Aloe (Aloe Barbadensis Mill.) Gel as an Agent in Delaying the Post-Harvest Deterioration of Eggplant (Solanum Melongena), Tomato (Lycopersicum Esculentum), and Bell Pepper (Capsicum Annum)

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ABSTRACT

Solanaceous crops such as eggplant, tomato, and bell pepper are highly valuable crops in the Philippines for its versatility in Filipino food cuisines. However, these crops after harvest are prone to deterioration due to faster ripening and microbial contamination leading to short life duration during transport and storage. To address this challenge, introduction of botanical coatings to delay post-harvest deterioration of these crops is promising eco-friendly solution. Aloe (Aloe barbadensis Mill.) plant which is widely planted for its gel has been reported to contain biologically active compounds that are highly valuable for medicinal, cosmetic, and industrial uses. In the Philippines, aloe vera is valued as an ornamental plant with strong domestic demand and emerging export opportunities. It has also been studied as a potential edible coating to improve the post-harvest life of fruits, and has extensively applied for fresh produce preservation. However, studies about its effects on the post-harvest life of solanaceous crops in Philippine condition is limited. Thus, this study sought to investigate the effect of the different aloe gel (AG) concentrations as pre-treatment on the quality of eggplant, tomato, and bell pepper fruits during storage. Fruits were coated with AG and changes in the physical quality of the solanaceous fruits were measured during storage within 7, 12, and 21 days. The present study showed that coating with 20%-30% AG reduced the weight loss, and consequently, decreased loss of firmness, less shrinkage, lesser disease incidence and severity, thereby improving the visual quality of the fruits. Pre-treating the fruit with AG was done by mixing it with water to enhance the storage quality of the fruits. Results obtained from this study show that aloe gel coating can be useful in extending the postharvest storage life and maintaining the quality of solanaceous fruits during storage.

Keywords: Post-harvest, fruit deterioration, pre-treating fruits, aloe gel coatings, Monkayo

INTRODUCTION

Major challenge for crop improvement of solanaceous crops such as eggplant (Solanum melongena), tomato (Lycopersicum esculentum), and bell pepper (Capsicum annum) is the enhancement of their nutritive values while improving the quality and reducing the postharvest waste (Seymour, et al., 2013). These crops were prone to physiological deterioration due its short shelf-life duration, increase ethylene production, increase respiration, storage methods, and also the influence of environmental factors such as temperature and light (Barkai-Golan, 2001). In addition, the pest and diseases also contributed to the deterioration processes of these crops such as the anthracnose that is commonly caused by Colletotrichum spp. (Ali, et al., 2016), and bacterial wilt caused by Ralstonia solanacearum (Manda, et al., 2020) which can later cause postharvest losses if not manage as early as possible.

Philippine production of eggplant in the year 2021 was 0.5 % higher than the output in 2020, which also have an average annual rate of 0.2 % from 2017 to 2021 (PSA, 2023). However, this increase in production doesn't mean that there are no losses. In fact, Flores et al. (2018) reported that the postharvest system's loss of eggplant ranged from 4.78 to 8.05% for a period of two days from harvest at the farm to retail market level which implies that losses of this crop lie at the post-harvest operation. The same goes to the domestic production of tomato and bell pepper where there were a 1.6%, and 7.0% annual increase as reported by PSA (2022). Despite of this increasing production, the losses due to several factors still exist where in fact tomato has a postharvest loss of up to 25-42%

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globally according to Khan and Jan (2007). Also, according to SEARCA, (2022), tomato produced in Nueva Ecija, Philippines incurred post-harvest losses of 10.94% where the volume of post-harvest losses reached 1, 930 tons with a value of 47 million pesos. Thus, proper management and prevention practices is necessary to lessen the losses of these crops during the post- harvest period.

However, one of the utmost concerns in terms of management is that our local farmers habitually use synthetic pesticides to directly control the deterioration process of the harvested crops while unconsciously harming the ecosystem and human health (Bonmatin, et al., 2021). The use of these synthetic pesticides was practiced by the local farmers for many years which also became a culture of every farm with the hope of producing a customers' preferred appearance such as having a shiny surface without any bruises or diseases.

Therefore, to lessen the harmful effects of synthetic chemicals while reducing post-harvest losses, the optimization of naturally based products to delay the crop deterioration is a trend. In fact, food losses reduction according to Chakraborty and Chattopadhyay, (2018) is less costly than the equivalent increase in food production, and that the success of food production lies in the proper distribution of produce and its subsequent utilization by the consumers with least waste in the process.

Furthermore, Martínez-Romero, et al., (2006) believed that coating fruits with preservative compounds provides a modified atmosphere by creating a semi-permeable barrier against oxygen, carbon dioxide, moisture, and solute movement, thereby, retarding the deterioration of fruits and vegetables. In addition, the study of Farina, et al., (2020) concluded that the postharvest application of aloe vera gel-based edible coating improved the quality and storage stability of fresh-cut papaya.

Hence, in this study, optimization of aloe vera, scientifically known as Aloe barbadensis Miller, with its clear, mucilaginous fluid known as aloe vera gel found inside the parenchyma cells (Ramachandra, et al., 2008) was used to delay the physical deterioration of solanaceous crops such as the eggplant, tomato, and bell pepper. Specifically, the study aimed to determine the effects of aloe vera gel application at different concentrations to the physical appearance of solanaceous crops (eggplant, tomato, and bell pepper fruits); evaluate the efficacy of aloe vera gel at lower concentration in extending shelf-life, maintaining physical quality, and controlling disease incidence of solanaceous crops; and evaluate the various responses of these solanaceous crops to its physical attributes with the application of aloe vera gel.

MATERIALS AND METHODS

Collection of Solanaceous Fruits

This study was conducted at Monkayo College of Arts, Sciences, and Technology, Poblacion, Monkayo, Davao de Oro, Philippines. Commodity used in this study were the freshly harvested solanaceous fruits from the municipality of Monkayo, Davao de Oro. It was traveled inside a cooler container to ensure freshness, prevent pest and diseases, as well as to avoid temperature and mechanical injuries. Fruits with defects (sunburn, cracks, bruises and cuts) were discarded, while only the fruits with healthy epidermis, even maturity, homogenous sizes and appearances were used.

Aloe Vera Gel Preparation

Aloe vera gel (aloe gel) was prepared following the procedure of Ramachandra, et al., (2008) with slight modification to resort available resources. The aloe vera leaves were freshly harvested, and transported inside a cooler container from the field to the laboratory to allow undamaged, disease free, and matured (3-4 years) leaves, as well as to keep all the active ingredients in full concentration. Upon the arrival of the aloe vera leaves, filleting operation was completed within 24 hours to avoid decomposition of the biological activities. Thereafter, the aloe gel fillets were crushed and homogenized using a commercial high-speed blender within 3 minutes at room temperature (25°C). This process was to prevent the reaction of enzymatic browning, since the longer the grinding time, the higher the browning index of aloe vera gel juice (Liu, 2001).

This study conducted enzyme treatment where the AG was subjected to double boiling method for 50°C within 20 min as cited by Ramachandra, et al., (2008) from the procedure of Maughan (1984) to reduce the loss of

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biological activity of polysaccharide (55%) in aloe vera gel (Luta and McAnalley, 2005). To stabilize and preserved the aloe gel, its juice was fortified with citric acid naturally present and abundant in citrus fruits such as the lemon. This was also used to avoid enzymatic browning reaction, thereby improving the quality of aloe gel. Thereafter, the pH of aloe gel was adjusted between 3.0 and 3.5 using a pH meter paper.

Pasteurization process on other hand was done through HTST (high temperature in short time) treatment at 85-95°C for 1-2 mins, as it is an effective method to avoid the loss of biological activity of the aloe gel (Eshun, 2003). Thereafter, the juice was flashed cooled to 5°C within 10-15 seconds to preserve biological activity of the aloe vera gel.

Experimental Design and Lay-out

Aloe gel (AG) concentration used in this study were 5%, 10%, 15%, 20%, 25%, and 30% in 500 ml water. The lower aloe gel concentrations were further evaluated in the in vivo test. Experiment was laid-out in a Completely Randomized Design (CRD) with seven (7) treatments replicated three (3) times at three (3) sample fruits per replication or a total population of 63 fruits for each crop.

In vivo Test

Efficacy of the lower aloe gel concentration in extending shelf-life, maintaining physical quality, and disease incidence and severity reduction was evaluated. Treatments used were T1-Control (untreated), T2 – 5% AG, T3 – 10% AG, T4 – 15% AG, T5 – 20% AG, T6 – 25% AG, T7 – 30% AG.

Data Gathered

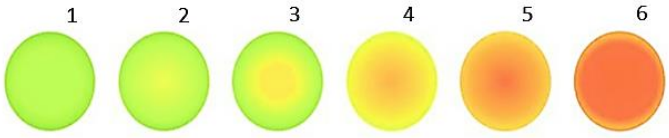
The fruit samples were observed visually in daily manner for weight loss, and with a time interval of two days for visual aspect such as shrinkage or shriveling, color change of the skin, microbial growth, softening nature until it reached visual quality rating (VQR) of 3 which is the limit of marketability.

Cumulative Weight loss (CWL)

Weights of the three (3) samples fruits in each treatment were recorded daily. Cumulative weight loss was calculated with the formula: %CWL= Wi – Wd / Wi (100) where: CWL= cumulative weight loss (%); Wi = initial weight (g); and Wd = weight at date of observation (g).

Ripening Color

Fruit color was evaluated through a standard color chart for ripening index of tomato, and bell pepper, used by Barua, et al., (2018). Standard color chart below was used.



Source: Barua et al. Advances in Agricultural Science 6 (2018), 03:49-60

Visual Quality Rating (VQR)

Scale used in this study followed the VQR used by Bayogan, et al., (2019) to measure the visual quality of the crops applied with aloe vera gel which was based from 1- excellent, field fresh; 2- Very good, minor defects; 3- fair, moderate defects, limit of marketability; 4- poor, defects serious, usable but not saleable; and 5- limit of edibility, non-edible under usual conditions.

Firmness

Scale used in this study followed the index used by Bayogan, et al., (2019) with slight modification, to measure

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the firmness of the fruits occurs with the application of aloe gel. This was done by pressing gently the fruits to feel its firmness. The rating scale was 1- firm; 2- slightly soft, (20% soft-80% firm); 3- moderately soft, (50% soft-50% firm) (limit of marketability); 4- severely soft, (75% soft-25% firm), usable but not saleable; and 5- limit of edibility, extreme softness, (≥76% soft).

Shriveling Index

Scale used in this study followed the index used by Bayogan, et al., (2019) to measure when the shrinkage of the fruits occurs when applied with aloe vera gel presented as 1- no shriveling; 2- slightly shriveled, (1%-15%); 3- moderate, 16%-30% shriveling (limit of marketability); 4- severe, 31%-49% shriveling; and 5- extreme, ≥ 50%.

Post-Harvest Disease Incidence (%)

The number of diseased fruits (Df) was counted on every two days after treatment application. Then the values of mean per data collection were calculated with the formula: %PHD = Df/n (100) where; %PHD = (%) post-harvest decay; Df = number of decayed fruits; and n = total population of fruits.

Post-Harvest Disease Severity (%)

Fruit samples were visually evaluated. All fruits from each treatment were used for the evaluation. A fruit was considered as decayed when the development of surface microbial inoculum such as the mycelia/conidia/conidiophores and bacterial oozing were visually observed. scale used was 1- no infection or symptoms; 2- trace infection (1%-10%); 3- slight infection (11%-25%); 4- moderate infection (26%-50%); 5- severe infection (>50%).

Statistical Analysis

Collected data were analyzed using the Analysis of Variance (ANOVA), following the Completely Randomized Design (CRD) and the significant difference among treatment means were compared using Tukey's Honest Significant Difference (THSD)

RESULTS AND DISCUSSION

Effects of Aloe Gel to Weight Loss

Weight loss of eggplant, tomato, and bell pepper was inevitable in normal condition. However, in this study, there was a significant difference among treatment means as affected by the application of aloe gel (Table 1.a-c). Eggplant showed a significant difference as early as day 1 (D1) with the lowest weight loss of 4.88% obtained from T7-30% AG (Table 1.a). Additionally, the aloe gel-treated eggplant were comparable to the untreated (T1-control) samples, hence a trend on reduced weight loss was observed within seven (7) days of observation.

Table 1.a. Mean percentage of the cumulative weight loss (CWL) of eggplant applied with the different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION						
	D1	D2	D3	D4	D5	D6	D7
T1 - Control	6.51^{b}	11.89^{c}	17.17^{b}	21.7^{b}	24.77^{b}	28.10^{b}	31.63^{b}
T2 - 05% AG	6.09^{ab}	10.79^{bc}	14.30^{a}	17.49^{a}	21.17^{ab}	24.24^{ab}	27.65^{ab}
T3 - 10% AG	5.56^{ab}	9.99^{ab}	13.64^{a}	17.35^{a}	21.15^{ab}	24.17^{ab}	26.46^{a}
T4 - 15% AG	5.43^{ab}	9.64^{ab}	13.52^{a}	17.22^{a}	21.07^{ab}	23.12^{a}	26.23^{a}
T5 - 20% AG	5.38^{ab}	9.54^{ab}	13.12^{a}	16.70^{a}	19.69^{a}	22.97^{a}	25.64^{a}
T6 - 25% AG	5.21^{a}	8.49^{a}	12.65^{a}	15.92^{a}	19.04^{a}	21.73^{a}	24.11^{a}
T7 - 30% AG	4.88^{a}	8.53^{a}	12.52^{a}	16.02^{a}	18.91^{a}	21.50^{a}	24.10^{a}
CV (%)	8.03	5.47	7.44	6.59	7.17	7.11	6.15
Pr (> F)	0.0098	0.0000	0.0012	0.0004	0.0045	0.0053	0.0010

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Means with the same letter are not significantly different at 5% level; ns – not significance; and values are the means of the three replications.

Application of aloe gel on eggplants had an evident result in reducing the weight loss than the untreated eggplant samples. Aloe gel at 30% obtained the lowest weight loss from day 1 to 7 after application, followed by the eggplants treated with 25% aloe gel which recorded the lowest weight loss on day 2 and 4. Moreover, on 3 to 4 days, there was a relatively higher difference between the untreated and treated samples, statistically (Table 1.a.). This can be the result of the ability of aloe vera gel to limit moisture loss as coating of the fruits (Nicolau-Lapena et al., 2021). It is also explained by Morillon et al. (2002) that the reduced weight loss is an effect of applying aloe gel as it enables the formation of barrier to water diffusion between fruit and the environment that reduces the external transference. Moreover, the polysaccharide composition of aloe vera gel also plays a role in limiting moisture loss (Perez-Gago et al., 2002; Ni et al., 2004).

Further, aloe gel-treated tomato (Table 1.b.) and bell pepper (Table 1.c.) fruits showed no significant difference among treatments means. This implied that the application of aloe gel at lower concentration was ineffective in reducing its weight losses. Thus, the efficacy of aloe gel to the reduction of weight losses of tomato and bell pepper relies on its concentration level. The result of this study was in partial agreement with the study of Dadzie, et al, (2021) aloe-coating on tomatoes was not effective as no significant changes were found on weight loss during 7- or 14-days' storage comparing to the control

Table 1. Mean percentage of the cumulative weight loss (CWL) of tomato applied with the different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION										
	D1	D3	D5	D7	D9	D11	D13	D15	D17	D19	D21
T1 - Control	3.81	8.20	11.82	15.35	16.78	18.41	19.60	21.28	22.47	24.16	26.09^{ns}
T2 - 05% AG	3.30	5.07	7.04	8.36	9.02	11.00	12.55	14.52	16.07	16.72	18.92^{ns}
T3 - 10% AG	2.94	5.39	7.11	8.10	9.83	10.82	12.31	14.04	15.53	17.01	18.02^{ns}
T4 - 15% AG	3.24	5.03	6.06	7.54	8.26	9.74	12.02	13.24	14.76	15.57	17.05^{ns}
T5 - 20% AG	3.52	5.28	6.29	7.54	8.54	9.80	10.81	12.07	13.57	14.83	16.09^{ns}
T6 - 25% AG	3.13	4.16	5.92	6.99	7.73	9.09	10.45	12.07	13.34	14.38	15.45^{ns}
T7 - 30% AG	2.77	4.12	5.42	6.44	7.71	9.24	9.75	10.71	11.72	13.45	13.91^{ns}
CV (%)	62.9	48.9	47.3	53.6	49.54	43.87	38.31	34.81	30.47	29.18	27.41
Pr (> F)	0.99	0.56	0.34	0.32	0.30	0.30	0.27	0.24	0.20	0.21	0.14

Means with the same letter are not significantly different at 5% level; ns – not significance; and values are the means of the three replications.

In tomato fruits, aloe gel had no significant effect on weight loss from 1 to 21 days after treatment application. However, there was a slight difference of means between the untreated and treated tomatoes. Similarly, Chrysargyris et al. (2016) reported that there was no significant difference in the respiration rates of tomato where carbon loss in respiration is included in summing up the weight loss of fruits and vegetables other than the moisture loss by transpiration (Becker and Fricke, 1996).

Table 1. Mean percentage of the cumulative weight loss (CWL) of bell pepper applied with the different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION											
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
T1 - Control	12.79	20.34	28.31	35.62	41.60	46.69	51.78	55.99	61.16	65.37	68.44	71.54^{ns}
T2 - 05% AG	11.97	19.14	26.86	33.53	39.44	45.23	50.52	54.50	59.24	63.82	68.01	70.16^{ns}
T3 - 10% AG	11.78	19.57	26.85	32.95	39.00	44.69	50.79	54.11	58.66	62.59	67.39	70.67^{ns}
T4 - 15% AG	11.19	18.21	25.71	31.96	37.51	43.59	49.90	52.46	57.34	61.92	65.30	68.46^{ns}
T5 - 20% AG	11.23	17.50	24.34	31.75	37.23	43.27	49.28	52.84	57.76	61.59	65.43	68.76^{ns}
T6 - 25% AG	10.55	16.77	24.11	31.20	37.13	42.34	48.92	52.82	57.43	61.11	65.49	68.63^{ns}
T7 - 30% AG	10.26	16.16	22.78	29.71	35.92	41.86	47.45	50.55	55.27	59.36	63.37	66.52^{ns}
CV (%)	12.83	12.88	9.73	7.88	7.72	6.40	6.10	5.86	5.46	4.51	3.64	3.09
Pr (> F)	0.44	0.33	0.17	0.21	0.35	0.42	0.69	0.51	0.46	0.27	0.19	0.16

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Means with the same letter are not significantly different at 5% level; ^{ns} – not significance; and values are the means of the three replications.

For the weight loss of bell pepper, the findings of the present study showed no significant difference which indicates that aloe vera gel do not affect the weight loss of bell pepper. On the other hand, there was a slight difference of means of bell pepper treated with 30% aloe vera gel among other treatments but were statistically insignificant. It contradicts to the study Kumara et al. (2019), where bell peppers have low weight loss when applied with aloe vera.

Loss of weight observed in fruit can be also ascribed to water loss caused by metabolic activities during transpiration and respiration (Nicolau-Lapena et al., 2021). The reduced weight loss of treated eggplant in this study can be explained by the ability of aloe vera coating to limit moisture loss. The high rate of weight loss recorded for untreated can be partly explained by an increased rate of metabolic activities or higher rate of moisture evaporation caused by the higher environmental temperature (Dadzie, et al, 2021).

Effects of Aloe Gel to the Ripening Color of Tomato and Bell Pepper

Treated tomato fruits showed significance difference, comparable to the untreated ones within 3 to 5 days of application (Table 2.a.). However, beyond 7 days of aloe gel application, treatments showed no significance difference. This implies that beyond 7 days of application, changes of color from green (1) to red (6) due to ripening was unstoppable. Factors such as the temperature, maturity of samples, and natural ethylene gas production can be the reason behind this phenomenon. In fact, the tomato fruits pigment content changed during fruit development, while the chlorophyll content is reduced during maturation and carotenoids are produced promptly, thus synthesizing the red pigment lycopene and β-carotene (Santoro, et al. 2028).

In the present study, in control fruits, β-carotene and lycopene content significantly changed the first 5 days of storage, while they remained significantly similar to other levels after 7 days of storage (Table 2.a.). This result also corroborates with the study of Kumar, et al, (2019) in which the aloe coating they used had no profound effect on fruit color. The lightness was decreased, while the redness was increased during storage in both coated and uncoated fruit, and the highest decrease in lightness was observed in 20% AG coated fruit after 14 days of storage.

With respect to the ripening color of tomato, there were significant effects on the 3 and 5 days after treatment. Tomato fruits treated with 30% aloe vera gel has the lowest rate of color change next is the treatment with 25% aloe vera gel after 3 days of treatment application. On the other hand, at the 5 days after application, tomatoes treated with 30% and 15% aloe vera gel have the same results of having the lowest color change. However, in the 7 to 21 days after application, there were no significant changes among all treatments.

Table 2. Mean of the repining color of tomato applied with the different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION											
	Initial	D1	D3	D5	D7	D9	D11	D13	D15	D17	D19	D21
T1 - Control	1.11^{ns}	1.22^{ns}	2.00^{b}	2.56^{b}	3.44^{ns}	3.78^{ns}	4.33^{ns}	4.33^{ns}	4.56^{ns}	4.78^{ns}	5.00^{ns}	5.00^{ns}
T2 - 05% AG	1.11^{ns}	1.11^{ns}	1.33^{ab}	2.11^{ab}	2.56^{ns}	2.56^{ns}	2.67^{ns}	3.11^{ns}	3.44^{ns}	4.22^{ns}	4.78^{ns}	5.00^{ns}
T3 - 10% AG	1.22^{ns}	1.22^{ns}	1.33^{ab}	1.78^{ab}	2.00^{ns}	2.22^{ns}	3.00^{ns}	3.00^{ns}	3.67^{ns}	4.11^{ns}	4.78^{ns}	4.89^{ns}
T4 - 15% AG	1.11^{ns}	1.11^{ns}	1.22^{ab}	1.22^{a}	2.11^{ns}	2.89^{ns}	2.89^{ns}	3.00^{ns}	3.67^{ns}	4.22^{ns}	4.78^{ns}	5.00^{ns}
T5 - 20% AG	1.00^{ns}	1.00^{ns}	1.22^{ab}	1.89^{ab}	2.44^{ns}	3.00^{ns}	3.33^{ns}	3.56^{ns}	3.89^{ns}	4.33^{ns}	4.78^{ns}	5.00^{ns}
T6 - 25% AG	1.00^{ns}	1.00^{ns}	1.11^{a}	1.56^{ab}	2.44^{ns}	3.22^{ns}	3.22^{ns}	3.22^{ns}	3.44^{ns}	3.89^{ns}	4.33^{ns}	4.67^{ns}
T7 - 30% AG	1.00^{ns}	1.00^{ns}	1.00^{a}	1.22^{a}	1.78^{ns}	3.00^{ns}	3.78^{ns}	3.78^{ns}	4.00^{ns}	4.11^{ns}	4.22^{ns}	4.33^{ns}
CV (%)	13.35	17.6	23.43	21.80	24.12	22.84	22.79	20.58	20.19	14.57	11.67	10.19
Pr (> F)	0.46	0.58	0.029	0.007	0.06	0.22	0.19	0.26	0.61	0.73	0.59	0.58

Means with the same letter are not significantly different at 5% level; ^{ns} – not significance; and values are the means of the three replications.

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Treated bell pepper fruits on the other hand, showed significant difference among treatment means, comparable to the untreated (T1) within 11 days of application (Table 2.b.). However, beyond 12 days of aloe gel application, treatments showed no significance which implies that beyond this duration of storage after application, changes of color from green to red due to ripening continues. Moreover, among treated fruits, T7 - 30% AG showed the highest color change reduction, and only reached the limit of marketability after 11 days of application.

Thus, different concentration of aloe gel resulted to varied sample reaction. This can be explained by the increase of respiration rates and ethylene emission of fruits which can cause fasten ripening of the nearby fruits. This was in agreement with Chrysargyris, et al, (2016) which states that addition of aloe gel did not affect the respiration rates, being in accordance with previous studies when various aloe gel concentrations were tested.

The results of the study agree with the findings of Nasrin et al. (2018), where bell pepper coated with aloe vera gel preserves the color of the fruit. The same findings for apples (Ergun and Satici, 2012), grapes (Serrano et al., 2006) and papaya (Brishti et al., 2013). The delay of color changes can be due to the decrease of ethylene production that delays the ripening, chlorophyll degradation, anthocyanin accumulation and carotenoid synthesis because of the modified atmosphere created by the aloe vera gel (Carrillo-Lopez et al., 2000).

Table 2.b. Mean of the repining color of bell pepper applied with the different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION											
	Initial^{ns}	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
T1 - Control	1.00	1.78^{b}	2.44^{b}	3.22^{c}	3.22^{c}	3.33^{c}	3.44^{b}	3.78^{b}	4.33^{b}	4.56^{b}	5.00^{b}	5.00^{b}	5.00^{ns}
T2 - 05% AG	1.00	1.00^{a}	1.11^{a}	1.89^{b}	1.89^{b}	1.89^{b}	1.89^{a}	2.44^{a}	2.78^{a}	3.33^{a}	4.00^{a}	4.67^{ab}	5.00^{ns}
T3 - 10% AG	1.00	1.00^{a}	1.11^{a}	1.56^{ab}	1.56^{ab}	1.56^{ab}	2.00^{a}	2.22^{a}	2.89^{a}	3.11^{a}	3.67^{a}	4.56^{ab}	5.00^{ns}
T4 - 15% AG	1.00	1.00^{a}	1.00^{a}	1.67^{ab}	1.67^{ab}	1.67^{ab}	2.00^{a}	2.56^{a}	2.78^{a}	3.22^{a}	3.78^{a}	4.56^{ab}	5.00^{ns}
T5 - 20% AG	1.00	1.00^{a}	1.00^{a}	1.33^{a}	1.33^{a}	1.33^{a}	1.56^{a}	2.33^{a}	2.33^{a}	3.11^{a}	3.56^{a}	4.22^{a}	5.00^{ns}
T6 - 25% AG	1.00	1.00^{a}	1.00^{a}	1.33^{a}	1.33^{a}	1.33^{a}	1.78^{a}	2.33^{a}	2.67^{a}	2.89^{a}	3.56^{a}	4.11^{a}	5.00^{ns}
T7 - 30% AG	1.00	1.00^{a}	1.00^{a}	1.33^{a}	1.33^{a}	1.33^{a}	1.67^{a}	2.00^{a}	2.44^{a}	2.89^{a}	3.44^{a}	4.00^{a}	5.00^{ns}
CV (%)		6.48	10.18	10.12	10.12	9.18	16.66	11.60	11.01	9.36	7.55	5.91	
Pr (> F)		0.000	0.000	0.000	0.000	0.000	0.0002	0.0001	0.000	0.0002	0.0002	0.0045	

Means with the same letter are not significantly different at 5% level; ^{ns} – not significance; and values are the means of the three replications.

Ethylene is responsible for the ripening of fruits and vegetables. Chrysargyris et al. (2016) indicates that aloe vera gel decreases the ethylene production as it limits the gas permeability in fruit surface. In addition, during ripening, the chlorophyll present in the fruit decreases that causes to the synthesis of carotenoids that is responsible for pigment changing (Guo et al., 2020). In the present study, the delay of color change might be due to the reduction of carotenoids that is related to the reduced ethylene emissions (Chrysargyris et al., 2016) which causes the delay of ripening.

Effects of Aloe Gel to the Visual Quality

Among the crops used in this study, only the eggplant and bell pepper showed significant difference among treatment means within its particular duration (Table 3.a.). Eggplant treated with 30% aloe gel obtained the highest visual quality with only 1.89 (excellent to good) after 7 days of aloe gel application (Figure 1).

Table 3.a. Mean percentage of the visual quality rating (VQR) of eggplant applied with the different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION							
	Initial	D1	D2	D3	D4	D5	D6	D7
T1 - Control	1.00	1.00	1.89^{c}	2.78^{d}	3.67^{c}	4.78^{c}	5.00^{c}	5.00^{c}
T2 - 5% AG	1.00	1.00	1.44^{b}	2.00^{c}	2.44^{b}	3.11^{b}	4.22^{bc}	4.44^{bc}
T3 - 10% AG	1.00	1.00	1.44^{b}	2.00^{c}	2.22^{b}	2.89^{b}	3.67^{bc}	3.89^{bc}
T4 - 15% AG	1.00	1.00	1.11^{ab}	1.56^{bc}	2.22^{b}	2.89^{b}	3.78^{bc}	3.89^{bc}
T5 - 20% AG	1.00	1.00	1.00^{a}	1.67^{bc}	2.44^{b}	2.78^{b}	3.44^{b}	3.78^{bc}
T6 - 25% AG	1.00	1.00	1.00^{a}	1.44^{ab}	1.89^{ab}	2.33^{b}	2.89^{ab}	3.00^{ab}
T7 - 30% AG	1.00	1.00	1.00^{a}	1.00^{a}	1.22^{a}	1.44^{a}	1.67^{a}	1.89^{a}
CV (%)			11.52	10.02	13.46	10.66	14.00	16.57
Pr (> F)			0.0000	0.0000	0.0000	0.0000	0.0000	0.0007

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Means with the same letter are not significantly different at 5% level; ^{ns} – not significance; and values are the means of the three replications.

Treated samples were also comparable to untreated ones which implied that the application of aloe gel had a potential in improving the visual quality of eggplant due to the formation of an impermeable layer that limits the exchange of moisture and gases such as oxygen and carbon dioxide between the fruit and the environment (Nicolau-Lapena et al., 2021). This phenomenon resulted in a decrease in moisture loss and respiration, consequently, minimizing loss of fruit quality in terms of weight, firmness and color.

Figure 1. visual appearance of eggplant as affected by the differrent aloe gel cocentration after7 days of application (a) control(untreated,(b) 5% aloe gel,(c)10% aloe gel, (d)15% aloe gel ,(e) 20% aloe gel , (f) 25%% aloe gel, (g)30% aloe gel.

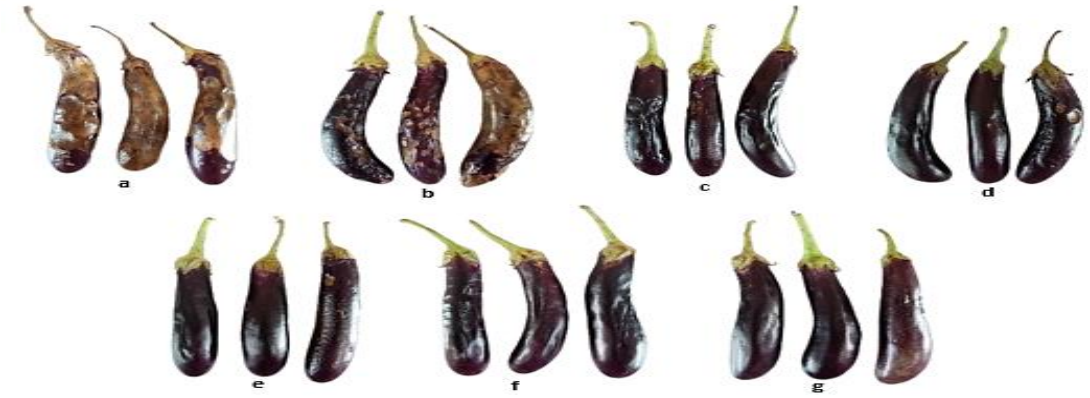
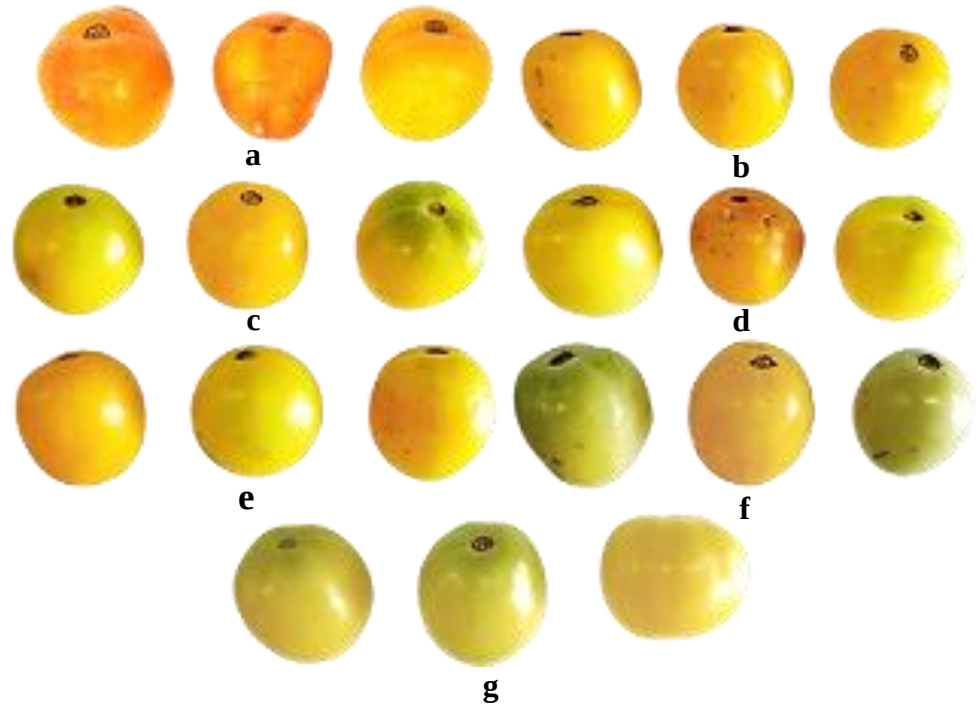


Figure 2. Visual appearance of tomato fruits as affected by the different aloe gel concentration after 7 days of application (a) control (untreated), (b)5% Aloe gel (c) 10% Aloe gel, (d) 15% aloe gel, (e) 20% aloe gel, (f) 25% aloe gel, (g)30% aloe gel.



This study has the same results of Gonzales and Benitez (2019), where the application of aloe vera gel maintained the VQR that results in longer shelf life. The effect could be caused by the aloe vera gel generating a modified atmosphere that enables to preserve the visual quality of the eggplants by delaying the ripening and physicochemical quality of the fruit (Gol and Rao, 2011). Also, Kittur et al. (2001) states that polysaccharide-based coatings slow the metabolism which in turn extends the shelf of a fruit.

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Aloe gel-treated tomato on the other hand however showed significant difference among treatment means within 11-13 days (Figure 2), but beyond 15 days, all the treatments showed no significant difference (Table 3.b). This phenomenon can be best explained by the immediate effect of aloe gel application which resulted to decreased fruit ethylene emission for only 13 days while after 15 days of application, increased ethylene emission and respiration rates could be inevitable as the coating compound of aloe gel must be degraded due to the environment (Tzortzakis, et al, 2019).

Table 3.b. Mean percentage of the visual quality rating (VQR) of tomato applied with the different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION											
	Initial	D1	D3	D5	D7	D9	D11	D13	D15	D17	D19	D21
T1 - Control	1.00	1.00	1.00	1.00	1.11	1.22	1.67^{b}	2.00^{b}	2.33^{ns}	3.00^{ns}	3.33^{ns}	3.78^{ns}
T2 - 05% AG	1.00	1.00	1.00	1.00	1.00	1.11	1.33^{ab}	2.00^{b}	2.22^{ns}	2.89^{ns}	3.33^{ns}	3.56^{ns}
T3 - 10% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.22^{ab}	2.00^{b}	2.11^{ns}	2.44^{ns}	3.00^{ns}	3.22^{ns}
T4 - 15% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.22^{ab}	2.00^{b}	2.11^{ns}	2.56^{ns}	3.00^{ns}	3.11^{ns}
T5 - 20% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.33^{ab}	2.00^{b}	2.00^{ns}	2.67^{ns}	3.11^{ns}	3.33^{ns}
T6 - 25% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00^{a}	1.89^{b}	1.89^{ns}	2.33^{ns}	2.67^{ns}	3.00^{ns}
T7 - 30% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00^{a}	1.56^{a}	1.78^{ns}	2.11^{ns}	2.56^{ns}	2.78^{ns}
CV (%)					7.09	9.73	12.97	5.38	9.93	13.28	10.83	10.74
Pr (> F)					0.4628	0.1095	0.0028	0.0008	0.0679	0.0752	0.0692	0.0538

Means with the same letter are not significantly different at 5% level; ^{ns} – not significance; and values are the means of the three replications.

In addition, visual quality of aloe gel-treated bell peppers had also improved (Table 3.c). Fruits treated with 25%-30% aloe gel resulted with a significant difference among treatment means. Moreover, all the concentration (5%-30%) used in this study had improved the visual quality of bell peppers within 12 days of observation. Thus, implying that post-harvest losses of bell peppers could be reduced by the application of aloe gel.

Table 3.c. Mean of the visual quality rating (VQR) of bell pepper applied with the different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION												
	Initial	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
T1 - Control	1.00	1.11	1.67^{b}	2.22^{c}	2.56^{d}	2.67^{b}	3.00^{c}	3.44^{c}	3.78^{c}	4.22^{c}	5.00^{b}	5.00^{b}	5.00^{c}
T2 - 05% AG	1.00	1.00	1.11^{a}	1.89^{bc}	2.00^{cd}	2.33^{b}	2.56^{bc}	2.89^{bc}	3.00^{bc}	3.33^{bc}	4.44^{b}	5.00^{b}	5.00^{c}
T3 - 10% AG	1.00	1.00	1.00^{a}	1.44^{ab}	1.89^{bc}	2.00^{ab}	2.11^{b}	2.44^{ab}	2.56^{ab}	2.67^{ab}	3.11^{a}	4.11^{a}	4.89^{bc}
T4 - 15% AG	1.00	1.00	1.00^{a}	1.00^{a}	1.44^{abc}	1.67^{ab}	2.11^{b}	2.44^{ab}	2.44^{ab}	2.56^{ab}	3.44^{a}	4.00^{a}	4.67^{b}
T5 - 20% AG	1.00	1.00	1.00^{a}	1.00^{a}	1.33^{ab}	1.67^{ab}	2.11^{b}	2.22^{ab}	2.22^{ab}	2.56^{ab}	3.44^{a}	4.11^{a}	4.78^{bc}
T6 - 25% AG	1.00	1.00	1.00^{a}	1.00^{a}	1.00^{a}	1.22^{a}	1.44^{a}	1.89^{a}	2.00^{ab}	2.44^{ab}	3.22^{a}	3.89^{a}	4.33^{a}
T7 - 30% AG	1.00	1.00	1.00^{a}	1.00^{a}	1.11^{a}	1.11^{a}	1.22^{a}	1.56^{a}	1.56^{a}	2.22^{a}	3.00^{a}	3.78^{a}	4.33^{a}
CV (%)		7.09	13.11	13.12	14.22	21.64	10.46	14.15	15.59	13.02	7.42	4.46	2.16
Pr (> F)		0.4628	0.0004	0.000	0.000	0.0023	0.000	0.0002	0.0002	0.0002	0.000	0.000	0.000

Means with the same letter are not significantly different at 5% level; ^{ns} – not significance; and values are the means of the three replications.

According to Nicolau-Lapeña, et al., (2021), the bioactive compounds of aloe gel are aloin, aloe emodin, anthraquinones and acemannan. Similar to this, Shabir, et al., (2021) resulted that Guava coated with 2% $CaCl_2$ and 10% Aloe vera gel promisingly retained physico-chemical characteristics and also maintained the sensory attributes than all the other treatments performed and was found to be most effective treatment in maintaining the fruit quality attributes along with the shelf-life extension for 35 days.

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Figure 3. Visual appearance of bell pepper fruits as affected by the different aloe gel concentration after 7 days of application, (a) control (untreated), (b) 5% aloe gel, (c)10% aloe gel, (d) 15% aloe gel, (e) 20% aloe gel, (f) 25% aloe gel, (g) 30% aloe gel

Effects of Aloe Gel to the Firmness

Eggplant treated with 20%-30% of aloe gel showed significant difference among treatments. Treated samples were also comparable to untreated ones within 7 days of observation which implied that application of aloe gel could retain the firmness of eggplant thus leading to improved physical quality (Table 4.a). Similar results obtained from Dang et al. (2008) reported that mangoes-maintained firmness when 100% of aloe gel was used at shelf-life storage of the fruit.

Fruit firmness of eggplant was significantly affected by the application of aloe vera gel. Eggplants treated with 25% and 30% aloe vera gel has gradual changes in fruit firmness. Hasan et al. (2021) also has a positive effect in terms of fruit firmness using aloe vera gel. The firmness also relates to the weight loss of fruits (Marpudi et al., 2011) as reported in sweet cherry (Yaman and Bayoindirli, 2002) and nectarine fruits (Ahmed et al., 2009).

Table 4.a. Mean percentage of firmness of eggplant with the application of different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION							
	Initial	D1	D2	D3	D4	D5	D6	D7
T1 - Control	1.00	1.00	1.78^{b}	2.44^{b}	3.00^{b}	3.00^{b}	3.44^{b}	4.22^{b}
T2 - 05% AG	1.00	1.00	1.22^{a}	1.67^{a}	1.78^{b}	2.11^{ab}	2.78^{ab}	3.44^{ab}
T3 - 10% AG	1.00	1.00	1.00^{a}	1.56^{a}	1.89^{ab}	1.89^{ab}	2.78^{ab}	3.22^{ab}
T4 - 15% AG	1.00	1.00	1.00^{a}	1.67^{a}	1.78^{b}	1.89^{ab}	2.56^{ab}	3.11^{ab}
T5 - 20% AG	1.00	1.00	1.00^{a}	1.56^{a}	1.89^{ab}	1.89^{ab}	2.33^{a}	2.78^{a}
T6 - 25% AG	1.00	1.00	1.00^{a}	1.56^{a}	1.67^{a}	1.67^{a}	2.11^{a}	2.78^{a}
T7 - 30% AG	1.00	1.00	1.00^{a}	1.11^{a}	1.78^{a}	1.78^{a}	1.78^{a}	2.33^{a}
CV (%)			8.91	14.68	20.86	20.21	14.84	14.55
Pr (> F)			0.000	0.0007	0.0190	0.0236	0.0025	0.0050

Means with the same letter are not significantly different at 5% level; ^{ns} – not significance; and values are the means of the three replications.

Treated tomato fruits on the other hand, had different result from eggplant as shown in the Table 4.b, where treated aloe gel fruits only showed significant difference within 13-15 days, while beyond 17 days, there was no significant difference which means that firmness of tomato lessens during storage for both treated and untreated.

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Fruit firmness significantly decreased in control fruits during the entire storage period). The application of aloe gel led to lower softening in tomato following 15 days of storage compared to the control, but this effect did not persist after 17 days of storage. Similar to this findings, Martínez-Romero et al, (2013) reported that higher aloe gel concentration substantially decreased the firmness losses (≥50%) during storage of cherries.

Table 4.b. Mean percentage of firmness of tomato with the application of the different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION											
	Initial^{ns}	D1^{ns}	D3^{ns}	D5^{ns}	D7^{ns}	D9^{ns}	D11^{ns}	D13	D15	D17^{ns}	D19^{ns}	D21^{ns}
T1 - Control	1.00	1.00	1.00	1.00	1.00	1.00	1.11	1.78^{c}	2.00^{a}	2.44	3.00	3.00
T2 - 05% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.44^{b}	2.00^{a}	2.11	2.67	3.00
T3 - 10% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00^{a}	1.89^{a}	2.00	2.56	2.89
T4 - 15% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00^{a}	1.78^{a}	1.78	2.44	2.56
T5 - 20% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00^{a}	1.89^{a}	2.33	2.89	3.11
T6 - 25% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00^{a}	2.00^{a}	2.00	2.67	3.00
T7 - 30% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00^{a}	1.67^{a}	2.00	2.33	2.67
CV (%)	-	-	-	-	-	-	7.09	8.80	6.60	8.50	12.62	12.32
Pr (> F)	-	-	-	-	-	-	0.4628	0.000	0.0376	0.0073	0.2566	0.4759

Means with the same letter are not significantly different at 5% level; ^{ns} – not significance; and values are the means of the three replications.

Table 4.c. Mean of firmness of bell pepper with the application of different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION												
	Initial	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
T1 - Control	1.00	1.00	1.11	1.44	2.11^{b}	2.44^{a}	3.00	3.22^{a}	3.44^{b}	4.00^{c}	4.00^{b}	4.89^{d}	5.00^{b}
T2 - 05% AG	1.00	1.00	1.00	1.33	2.00^{b}	2.33^{a}	2.67	2.89^{a}	3.22^{b}	3.56^{bc}	3.78^{ab}	4.44^{cd}	5.00^{b}
T3 - 10% AG	1.00	1.00	1.00	1.11	1.89^{ab}	2.11^{a}	2.78	2.89^{a}	3.00^{ab}	3.11^{ab}	3.56^{ab}	4.22^{bc}	5.00^{b}
T4 - 15% AG	1.00	1.00	1.00	1.22	1.78^{ab}	1.89^{a}	2.56	2.67^{a}	3.00^{ab}	3.22^{ab}	3.56^{ab}	4.22^{bc}	5.00^{b}
T5 - 20% AG	1.00	1.00	1.00	1.11	1.89^{ab}	2.22^{a}	2.56	2.56^{a}	2.89^{ab}	3.11^{ab}	3.56^{ab}	4.00^{abc}	4.89^{b}
T6 - 25% AG	1.00	1.00	1.00	1.11	1.22^{a}	1.89^{a}	2.44	2.44^{a}	2.56^{a}	2.78^{a}	3.33^{a}	3.67^{a}	4.33^{a}
T7 - 30% AG	1.00	1.00	1.00	1.00	1.56^{a}	2.00^{a}	2.11	2.44^{a}	2.56^{a}	2.89^{a}	3.22^{a}	3.78^{a}	4.22^{a}
CV (%)			7.09	13.63	14.12	9.69	12.62	10.35	6.98	7.77	5.80	3.88	3.40
Pr (> F)			0.4628	0.0612	0.0113	0.0311	0.1086	0.0396	0.0010	0.0006	0.0077	0.000	0.000

Means with the same letter are not significantly different at 5% level; ^{ns} – not significance; and values are the means of the three replications.

In addition, bell peppers treated with 25%-30% aloe gel showed significant difference among treatments means with 12 days of observation and was comparable to untreated ones (Table 4.c.), which implies that the application of aloe gel with this concentration level is effective to retain the commodity's firmness. Furthermore, partially similar to this result was by Dang et al. (20080 reported that mangoes-maintained firmness when 100% of aloe gel was used at shelf-life storage of the fruit. Therefore, its effects might be related to the higher aloe gel ratio and different species used.

Effects of Aloe Gel to the Shrinkage

Eggplant treated with 30% of aloe gel showed significant difference among treatments (Table 5.a). Treated samples were also comparable to untreated ones within 7 days of observation which implied that application of aloe gel could reduce the shrinkage of eggplant thus leading to improved physical quality and higher marketability.

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Table 5.a. Mean percentage of shrinkage index of eggplant with the application of different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION							
	Initial^{ns}	D1^{ns}	D2^{ns}	D3	D4	D5	D6	D7
T1 - Control	1.00	1.00	1.33	2.00^{b}	2.22^{c}	3.00^{c}	3.56^{b}	4.33^{c}
T2 - 05% AG	1.00	1.00	1.33	1.56^{ab}	2.11^{bc}	2.56^{bc}	3.00^{ab}	3.89^{bc}
T3 - 10% AG	1.00	1.00	1.00	1.44^{ab}	2.11^{bc}	2.33^{b}	2.44^{ab}	3.33^{b}
T4 - 15% AG	1.00	1.00	1.00	1.33^{ab}	1.89^{bc}	2.11^{ab}	2.44^{ab}	3.22^{b}
T5 - 20% AG	1.00	1.00	1.00	1.33^{ab}	2.11^{bc}	2.11^{ab}	2.67^{ab}	3.33^{b}
T6 - 25% AG	1.00	1.00	1.00	1.11^{a}	1.56^{ab}	2.00^{ab}	2.22^{a}	3.11^{ab}
T7 - 30% AG	1.00	1.00	1.00	1.00^{a}	1.00^{a}	1.67^{a}	2.00^{a}	2.33^{a}
CV (%)	-	-	-	20.23	11.75	9.67	16.19	8.39
Pr (> F)	-	-	-	0.0152	0.0001	0.0001	0.0092	0.0000

Means with the same letter are not significantly different at 5% level; ^{ns} – not significance; and values are the means of the three replications.

Treated tomato fruits however showed significant difference only after 17 days of application where the application of 30% aloe gel obtained shrinkage index of 1.78 presented in Table 5.b, and beyond 19 days, it can also be observed that there was no significant difference which means that shrinkage of tomato continues during storage even if treated with different concentration of aloe gel.

Table 5.b. Mean percentage of shrinkage index of tomato with the application of different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION											
	Initial^{ns}	D1^{ns}	D3^{ns}	D5^{ns}	D7^{ns}	D9^{ns}	D11^{ns}	D13^{ns}	D15^{ns}	D17	D19^{ns}	D21^{ns}
T1 - Control	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.67	1.89^{ns}	2.44^{b}	3.00^{ns}	3.11^{ns}
T2 - 05% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.33	2.00^{ns}	2.00^{ab}	2.56^{ns}	2.89^{ns}
T3 - 10% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.78^{ns}	1.89^{ab}	2.44^{ns}	2.78^{ns}
T4 - 15% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.67^{ns}	1.78^{a}	2.33^{ns}	2.44^{ns}
T5 - 20% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.78^{ns}	2.22^{ab}	2.78^{ns}	2.89^{ns}
T6 - 25% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.89^{ns}	1.89^{ab}	2.56^{ns}	2.78^{ns}
T7 - 30% AG	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.44^{ns}	1.78^{a}	2.11^{ns}	2.44^{ns}
CV (%)	-	-	-	-	-	-	-	-	13.62	10.87	14.64	17.29
Pr (> F)	-	-	-	-	-	-	-	-	0.1962	0.0168	0.1669	0.5975

Means with the same letter are not significantly different at 5% level; ^{ns} – not significance; and values are the means of the three replications.

On the other hand, bell peppers treated with 20%-30% aloe gel showed significant difference among treatments means within 12 days of observation, and was comparable to the untreated ones and lower aloe concentration (5%-15%) as presented in Table 4.c. This event implied that the application of aloe gel with this concentration level is effective to reduce the inevitable shriveling activity of bell pepper fruits due to various factors such as temperature, and maturity index of the crop.

Table 5.c. Mean percentage of shrinkage index of bell pepper with the application of different concentration of aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION											
	Initial	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
T1 - Control	1.00	1.00	1.00	1.33^{ns}	2.11^{b}	2.44^{c}	2.89^{d}	3.11^{c}	3.67^{b}	4.11^{b}	4.78^{c}	5.00^{b}	5.00^{c}
T2 - 05% AG	1.00	1.00	1.00	1.22^{ns}	1.44^{a}	2.00^{bc}	2.22^{abc}	2.56^{abc}	2.89^{ab}	3.00^{a}	3.89^{b}	4.22^{a}	5.00^{c}
T3 - 10% AG	1.00	1.00	1.00	1.11^{ns}	1.56^{a}	2.11^{bc}	2.56^{cd}	2.56^{abc}	2.67^{a}	3.00^{a}	3.56^{ab}	4.00^{a}	4.89^{c}
T4 - 15% AG	1.00	1.00	1.00	1.11^{ns}	1.44^{a}	1.89^{abc}	2.44^{bcd}	2.67^{bc}	2.67^{a}	3.00^{a}	3.67^{ab}	4.00^{a}	4.89^{c}
T5 - 20% AG	1.00	1.00	1.00	1.11^{ns}	1.33^{a}	1.78^{abc}	2.00^{abc}	2.33^{ab}	2.44^{a}	2.89^{a}	3.33^{ab}	3.78^{a}	4.67^{bc}
T6 - 25% AG	1.00	1.00	1.00	1.00^{ns}	1.00^{a}	1.33^{ab}	1.78^{a}	1.89^{a}	2.22^{a}	2.78^{a}	3.22^{ab}	3.89^{a}	4.33^{ab}
T7 - 30% AG	1.00	1.00	1.00	1.00^{ns}	1.00^{a}	1.22^{a}	1.89^{a}	2.00^{a}	2.11^{a}	2.44^{a}	3.00^{a}	3.56^{a}	4.11^{a}
CV (%)				12.79	16.35	16.42	9.71	10.75	11.93	9.56	7.21	6.43	3.78
Pr (> F)				0.1338	0.0007	0.0024	0.0002	0.0010	0.0007	0.0003	0.0000	0.0003	0.0001

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Means with the same letter are not significantly different at 5% level; ns – not significance; and values are the means of the three replications.

Also, according to the study of Nicolau-Lapeña, et al., (2021), aloe gel decreases respiration and ripening processes, delays firmness loss, weight loss, and preserves phenolic content and delays browning of coated fruits and vegetables. Serrano, et al., (2006) also had a similar result in which table grapes coated with aloe gel significantly delayed the ripening changes, as well as it retains citric acid, therefore concluded that aloe vera gel coating as a simple and non-contaminating treatment, maintained the functional properties of table grapes during postharvest storage.

Effects of Aloe Gel to the Incidence and Severity Percentage

During post-harvest storage of solanaceous crops particularly the eggplant, pest and diseases could arise anytime. Fortunately, disease incidence of eggplant within 7 days of storage were lessen with the application of aloe gel as observed on Table 6.a. Among the treatments, 20%-30% aloe gel had lesser disease incidence percentage, being comparable to untreated samples. Within the duration the higher concentration showed a trend of significant difference.

Table 6.a. Mean percentage of disease incidence of eggplant with the application of different concentration of Aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION							
	Initial	D1	D2	D3	D4	D5	D6	D7
T1 - Control	0.00	0.00	11.11	55.56	77.78^{c}	77.78^{b}	100.00^{a}	100.00^{b}
T2 - 05% AG	0.00	0.00	0.00	33.33	66.67^{bc}	66.67^{b}	100.00^{b}	100.00^{b}
T3 - 10% AG	0.00	0.00	0.00	22.22	33.33^{abc}	33.33^{b}	66.67^{ab}	77.78^{ab}
T4 - 15% AG	0.00	0.00	0.00	0.00	22.22^{abc}	44.44^{ab}	44.44^{ab}	44.44^{ab}
T5 - 20% AG	0.00	0.00	0.00	0.00	11.11^{ab}	22.22^{ab}	22.22^{a}	22.22^{a}
T6 - 25% AG	0.00	0.00	0.00	0.00	11.11^{ab}	11.11^{a}	11.11^{a}	11.11^{a}
T7 - 30% AG	0.00	0.00	0.00	0.00	0.00^{a}	11.11^{a}	11.11^{a}	11.11^{a}
CV (%)	-	-	458.26	171.47	72.46	63.33	45.29	46.06
Pr (> F)	-	-	0.4628	0.1378	0.0062	0.0232	0.0005	0.0006

Means with the same letter are not significantly different at 5% level; ns – not significance; and values are the means of the three replications.

Severity of the diseases was also assessed to determine how severe was, the post-harvest pathogen's infection. And, the study resulted that 20%-30% aloe gel concentration could lessen the infection thus preventing losses due to diseases. The result of this study showed that higher aloe concentration had significant difference and was comparable to untreated one. Aloe gel (AG) according to Martínez-Romero et al., (2006) has shown antimicrobial effects It is believed that coating fruit with preservative compounds generates a modified atmosphere by creating a semipermeable barrier against oxygen, carbon dioxide, moisture, and solute movement, thereby, retarding ripening and senescence, as well as extending the shelf life of fruits and vegetables.

Table 6.b. Mean percentage of disease severity of eggplant with the application of different concentration of Aloe (A. barbadensis) gel (AG)

TREATMENT	DAYS OF APPLICATION							
	Initial	D1	D2	D3	D4	D5	D6	D7
T1 - Control	0.00	0.00	2.22	13.33	31.11^{b}	46.67^{b}	66.67^{c}	84.44^{c}
T2 - 05% AG	0.00	0.00	0.00	6.67	20.00^{ab}	33.33^{ab}	51.11^{bc}	62.22^{bc}
T3 - 10% AG	0.00	0.00	0.00	4.44	11.11^{ab}	20.00^{ab}	35.56^{abc}	44.44^{abc}
T4 - 15% AG	0.00	0.00	0.00	0.00	4.44^{a}	15.56^{ab}	24.44^{ab}	28.89^{ab}
T5 - 20% AG	0.00	0.00	0.00	0.00	2.22^{a}	8.89^{a}	11.11^{a}	15.56^{a}
T6 - 25% AG	0.00	0.00	0.00	0.00	2.22^{a}	4.44^{a}	6.67^{a}	8.89^{a}
T7 - 30% AG	0.00	0.00	0.00	0.00	0.00^{a}	2.22^{a}	4.44^{a}	6.67^{a}
CV (%)	-	-	458.26	181.55	91.69	62.14	45.54	44.98
Pr (> F)	-	-	0.4628	0.1425	0.0088	0.0032	0.0002	0.0002

Means with the same letter are not significantly different at 5% level; ns – not significance; and values are the means of the three replications.

Disease incidence and severity was mainly attributed to the anthracnose rot (triggered by Colletotrichum spp) and secondary black spot symptoms (triggered by Alternaria spp.). The observation of fungal symptoms was the indicative of fruit decay but additional research is required for any other physiological or bacterial symptoms presence. Several studies indicated the antimicrobial capacity of naturally produced chemicals in vitro and/or in fresh commodities (Tzortzakis, et al. 2009; Navarro et al, 2011; Castillo et al 2010).

CONCLUSION

This study demonstrated that application of aloe gel aids for the extension of postharvest life of eggplants, tomato, and bell pepper by delaying ripening process, having greater firmness, fruit color, less shriveling, as reflected in lower weight loss and lesser changes in physical parameters. It showed that eggplant coated with 20% to 30% aloe gel significant delay the post-harvest deterioration of the solanaceous crops during storage, compared with untreated control fruits. Coating of eggplant, tomato, and bell pepper fruits at room temperature with aloe gel minimized weight and firmness loss, as well as delayed color changes during storage. In addition, the ripening index of bell pepper and tomato fruits was delayed within 12 days of storage. Moreover, the present study proved the efficiency of aloe gel as an eco-friendly material in improving the post-harvest life of solanaceous crops. This effect can also be related to the higher aloe gel ratio and different species used.

RECOMMENDATION

Further studies should be conducted on the coating properties which might be related to the improvement of hydrophobic properties of the aloe gel and the gaseous exchange towards fruits. New formulation and application developments to different fruit and vegetables may be explored. Further investigation is also needed to elucidate the underlying relationship between aloe gel and the crops.

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Ethical Considerations

Authors of this paper were permitted to conduct the study as one of the institutional research outputs noting that all experimental procedures were performed in accordance with the institutional and scientific guidelines.

Conflict of Interest

The authors declare that there are no conflicts of interest, financial or otherwise that could have influenced the design, execution, interpretation, or reporting of this research.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request, as the dataset is not publicly archived.

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