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Effect of *Aloe vera* gel coating combined with chitosan on postharvest quality of tomato during ambient storage

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Abstract
Aloe vera gel, mainly composed of polysaccharides, has been recently explored as an edible coating owing to its antifungal activity. Chitosan-natural polysaccharide is an established coating material with antifungal activity. In this study, the impact of *Aloe vera* gel and its combination with chitosan was investigated on the storage life of tomato. Edible coatings based on *Aloe vera* gel (AG) and its combination with chitosan (CH) in different concentrations were developed and applied to tomato, in order to improve its quality and shelf life during storage. Weight loss, changes in soluble solids, lycopene content, titratable acidity, pH and the percentage of shrinkage of uncoated and coated samples were determined throughout ambient storage for a period of 30 days. The above parameters which are related to postharvest quality loss were controlled in the tomato coated in the following order 2.5% AG+CH > 8% AG > 2% AG+CH > Control. The storability of tomato was extended up to 30 days. On the basis of the overall Physico-chemical changes, 2.5% *Aloe vera* gel in combination with 2.5% chitosan coating has been identified as a suitable method to extend the shelf life of tomato. It was concluded CA_4 coating for tomato could serve as an alternative to postharvest chemical treatments.

Keywords: *Aloe vera* gel, tomato, chitosan, shelf life

1. Introduction
Tomato as an agricultural product is extremely perishable. As climacteric fruits, tomato is highly perishable due to many processes affected to the quality loss after harvest and during storage including transpiration and respiration that will be followed by physiological changes such as softening tissues, reducing organic acids, color alteration, and volatile compounds losses (Zapata *et al.*, 2008 & Bailen *et al*., 2006) [1, 2]. The deterioration of tomato's quality during storage and transportation is still becoming a serious post harvest problem for traders. Therefore, development of preservation technology is required to avoid postharvest losses and deterioration of tomatoes. Edible coatings are thin layers, used to improve quality, storage, transportation, safety and it also good carrier of bio active compounds like vitamins, minerals and other. Edible coatings are mostly tasteless, colorless, odorless and good mechanical properties.
Aloe vera belongs to family Liliaceae. The leaves of *Aloe vera* are the source of *Aloe vera* gel. *Aloe vera* gel due to moisturizing effect, antibacterial and antifungal properties can be used to develop novel edible coatings for fruits and vegetables to extend their shelf life. Aloe gel based coatings have shown to prevent loss of moisture and firmness, control respiration rate and maturation development, delay oxidative browning and reduce microorganism proliferation (Panwar *et al.*, 2015) [3].
Chitosan is an abundant non-toxic, biodegradable polymer with versatile applications. It is a linear amino polysaccharide obtained from crustacean shells. It is derived from chitin. The physicochemical and biological properties of chitosan justify its introduction in food formulations since it could improve nutritional, hygienic and sensory properties, because of its emulsifying, antimicrobial, antioxidant and gelling properties, while also acting as a functional fiber. This makes it particularly suitable for the formulation of edible coatings, for maintaining the quality and extending the shelf-life of fruits and vegetables such as citrus, peach, kiwifruit, strawberries, tomatoes and apples.
Edible coatings can be applied solely and in combination with other natural preservatives and post harvest treatments (Prasad *et al.*, 2018) [4]. In view of these, the project was undertaken to preserve the post harvest quality of tomato by coating them with *Aloe vera* gel and in combination with chitosan.

2. Materials and Methods

2.1 Experimental materials

The raw materials used are tomatoes of (9005 Siri) variety were procured from local farm, Kotagiri, Nizamabad dist. Shrimps were purchased from local market, Bodhan, Nizamabad dist, Telangana state. *Aloe vera* was obtained from nearby household. The chemicals such as Hexane, Acetone, Ethanol, HCl, NaOH, Glycerol, Ascorbic acid, Citric acid and Phenolphthalein indicator for shelf-life study were purchased from Telangana scientific Pvt Ltd, Hyderabad, Telangana state.

2.2 Preparation of *Aloe vera* gel

Aloe vera, a perennial plant with turgid green leaves, tropical or sub-tropical herb, monocot and almost sessile is one of the most biologically active plant, since it is a rich source of antimicrobial and antioxidant agents. The plant contains two separate juice materials yellow exudate (designated latex), known for its laxative capacity, extracted from vascular bundles at junction between rind and fillets and, a transparent mucilaginous gel, extruded from the inner pulp.

Aloe vera gel matrix was separated from the outer cortex of *Aloe vera* leaf and this colorless hydro parenchyma was ground in a blender. The resulting mixture was filtered to remove the fibers. The liquid obtained constituted fresh *Aloe vera* gel. The gel matrix was heated at 70 °C for 45 min. Immediately, it was cooled to an ambient temperature and ascorbic acid was added in the range of 1.9-2.0g/L. This gel was cooled to about 23 °C in less than 15 min. Citric acid (4.5 – 4.6g/L) was added to this gel to maintain the pH at 4. (Mani *et al.*, 2017) [5].

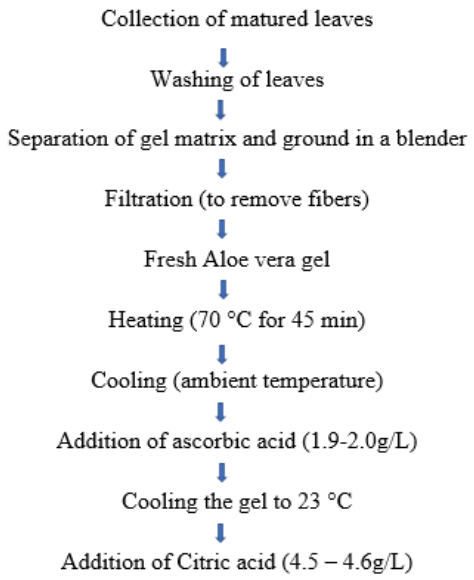

Fig 1: Flow chart for the extraction of *Aloe vera* gel

2.3 Preparation of Chitosan

Fresh shrimp was collected from local market. Shrimp head and skin was separated from shrimp using sharp knife. The collected shrimp wastes were then washed with tap water and crushed with mortar pestle. Crushed shrimp waste was kept in a polyethylene bag at ambient temperature (28±2 °C) for 24 h for partial autolysis to facilitate chemical extraction of chitosan and to improve the quality of chitosan. Then isolation of chitosan was carried out using the following 3 (three) steps, namely demineralization, deproteinization and deacetylation. Demineralization of shrimp shell has been carried out with 3% HCl at ambient temperature (28±2 °C) with a solid to solvent ratio 1:5 (w/v) for 16 h. The residue was washed and soaked in tap water until neutral pH was obtained. Deproteinization of shrimp shell was done with 4% NaOH at ambient temperature (28±2 °C) with a solid to solvent ratio 1:5 (w/v) for 20 h. The residue was washed and soaked in tap water until neutral pH was obtained. Then purified chitin was dried. Chitin flakes were ground into smaller size particles to facilitate deacetylation for removal of acetyl groups from chitin. Deacetylation was experimented using four different concentrations of NaOH (30%, 40%, 50%, 60%) at 65 °C temperature with a solid to solvent ratio 1:10 (w/v) for 20 h (Toan, 2009) [6]. The residue was washed until neutral pH with tap water. The resulting chitosan was then dried in cabinet dryer for 4 h at 65±5 °C and subsequently used for coating purposes.

2.4 Preparation of coating solutions

Aloe vera gel coating solutions with concentrations 2%, 4%, 6%, 8%, 0.5%, 1.5%, 2% and 2.5% were prepared using distilled water (v/v). Each of the solutions were thoroughly mixed. Shrimp shell chitosan solutions with concentrations 0.5%, 1.5%, 2% and 2.5% were prepared by adding 0.6% acetic acid and 25% glycerol (w/w chitosan). Each of the solutions were thoroughly mixed, filtered and the pH was adjusted to 5.6 using 1M sodium hydroxide (Park *et al.*, 2004) [7].

Table 1: Different treatments of coating solutions applied to tomatoes

S. No	Type of coating	Treatments	Concentrations (%)
1.	*Aloe vera* gel	**Control**	**Uncoated**
		A_1	2
		A_2	4
		A_3	6
		A_4	8
2.	Chitosan + *Aloe vera* gel	**Control**	**Uncoated**
		CA_1	0.5 + 0.5
		CA_2	1.5 + 1.5
		CA_3	2 + 2
		CA_4	2.5 + 2.5

2.5 Application of coating solutions

Mature Green Tomatoes variety (9005 Siri) were procured from local farm, Kotagiri, Nizamabad. Tomatoes were properly sorted to discard the tomatoes mechanically damaged while transportation. The procured tomatoes were washed thoroughly with running water and surface dried before coating for proper adherence of coating solutions on the surface of the tomato (Athmaselvi *et al.*, 2013) [8].

The fresh fruits were dipped in the coating solutions at room temperature for 1 min. At regular intervals, the fruits were rotated for uniform application of coating. They were then allowed to dry at room temperature. Weights of the coated fruits were taken. The fruits were stored at room temperature (30 ± 3 °C). The experiment was done in triplicates.

2.6 Physico-chemical analysis

The following physico-chemical analysis was carried out for the tomatoes to assess the effect of coating solutions on the quality attributes of tomato.

2.6.1 Shrinkage percentage

The weight measurement on shrinkage of tomato fruit on n^{th} day of storage was done using the following equation.

$$\text{Weight of shrinkage} = \frac{(\text{fruit weight on } 0^{th} \text{ day}) - (\text{fruit weight on } n^{th} \text{ day})}{(\text{fruit weight on } 0^{th} \text{ day})}$$

2.6.2 Total soluble solids (% Brix)
Total soluble solids (TSS) were measured by the procedure given by Dong *et al.*, (2001). Individual tomato fruit from each treatment will be ground in an electric juice extractor for freshly prepared juice. Soluble solids content was measured using Digital hand held pocket Refractometer (ATAGO) in % Brix. The range of the refractometer is 0 to 85%.

2.6.3 pH
Tomatoes were cut into small pieces and ground. 10 g of ground tomato sample was suspended in 100 ml of distilled water and then filtered. The filtered sample was used for assessment of pH using a pH meter (blue lab).

2.6.4 Titratable acidity
Titratable acidity was determined according to the procedure of AOAC 2000. Five grams of tomato juice diluted in 25 mL of distilled water, two drops of phenolphthalein indicator and titrated by 0.1N sodium hydroxide (NaOH). The titratable acidity was expressed as g citric acid/kg tomato, according to the following equation:

$$\text{Titratable acidity (g citric acid/kg of tomato)} = \frac{(V \times 0.1 \times 1000 \times 0.064)}{m}$$

Where, 0.1 is the normality of NaOH (N)
0.064 is the conversion factor for citric acid
V is the volume of NaOH required (mL)
m is the mass of tomato juice sample used (g)

2.6.5 Lycopene content
Fresh tomato juice was carefully weighed (4 ± 0.01 g) into a 200mL flask wrapped with aluminium foil to protect it from exposure to light. A 100mL mixture of hexane-acetone-ethanol, 2:1:1 (v/v %), was added to the flask and agitated continuously for 10 min on shaking water bath. Thereafter 15 mL of water was added followed by agitation for another 5 min. The solution was then left for separation into distinct polar and non-polar layers and filtered using filter paper (Whatman grade 42). Lycopene concentration was estimated by measuring the absorbance of the extract at 503 nm by UV-VIS Spectrophotometer using hexane as a blank (Ranveer *et al.* 2013) [11]. The lycopene concentration was calculated using its specific extinction coefficient (E1%, 1 cm) of 3120 in hexane at 503 nm. The lycopene concentration was expressed as mg/kg fresh tomato, and calculated by the following formula:

$$\text{Lycopene (mg/kg fresh wt.)} = \frac{(A_{503} \times 537 \times 100 \times 0.55)}{(4 \times 172)}$$

$$= A_{503} \times 42.9$$

Where: 537 g/mole is the molecular weight of lycopene, 100 mL is the volume of mixed solvent, 0.55 is the volume ratio of the upper layer to the mixed solvents, four grams are the weight of tomato added, and 172 mM^{-1} is the extinction coefficient for lycopene in hexane.

3. Results and Discussion
3.1 Changes in Total Soluble Solids (TSS)
The effect of *Aloe vera* gel concentration and its combination with chitosan concentrations on TSS are as shown in Fig 2. It is observed that TSS generally increased on storage for all the treatments in the study. The highest brix of 6.8 was observed in control sample on 20th day of storage. The control sample then deteriorated, so the data of control sample was given till 20th day. The increase in TSS was least in 2.5% chitosan + 2.5% *Aloe vera* gel (CA_4), 8% *Aloe vera* gel (A_4), 2% chitosan+ 2% *Aloe vera* gel (CA_3). The TSS value of 6.23% Brix was observed in the above concentrations on 30th day of storage under ambient conditions. Variation was very less and similar values were obtained. This may be due to suppressed respiration rate that slows down the synthesis and the use of metabolites, resulting in lower soluble solids due to the slower hydrolysis of carbohydrates to sugars (Das *et al.*, 2013) [12].

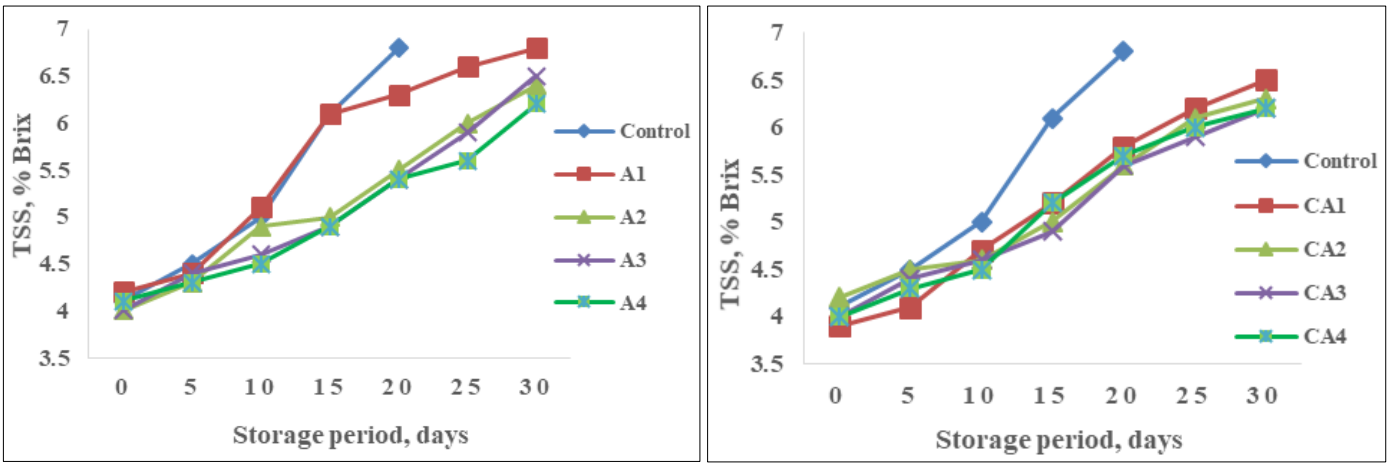

Fig 2: Changes in TSS of tomatoes on application of different *Aloe vera* gel and *Aloe vera* gel + chitosan treatments during storage

3.2 Change in pH
It is evident from the figure 3 that pH increased gradually upon storage but to a lesser extent in CA_4 than the other treatments. Control sample deteriorated on 20th day of storage. On 30th day of storage pH values of 4.19, 4.22, 4.29 were recorded in 2.5% chitosan + 2.5% *Aloe vera* gel (CA_4), 8% *Aloe vera* gel (A_4), 2% chitosan+ 2% *Aloe vera* gel (CA_3) respectively. This shows that combination of 2.5% chitosan and 2.5% *Aloe vera* gel was better in extending the shelf life of tomato.
Results of pH concluded that CA_4 treatment exhibited less increase in pH. It was most likely due to the semipermeable chitosan film formed on the surface of the tomato, which altered the internal atmosphere, as well as the breakdown of

acids with respiration during storage (Pesis *et al*., 1999) [13] and *Aloe vera* gel, which could reduce metabolic reactions by creating a modified internal atmosphere and thus increasing the pH during storage.

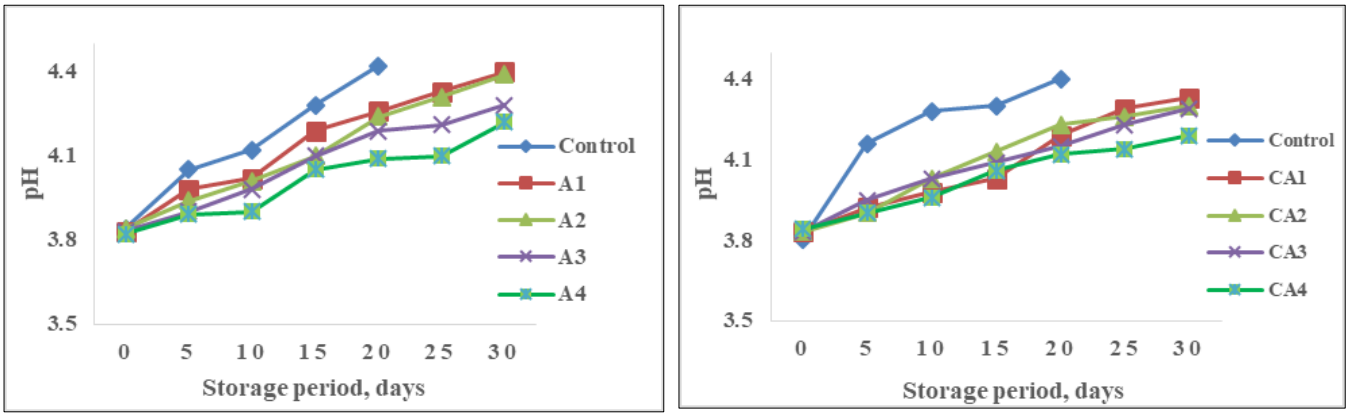

Fig 3: Changes in pH of tomatoes on application of different *Aloe vera* gel and *Aloe vera* gel + chitosan treatments during storage

3.3 Changes in Shrinkage (%)

The effect of *Aloe vera* gel and *Aloe vera* gel + chitosan concentration on shrinkage of tomato is shown in the Fig 4. On 20th day of storage, the weight loss of the control, 2%, 4%, 6%, 8% *Aloe vera* gel coated tomatoes were 29.23%, 18.89%, 14.92%, 12.36%, 10.23%, respectively and the shrinkage of CA_1, CA_2, CA_3, CA_4 coated tomatoes were 16.36%, 11.54%, 10.69%, 9.56% respectively It was observed that 2.5% chitosan + 2.5% *Aloe vera* gel (CA_4), 8% *Aloe vera* gel (A_4), 2% chitosan+ 2% *Aloe vera* gel (CA_3) were best in that order in reducing the weight loss of tomato than the other concentrations of coatings on storage. The slower rate of moisture loss from these coated fruits may be attributed to the additional barrier against diffusion through stomata (Paull *et al*., 1989) [14].

According to Adetunji *et al*. (2012) [15], *Aloe vera* gel applied as an edible coating on pineapple fruit has beneficial effect on the ripening process.

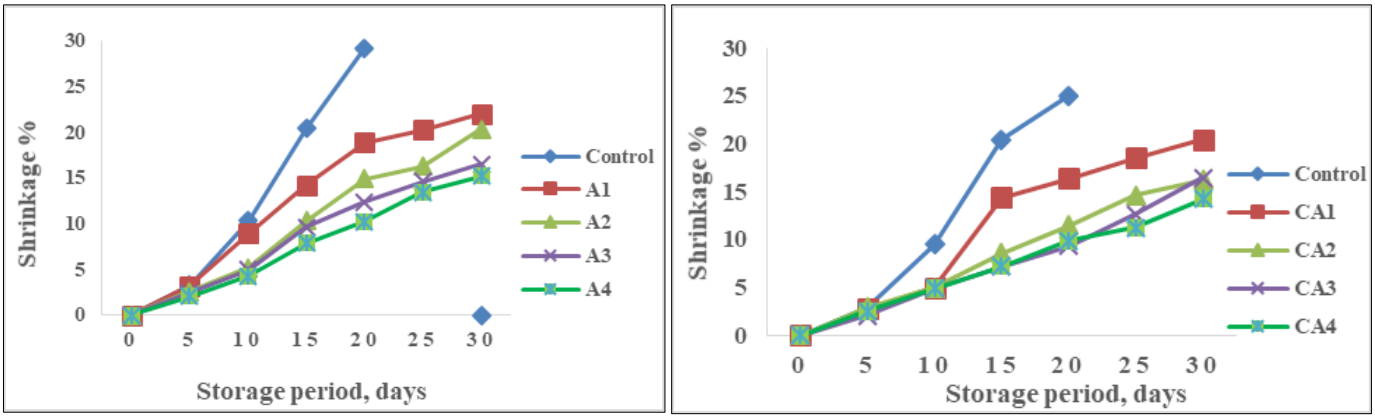

Fig 4: Changes in shrinkage (%) of tomatoes on application of different *Aloe vera* gel and *Aloe vera* gel + chitosan treatments during storage

3.4 Changes in Titratable Acidity (%)

The titratable acidity (TA) of the tomatoes decreased with maturity. The same results were observed in a study by Raffo *et al*., (2002) [16] which shows the acidity decreased with maturation.

The effect of *Aloe vera* gel and *Aloe vera* gel + chitosan treatments on titratable acidity of tomato during storage is shown in fig 5. *Aloe vera* gel stabilized titratable acidity compared to control samples. The combination of *Aloe vera* gel and chitosan showed less decrease in titratable acidity than *Aloe vera* gel alone. It was observed that 2.5% *Aloe vera* gel + chitosan (CA_4) 8% *Aloe vera* gel (A_4), 2% *Aloe vera* gel + chitosan (CA_3) coatings were better in extending shelf life in that order.

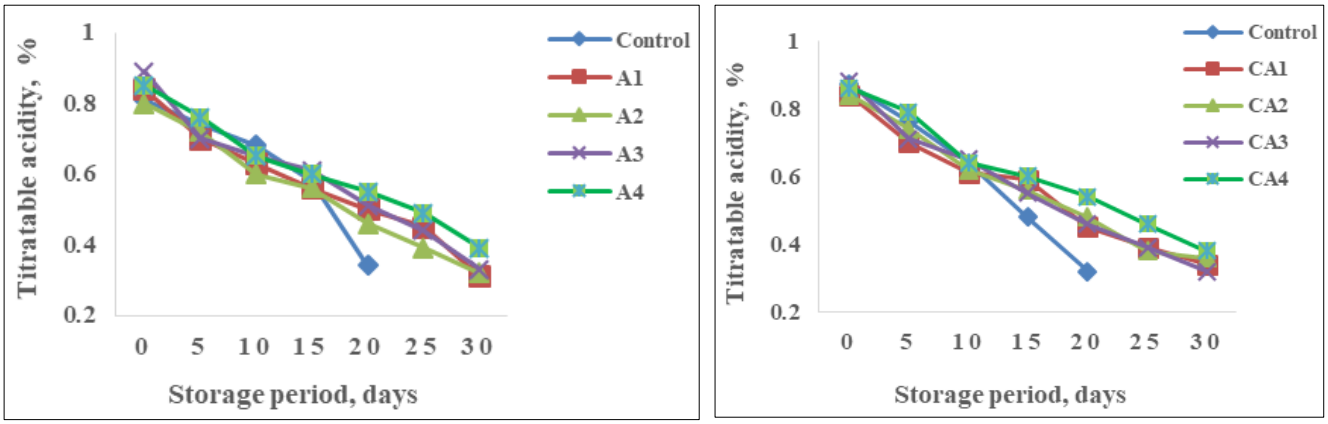

Fig 5: Changes in titratable acidity (%) of tomatoes on application of different *Aloe vera* gel and *Aloe vera* gel + chitosan treatments during storage

3.5 Change in Lycopene content

During ripening the chlorophyll content decreased, and there was a rapid synthesis of the red pigment lycopene. There was a steady increase of lycopene content on storage of coated and uncoated tomatoes as shown in the fig 6. Lycopene content of 43.36 mg/kg, 34.33 mg/kg, 38.44 mg/kg, 38.45 mg/kg was observed in control, 2.5% *Aloe vera* gel + 2.5% chitosan (CA_4) 8% *Aloe vera* gel (A_4), 2% *Aloe vera* gel + 2% chitosan (CA_3) on 20th day the storage respectively. The combination of *Aloe vera* gel and chitosan (CA_4) proved to be the most effective in delaying the ripening of tomato.

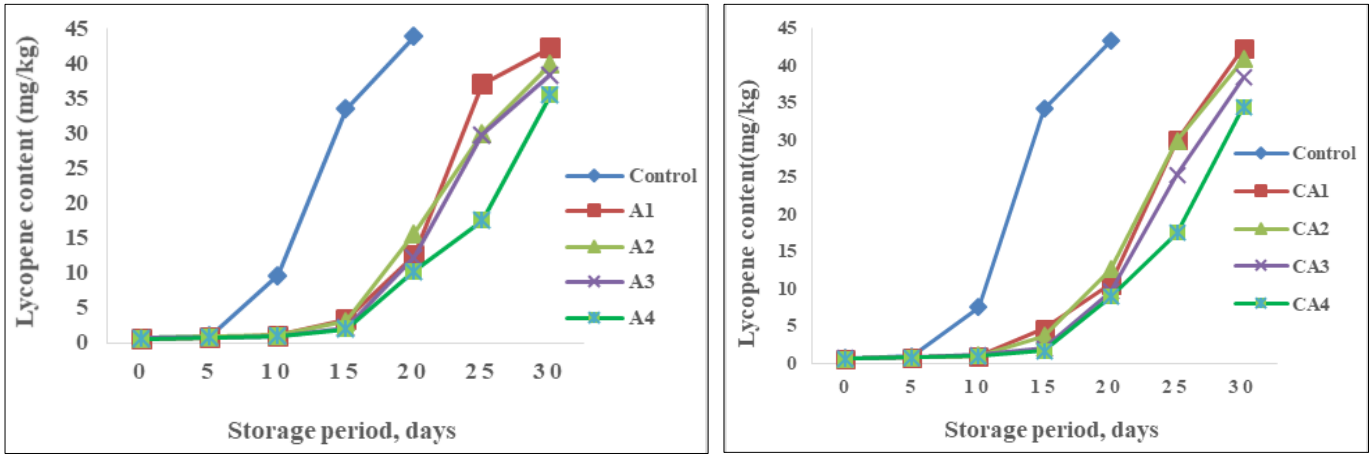

Fig 6: Changes in lycopene content (mg/kg) of tomatoes on application of different *Aloe vera* gel and *Aloe vera* gel + chitosan treatments during storage

4. Conclusion

Application of the *Aloe vera* gel and *Aloe vera* gel in combination with chitosan edible coatings to tomato promoted an increase in the shelf life of the produce. Coated tomatoes were firmer, less decayed, higher in titratable acidity and showed less change in the pH and TSS values when compared to the uncoated tomato until 30 days of ambient storage, and may be a viable alternative for the use of post harvest treatment and cold storage. On the contrary the control sample deteriorated after 20 days of storage.

Overall based on the physico-chemical data, it could be concluded that 2.5% *Aloe vera* gel + 2.5% chitosan (CA_4), 8% *Aloe vera* gel (A_4), 2% *Aloe vera* gel treatments are better in that order, the former being the best. As a consequence of the findings, it is concluded that the combination of *Aloe vera* gel and chitosan exerts greater effects than separate *Aloe vera* gel coatings throughout the storage duration and serves as the best way to increase the shelf life of tomato fruits for up to 30 days.

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