling and thus increasing the storage period. There was no significant difference between edible coatings treatments but There was a significant difference between edible coatings treatments and the control group. The untreated fruits (control) showed the highest wrinkling during the storage time. These results are in agreement with **Firdous *et al.*, (2020)** who found that tomato fruits coated with aloe vera gel decreased the wrinkling throughout storage compared with uncoated fruits. Similar results were reported by **Roshandel-hesari *et al.*, (2022)** who indicated that tomato fruits coated with casein reduced the wrinkling during storage compared with uncoated fruits.

tomato fruits coated with aloe vera gel create a physical barrier that decreases the transfer of moisture from the inside of the fruits to the outside and vice versa. Thus, dehydration and shriveling of tomato fruits can be controlled. These parameters of aloe vera gel are a result of its hygroscopic nature, presence of hydrophobic compounds, and higher polysaccharide contents which creates a water barrier between tomato skin and the outside atmosphere **Firdous *et al.*, (2020)**.

Tomato fruits coated with casein created a semi-permeable membrane that prevents water from passing through, thus decreasing the shrinkage of fruits during storage time **Roshandel-hesari *et al.*, (2022).**

Table 1. Effect of edible coating treatments on wrinkling % during storage at (8 ±1°C) and (90-95%RH) of tomato fruit.

Treatments	**Storage periods (per Day)**								
	0	**3**	**6**	**10**	**13**	**17**	**20**	**24**	**28**
Control (uncoated)	**1**	**1**	**1**	**1**	**1**	**2**	**3**	**4**	**4**
Starch (2%) + Citric acid (1%)	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**
Casein (2.5%)	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**
Aloe vera gel (10%)	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**

Wrinkling percentage severe, 4= moderately severe, 3=moderate, 2=slight and 1=none.

4- General appearance: -

Data presented in **Table (2)** revealed that all coating treatments had significant differences between treated and untreated (control) fruits in the general appearance of tomato fruits during storage periods. On the other hand, all coating treatments were effective in maintaining a general appearance during storage and gave the best appearance. The lowest score of general appearance was recorded with untreated fruits (control). These results are in agreement with **Tzortzakis *et al.*, (2019)** for aloe vera gel**, Adjouman *et al.*, (2018)** for starch, **and Roshandel-hesari *et al.*, (2022)** for casein on tomato fruits. In addition, coated fruit tomatoes with aloe vera gel exposed a good appearance during storage. Maybe this effect is due to controlling softening or fungus infection throughout storage **Ortega-Toro *et al.*, (2017)**. Aloe vera gel can maintain a general appearance by reducing the shrinking and decay percentage in tomato fruits during storage time. furthermore, aloe vera gel can create a water barrier between tomato skin and the outside atmosphere thus preserving its general appearance **Firdous *et al.*, (2020)**.

Starch-based coatings can maintain a general appearance in tomato fruits by decreasing the decay percentage and inhibiting the respiration rate in fruits during the storage period **Ambarsari *et al.*, (2018)**.

Coated fruit tomatoes with casein show a good appearance during storage. Maybe this effect is due to reducing the wrinkling of fruits during storage time. Furthermore, casein films create an effective barrier to oxygen and other nonpolar molecules. This property makes it an excellent choice for reducing the respiration rate of fruits thus maintaining its general appearance throughout the storage period **Roshandel-hesari *et al.*, (2022)**.

Table 2. Effect of edible coating treatments on general appearance during storage at the (8 ±1 °C and 90-95%RH) of tomato fruits.

Treatments	Storage period (per Day)								
	0	**3**	**6**	**10**	**13**	**17**	**20**	**24**	**28**
Control (uncoated)	**9**	**9**	**9**	**9**	**7**	**7**	**5**	**3**	**1**
Starch (2%) + Citric acid (1%)	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**7**	**5**
Casein (2.5%)	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**7**	**5**
Aloe vera gel (10%)	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**7**	**5**

General appearance 9= Excellent, 7 = good, 5=Fair, 3= Poor, 1= Unmarketable.

5- Storability: -

Data in **Fig. (3)** showed that all coating treatments gave significantly increase storability as compared with uncoated (control). These results are in accordance with **Chrysargyris *et al.*, (2016)** have found that tomato fruits coated with aloe vera gel increase storability during storage compared with untreated fruits. Similar results were reported by **Roshandel-hesari *et al.*, (2022)** indicated that tomato fruits coated with casein increased the storability throughout storage compared with uncoated fruits. Furthermore, **Ambarsari *et al.*, (2018)** reported that tomato fruits coated with starch incorporated with citric acid led to increasing storability during storage compared with untreated fruits. The results revealed that all coating treatments had a significant increase between treated and untreated (control) fruits in the storability of fruit tomatoes during postharvest storage. all coating treatments were effective in increasing storability during storage.in other words, these treatments gave the highest value of storability. The lowest score of storability was recorded with untreated fruits (control). these results agree with **Chrysargyris *et al.*, (2016)** for aloe vera gel**, Ambarsari *et al.*, (2018)** for starch **and Roshandel-hesari *et al.*, (2022)** for casein on tomato fruits. Tomato fruits coated with aloe vera gel increased storability during storage. Maybe this effect is due to increasing general appearance and reducing decay throughout storage **Chrysargyris *et al.*, (2016)**. Aloe vera gel can extend storability by decreasing the wrinkling in tomato fruits during storage time. furthermore, aloe vera gel can create a water barrier between tomato skin and the outside atmosphere thus prolonging the storability of fruits **Firdous *et al.*, (2020)**.

Starch-based edible coatings have shown considerable promise and are the greatest in food preservation after harvest. Starch coatings expose good barrier properties and regulate gas and moisture movement, delay senescence, and prolong postharvest life **Oyom *et al.*, (2022)**.

Tomato fruits Coated with casein treatments exhibited increased storability during storage. It might have happened due to reducing the wrinkling of fruits throughout the storage period. Moreover, casein films create an effective barrier to oxygen and other nonpolar molecules thus reducing the respiration rate of fruits **Roshandel-hesari *et al.*, (2022)**.

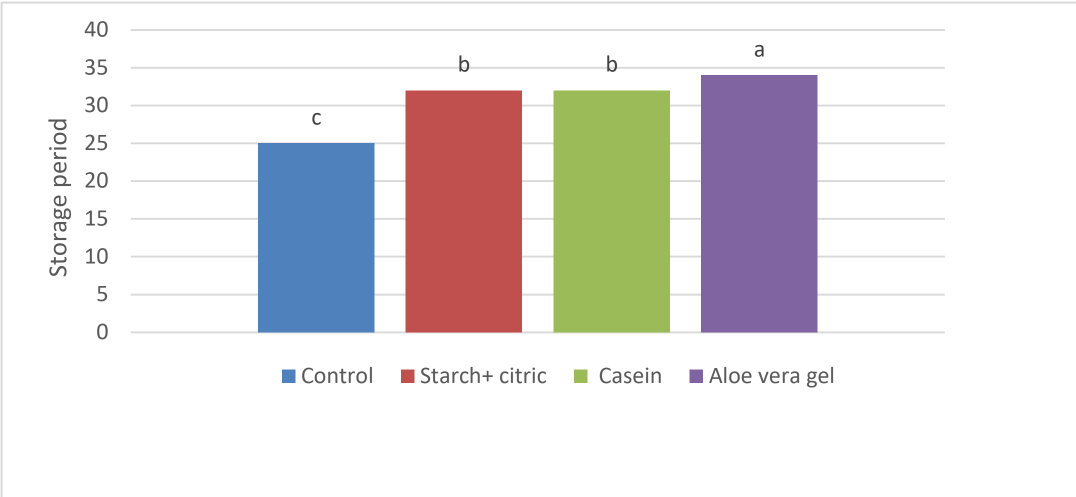

Fig. 3. Effect of edible coating treatments on storability of tomato fruits during storage (8 °±1C, 90-95% RH). A significant difference ($p<0.05$) between data is expressed by different letters. Values are the means of three samples ($n = 3$) per treatment. Values followed by the same letter in each column do not differ significantly ($P < 0.05$). among controls through the storage period.

6- Titratable acidity: -

As is shown in **Fig. (4)**, Data showed that all coating treatments gave significantly increase titratable acidity as compared with untreated (control) fruits. Similar results were reported by **Khatri *et al.*, (2020),** who found that tomato fruits coated with aloe vera gel increased titratable acidity during storage compared with untreated fruits. These results are in agree with **Nawab *et al.*, (2017)** indicated that tomato fruits coated with starch increased the titratable acidity throughout storage compared with uncoated fruits. Furthermore, **Roshandel-hesari *et al.*, (2022)** reported that tomato fruits coated with casein led to increasing titratable acidity during storage compared with untreated fruits.

Data revealed that all coating treatments were much better in increasing titratable acidity and thus maintaining its nutritional quality throughout storage. There was no significant difference between edible coatings treatments but There was a significant difference between edible coatings treatments and the control group. Coating treatments showed the highest value of titratable acidity at the end of storage time. The untreated fruits (control) showed the lowest value of titratable acidity at the end of storage time. These results are in accordance with **Khatri et al., (2020)** for aloe vera gel, **Nawab *et al.*, (2017)** for starch, and **Roshandel-hesari *et al.*, (2022**) for casein.

Aloe vera gel could be effective in decreasing the rate of respiration and metabolic activity thus maintaining the titratable acidity by providing a semi-permeable layer over the skin of the fruit tomatoes. metabolic activity **Khatri *et al.*, (2020).**

Organic acids are the main substrates involved in the respiration process of climacteric fruits, therefore a reduction in acidity was noticeable to be expected in heavily respiring fruits. Starch coatings cause a reduction in the rate of fruit respiration and consequently limit the excessive consumption of organic acids in respiration reactions thus retention the titratable acidity of fruits **Nawab *et al.*, (2017).**

organic acid breakdown may be due to metabolic biochemical activities such as ATP synthesis, however, casein coatings in tomato fruits increased titratable acidity by decreasing this metabolism of organic acids **Roshandel-hesari *et al.*, (2022).**

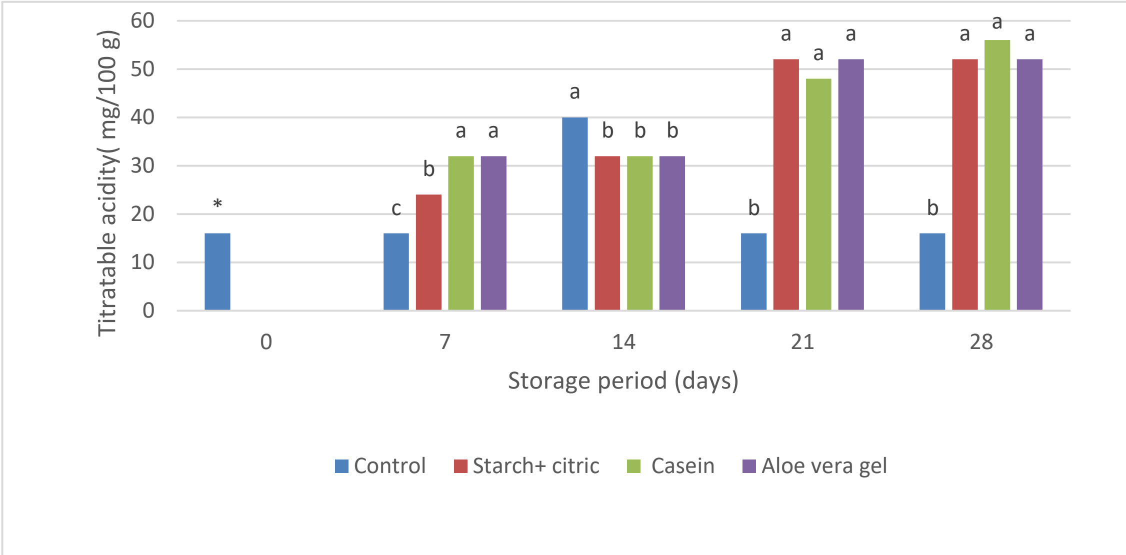

Fig. 4. Effect of edible coating treatments on titratable acidity (mg/100 g) of tomato fruits during storage at (8 °±1C, 90-95% RH). Significant difference ($p<0.05$) between data is expressed by different letters. Values are the means of three samples (n = 3) per treatment. Values followed by the same letter in each column do not differ significantly ($P < 0.05$). * Indicate not significance, among controls through storage period.

7- Ascorbic acid content (Vitamin C): -

Data in **Figure (5)** showed that all coating treatments were effective in preventing ascorbic acid degradation during storage as compared with untreated (control) fruits.In this respect, **Parven *et al.* (2020) and Yıldırım-Yalçın *et al.* (2022)** reported that the decrease in vitamin C content of tomato fruits with storage duration is may be attributed that the oxidation of ascorbic acid into de-hydro ascorbic acid through enzyme ascorbic acid oxidase. Similar results were reported by **Chrysargyris *et al.*,** (2016) found that the tomato fruits coated with aloe vera gel at 10% delayed the decline of ascorbic acid content compared to uncoated fruits during storage. Similarly, **Das *et al.*, (2013)** indicated that tomato fruits coated with starch increased the ascorbic acid content during storage compared to untreated (control) fruits. in accordance with (**Beulah *et al.*, (2021)** who observed that coated fruit with casein can increase the ascorbic acid content throughout storage compared to untreated guava fruits.

Data revealed that all coating treatments were much better in retention of the ascorbic acid content and thus enhancing the nutritional value of fruits. There was no significant difference between edible coatings treatments but There was a significant difference between edible coatings treatments and the control group. all coating treatments showed the highest value of ascorbic acid content at the end of storage time. The untreated fruits (control) showed the lowest value of ascorbic acid content at the end of storage time. These results are in accordance with **Chrysargyris *et al.*, (2016)** for aloe vera gel, **Das *et al.*, (2013)** for starch, and (**Beulah *et al.*, (2021)** for casein.

Aloe vera gel coatings were more effective in the preservation of ascorbic acid contents because of the resultant lower gas permeability which suppressed respiration rate and delayed the overall metabolic activities of fruits during storage **Chrysargyris *et al.*, (2016).** Furthermore, fruits coated with aloe vera gel work as a protective barrier layer and restrict O2 uptake and reduce oxidation of ascorbic acid thus resulting in higher levels of ascorbic acid **Nourozi and Sayyari (2020).**

Coated tomato fruits with starch showed a higher level of ascorbic acid compared to uncoated fruits. It might have happened due to a reduction in the respiration rate of fruits and prevent oxidation of ascorbic acid **(Nawab *et al.*, 2017 and Zhou et al., (2019)**.

Beulah *et al.*, (2021) the effect of casein coating in the retention of ascorbic acid might have happened due to creating a modified atmosphere and delaying the loss of vitamin C during storage.

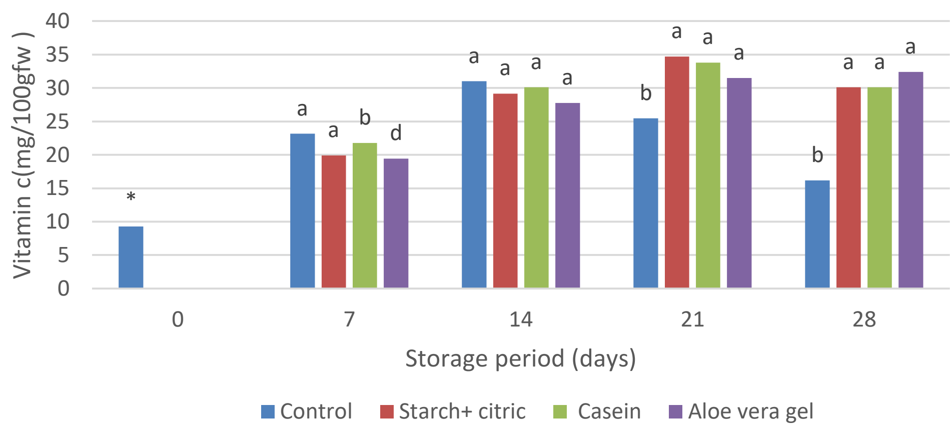

Fig. 5. Effect of edible coating treatments on vitamin C (mg/100gfw) of tomato fruits during storage at (8 °±1C, 90-95% RH). Significant difference ($p<0.05$) between data is expressed by different letters. Values are the means of three samples ($n = 3$) per treatment. Values followed by the same letter in each column do not differ significantly ($P < 0.05$). * Indicate not significance, among controls through the storage period.

8- Total soluble solids (T.S.S.):-

Data in **Fig. (6)** showed that all coating treatments gave a significant increase in the total soluble solids as compared with uncoated fruits. In general, an increase in the percentage of total soluble solids with the increase in the storage periods of fruits is common **(Parven *et al.*, 2020; Formiga *et al.*, 2022)**. These results are in accordance with **Tzortzakis *et al.*, (2019)** who found that tomato fruits coated with aloe vera gel led to a lower increase in total soluble solids during storage compared with untreated fruits which had a sharp increase. Similar results were reported by **Adjouman *et al.*, (2018)** reported that the total soluble solids increased sharply in the uncoated fruits while coated fruits had increased slightly during the storage period. Moreover, **Beulah *et al.*, (2021)** reported that uncoated fruits exposed the highest value for total soluble solids compared to coated guavafruits with casein during storage.

The results revealed that all coating treatments had a significant increase between treated and untreated (control) fruits in the total soluble solids of fruit tomatoes during postharvest storage. all coating treatments were effective in reducing total soluble solids at the end of storage .in other words, these treatments gave the lowest value of total soluble solids at the end of storage. The highest value of total soluble solids was recorded with untreated fruits (control). these results are in agreement with **Tzortzakis *et al.*, (2019)** for aloe vera gel**, Adjouman *et al.*, (2018)** for starch, **and Beulah *et al.*, (2021)** for casein.

Tomato fruits coated with aloe vera gel exposed a lower increase in total soluble solids compared to uncoated fruits. this effect may be due to reducing in the respiration rate of tomatoes consequently retard the metabolic activities such as the break-up of carbohydrates and pectin, partial hydrolysis of protein, and decomposition of glycosides **Kanmani *et al.*, (2017)**.

Starch coatings could be an effective treatment to create a barrier around the fruits, altering the internalatmosphere by reducing O2 and/or increasing CO2 and reducing ethylene production. Thus, reducing gas exchange (O2/CO2) rates also retard the synthesis and use of metabolites, resulting in a decrease in total soluble solids **(Das *et al.*, 2013 and Adjouman *et al.*, 2018).** casein coatings can suppress the gaseous exchange and make a modified atmosphere inside the coating thus inhibiting the respiration rate and decreasing total solublesolids Beulah et al., (2021).

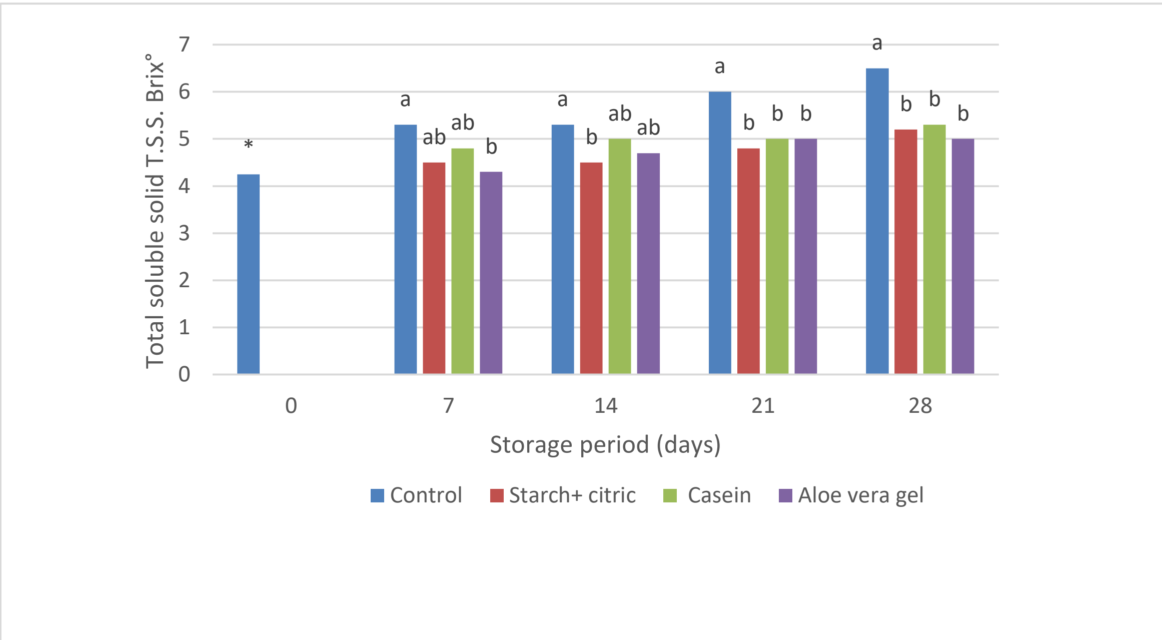

Fig. 6. Effect of edible coating treatments on total soluble solid T.S.S. Brix of tomato fruits during storage at (8 °±1C, 90-95% RH). Significant difference ($p<0.05$) between data is expressed by different letters. Values are the means of three samples (n = 3) per treatment. Values followed by the same letter in each column do notdiffer significantly ($P < 0.05$). * Indicate not significance, among controls through the storage period.

9- Lycopene content: -

As is shown in **Fig. (7)**, data showed that there was no significant difference between casein treatments and thecontrol group at the end of the storage period, but there was a significant increase between aloe vera gel, starchtreatments, and the control group. In summary, starch and aloe vera gel coatings were the most effective treatments to increase lycopene content at the end of storage. The results of this study are consistent with thoseof **Khatri *et al.*, (2020)** who found that the highest value of lycopene content was observed in coated fruits with aloe vera gel compared to uncoated fruits at the end of storage. Similar results had been reported by **Reis*et al.*, (2015)** who reported that uncoated fruits had the lowest values at the end of storage time while fruit tomato coated with yam starch had the highest value of lycopene content thus preserving the lycopene content. Aloe vera gel coatings were highly effective in preserving and maintaining the lycopene content of tomato fruits at the end of storage time. This effect may be due to reducing the metabolic respiration rate, which slowsthe biochemical changes associated with ripening **Yadav *et al.*, (2022).**

Starch coatings created a protective wall that reduces lycopene oxidation, consequently, reducing respiration rates and maintaining the lycopene content in fruit tomatoes **Reis *et al.*, (2015)**.

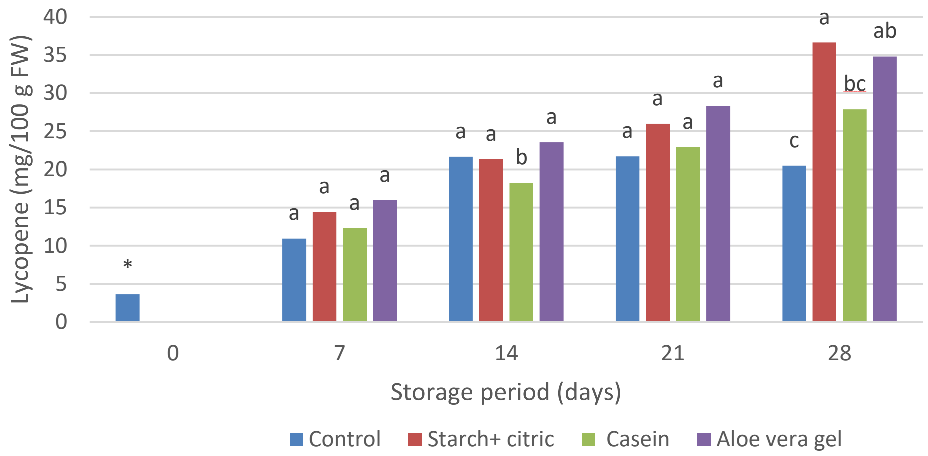

Fig. 7. Effect of edible coating treatments on lycopene (mg/100 g FW) of tomato fruits during storage at (8°±1C, 90-95% RH). Significant difference (p<0.05) between data is expressed by different letters. Values are the means of three samples (n = 3) per treatment. Values followed by the same letter in each column do not differ significantly (P < 0.05). * Indicate not significance, among controls through the storage period.

10- Total phenolic compounds: -

Data shown in **Fig. (8)** Shown the effect of some postharvest treatments on the total phenolic compounds of tomato fruits during storage at (8° ±1 C 90-95%RH). Results indicated that during storage the total phenolic compounds of fruit tomatoes significantly increased with time. these findings agree with those of **(Chrysargyris *et al.*, 2016 and Osae *et al.*, (2022).**

Regarding the effect of coating treatments, data showed that all coating treatments gave a significant increase in the total phenolic compounds at the end of storage time as compared with uncoated fruits. the lowest value of total phenolic compounds was observed in uncoated fruits compared to coated fruits at the end of storage. The results of this study are consistent with those of (**Chrysargyris *et al.*, 2016 and Osae *et al.*, (2022).**

The rapid decrease in total phenolic content of the uncoated fruits may be attributed to a higher respiration rate that resulted in a decrease or decline in total phenolic content due to the degradation of phenolic content. Moreover, the decrease in total phenolic compounds in the uncoated fruits might be attributed to the degradation of the cell structure and senescence that occurred during the storage period **Osae *et al.*, (2022)**.

Coated fruits with aloe vera gel were an effective treatment for increasing the total phenolic compound during storage. This effect might have happened due to the reduced spread of postharvest disease incidence and suppressed respiration rate during storage **Hasan *et al.*, (2021)**.

casein films create an effective barrier to oxygen and other nonpolar molecules. This property makes it an excellent choice for reducing the respiration rate of fruits **Roshandel-hesari *et al.*, (2022)**. thus, increasing the total phenolic compound during storage time.

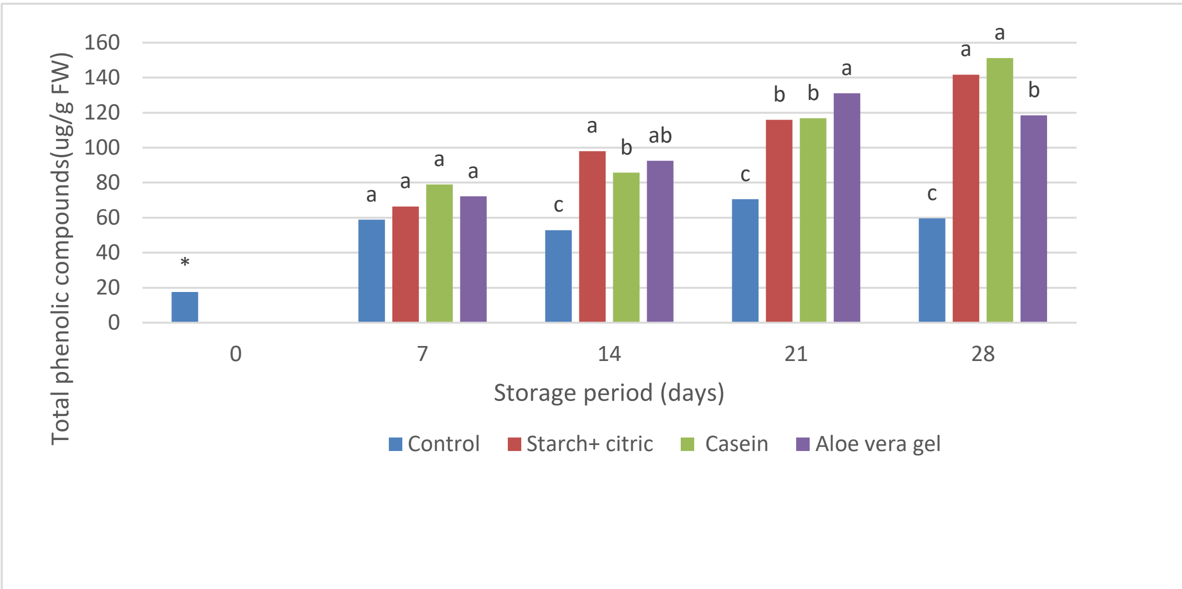

Fig. 8. Effect of edible coating treatments on total phenolic compounds (ug/G FW) of tomato fruits during storage at (8 °±1C, 90-95% RH). Significant difference ($p<0.05$) between data is expressed by different letters. Values are the means of three samples (n = 3) per treatment. Values followed by the same letter in each column do not differ significantly ($P < 0.05$). * Indicate not significance, among controls through the storage period.

11- Peroxidase (POD) activity:

Data shown in **Fig. (9)** Included the effect of some postharvest treatments on the peroxidase activity of tomato fruits during storage at the optimum condition (8° ±1 C 90-95%RH). Results indicated that the peroxidase (POD) activity of fruit tomatoes increased along with storage time. these findings agree with those of **Hasan *et al.*, (2021), Coelho *et al.*, (2017) and Murmu *et al.*, (2018).**

Concerning the effect of coating treatments, data showed that there was a significant difference between the coating treatments and the control group. Similar results were reported by **Hassanpour *et al.*, (2015)** the raspberry fruits coated with aloe vera gel increased the peroxidase (POD) activity compared to uncoated fruits during storage. Similarly, **Coelho *et al.*, (2017)** indicated that coated cut sweet cassava with starch increased the peroxidase (POD) activity during storage compared to uncoated (control) fruits. in accordance with **Murmu *et al.*, (2018)** who observed that coated guava fruit with casein can increase the peroxidase (POD) activity throughout storage compared to untreated fruits.

Data revealed that all coating treatments gave a significant increase in the peroxidase activity at the end of storage time as compared with uncoated fruits. furthermore, aloe vera gel at 10 % significantly had the highest value of peroxidase activity at the end of storage time. Followed by starch at 2% with citric acid 1% and casein at 2.5%. while the lowest ones were obtained from untreated fruits (control). These results are in accordance with **Hassanpour *et al.*, (2015)** for aloe vera gel**, Coelho *et al.*, (2017)** for starch **and Murmu *et al.*, (2018)** for casein**.**

Aloe vera gel coating could maintain the integrity of membranes by preserving the higher activities of peroxidase enzymes during storage. peroxidase enzymes are one of the antioxidant enzymes present in organelles that play the role of reducing lipid peroxidation and protecting against DNA hydroperoxides in fruits **Hasan *et al.*, (2021)**.

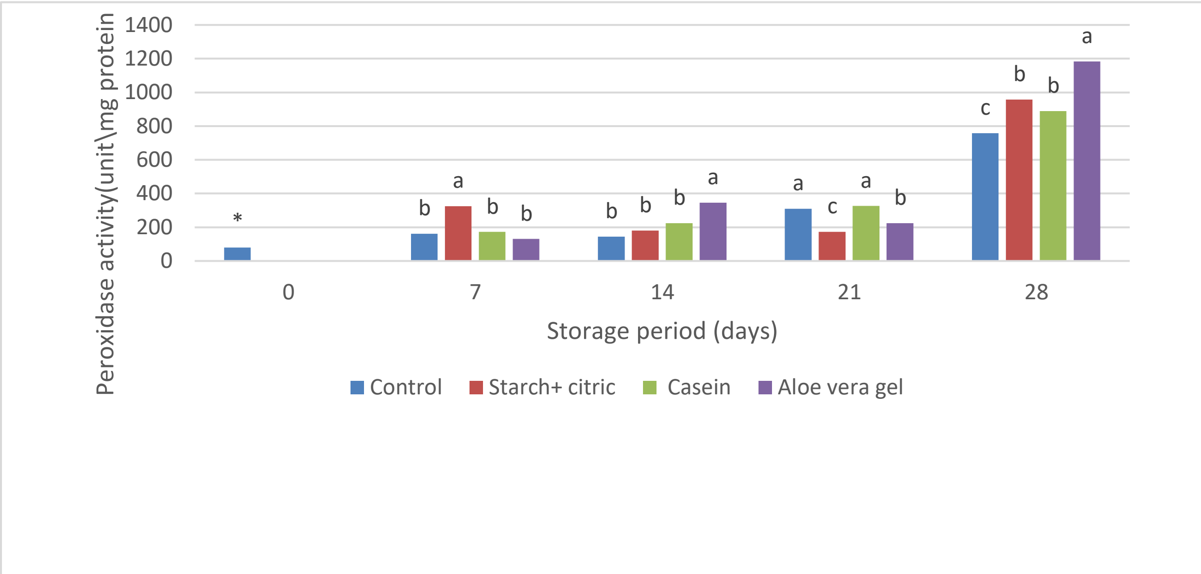

Fig. 9. Effect of edible coating treatments on peroxidase activity (unit\mg protein) of tomato fruits during storage at (8 °±1C, 90-95% RH). Significant difference (p<0.05) between data is expressed by different letters.Values are the means of three samples (n = 3) per treatment. Values followed by the same letter in each column do not differ significantly (P < 0.05). * Indicate not significance, among controls through the storage period.

12- Polyphenol oxidase activity (PPO) activity: -

Data shown in **Fig. (10**) clarified the effect of some postharvest treatments on the polyphenol oxidase activity (PPO) activity of tomato fruits during storage at the optimum condition (8° ±1 C 90-95%RH). Results indicated that there was a significant difference in the polyphenol oxidase activity of tomato fruits noticed at the end of the storage period, these findings agree with those of **Nia *et al.*, (2022)** and **Murmu *et al.*, (2017)**.

Concerning the effect of coating treatments, data showed there was a significant difference between the starch, aloe vera gel treatments, and the control group. But there was no significant difference between the casein and the control group. Starch and aloe vera gel had significantly the lowest value of polyphenol oxidase activity at the end of storage time.

Control fruits had significantly the highest value of polyphenol oxidase activity at the end of storage time. Similar results were reported by **Nia *et al.*, (2022)** who reported that table grapes fruits coated with aloe vera gel decreased the polyphenol oxidase activity compared to uncoated fruits during storage.

Similarly, **Murmu *et al.*, (2017)** indicated that coated guava fruits with casein reduced the polyphenol oxidase activity during storage compared to uncoated (control) fruits.

Edible coatings play a key role in decreasing the polyphenol oxidase activity by creating a modified atmosphere around the fruits and reducing the respiration and oxidation rates of phenols **Ebrahimi and**

Rastegar (2020). Aloe vera gel coatings decreased the respiration and oxidative reaction of phenols by reducing the activity of the PPO enzyme by creating a modified atmosphere around the fruit and maintaining CO2 levels above normal. Thus, retarding senescence and extending the storage life of fruits **Nia *et al.*, (2022).**

edible coatings treatments such as casein created a suitably modified atmosphere around fruits which might have decreased the availability of oxygen and the formation of hydrogen bonds was additionally responsible for limiting the rapid rise of PPO activity in the coated fruits compared with uncoated fruits **Murmu *et al.*, (2017)**.

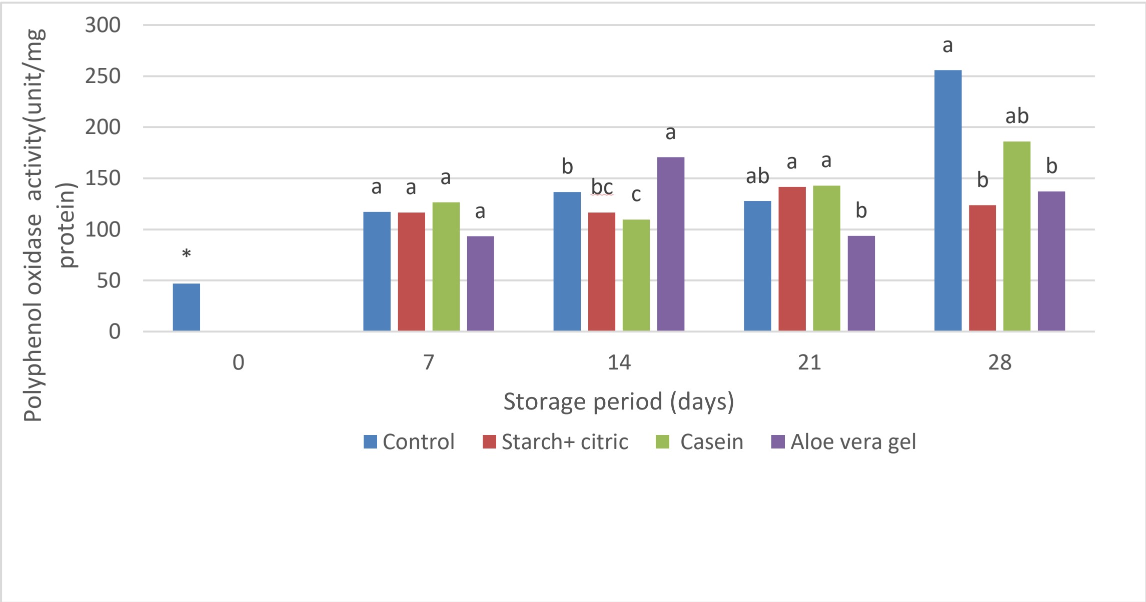

Fig.10. Effect of edible coating treatments on polyphenol oxidase activity (unit/mg protein) of tomato fruits during storage at (8 °±1C, 90-95% RH). Significant difference ($p<0.05$) between data is expressed by different letters. Values are the means of three samples ($n = 3$) per treatment. Values followed by the same letter in each column do not differ significantly ($P < 0.05$). * Indicate not significance, among controls through storage period

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