Pak. J. Agri. Sci., Vol. 52(2), 403-411; 2015
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
http://www.pakjas.com.pk

ENHANCING STORAGE LIFE OF BELL PEPPER BY UV-C IRRADIATION AND EDIBLE COATINGS

Nadeem Akhtar Abbasi*, Sonia Ashraf, Irfan Ali and Shahid Javed Butt

[1]Department of Horticulture PMAS-Arid Agriculture University, Rawalpindi, Pakistan
***Corresponding author's email address: nadeemabbasi65@yahoo.com**

Bell pepper is an important vegetable commodity; getting the intention of industry for fresh exports. However, short postharvest life is one of the major limitations. Comprehensive investigations were made for the possibility of extending storage life of bell pepper through UV-C (Shortwave ultraviolet radiations) and different edible coatings. The UV-C and different edible coatings had significant effects on the shelf life of bell pepper (*Capsicum annuum*) cv. "Royal Wonder" stored at low temperature. UV-C irradiation (3 and 5 min at 254 nm) as well as edible coatings including; *Aloe* gel (1.5 and 2.5%), cinnamon oil (0.30 and 0.40%) and chitosan (1 and 1.5%) were applied on the fruit of bell pepper cv. "Royal Wonder". The treated fruit was kept in cold storage for 24 days at 8±1°C with 80-85% RH. The fruit samples were analyzed for physical and chemical attributes with an interval of three days. The results indicated that, all the treatments maintained fruit quality and storage life, but UV-C application for 5 min and 1.5% Aloe gel delayed the changes in firmness, titratable acidity (TA), levels of ascorbic acid, soluble solids content (SSC) and fruit color development during storage. Moreover, weight loss, electrolyte leakage and disease incidence was also lowered by these treatments. Postharvest fruit performance indicated that UV-C application for 5 min and 1.5% Aloe gel significantly maintained the quality of pepper as compared to control up to 24 days.

Keywords: *Capsicum annuum*, storability, irradiation, *Aloe* gel, shelf life, quality

INTRODUCTION

Bell pepper (*Capsicum annum* L.) is famous for its vibrant colours, green when unripe while red, yellow, orange, brown, purple, white and salmon at ripe stage. The fruit is low in calories but rich in vitamins, especially A and C (Howard *et al*., 1994). The fruit being hollow inside with a limited ability to water storage, restricts the shelf life shorter than a week (Maalekuu *et al*., 2003), thus postharvest quality during long term storage is seriously affected by physico-pathological factors. Shriveling, associated with quick water loss and decay are two major factors limiting the storage life of bell pepper (Maalekuu *et al*., 2003).

The increased and consistent demand for consumable commodities which are free of pesticide has diverted attention towards the non-chemical methods to improve or maintain the quality of the commodities, like heat treatment and UV-C irradiation. Pre-storage exposure to shortwave ultraviolet radiation (UV-C) has shown evident control for fungal decay in several stored commodities like carrots, citrus and kumquat (Baka *et al*., 1999). It controls the storage diseases by inducing of disease resistance in the produce as well as killing or inactivation of pathogens by irradiation. In stored carrots, citrus and tomatoes, the application of UV-C has been reported to induce resistance to pathogens which is related with the accumulation of phytoalexins (Mercier *et al.,* 2000). The use of edible coating technology is another safe method to increase the shelf-life of produce by altering internal atmosphere. Edible coatings not only check deterioration but also maintain the safety of food. Because of natural biocidal activity and due to incorporation of antimicrobial compounds, the edible coatings are used extensively (Cha and Chinnan, 2004). Edible coatings are mostly derived from biological sources like *Aloe vera* and sea animal shells. A number of chemical compounds have been stated in *Aloe vera* gel composition (Ni *et al*., 2004) and aloe-emodin is one of the key components which take part in antioxidant activity. *Aloe vera* gel coating was reported to increase the shelf life of table grapes and sweet cherry by delaying deterioration. Chitosan, another important edible coating, is extracted from the shells of crab and prawn and has been used to manage many of the pre and postharvest diseases on a range of horticultural produce. Chitosan acts as a high molecular polymer with a bioactive and a non-toxic agent and has become a useful compound because of its fungicidal effect (Terry and Joyce, 2004). Due to the ability to create a semi-permeable coating, it reduces the weight loss, wilting, respiration rate and loss of colour and fungal infection in bell pepper fruit during storage (El-Ghaouth *et al.,* 1991). Cinnamic aldehyde is among the natural antimicrobials present in cinnamon (Lopez-Malo *et al*., 2006). Its spray was reported to act like a pesticide without any health hazard along with a pleasant smell (Cheng *et al*., 2004). Antimicrobial and antifungal characteristics of cinnamon oil

have also drawn interest of a number of researchers to be used as safer alternative of the pesticides (Kim *et al*., 2004).
Considering the importance of shelf life and quality of capsicum fruit, this study was conducted aiming to assess the usefulness of UV-C radiation and natural sourced edible coatings to enhance the shelf life and quality of bell pepper fruit.

MATERIALS AND METHODS

***Plant material*:** Bell pepper (*Capsicum annum* L. cv. Royal Wonder) was cultivated in the Horticulture Research Farm of PMAS- Arid Agriculture University, Rawalpindi, Pakistan. The fruits were harvested at commercial maturity stage and transported to the Postharvest Laboratory, Department of Horticulture, PMAS-Arid Agriculture University Rawalpindi.

***Postharvest treatments and storage*:** A total number of 2160 fruits of uniform size, maturity and free of disorders were selected, washed with tap water, surface dried at room temperature and subjected to different treatments including UV-C irradiation (3 min and 5 min) and edible coatings i.e. *Aloe* gel (1.5 and 2.5%); chitosan (1 and 1.5%) and cinnamon oil (0.30, 0.40 %); along with control. UV-C treatment was carried out in a wooden irradiation chamber (60 × 150 × 45 cm) fixed with 6 lamps UV-C (Philips, 15 W, model G15T8, 254 nm wavelength). A pair of lamps emitting 3.6 kJ m^{-2} was specified for fruit treatments at two intervals (3 and 5 min). Pepper fruits were spread on a screen at a distance of 24 cm from the lamps and irradiated. After half the time interval, the fruits were rotated at 180° to achieve thorough irradiation for 3 and 5 min, respectively. *Aloe* gel solutions were prepared by dilution of 100% pure *Aloe* gel (Aloe Pak, Lahore, Pakistan) in double distilled water; while cinnamon oil concentrations were prepared from 100% pure cinnamon oil (Dar-ul-Sehat Dawakhana-an Eastern drug store, Lahore, Pakistan) by using Tween-20 and double distilled water.

Fruit were rinsed with tap water in order to remove the heavy dirt, pesticides and fungal spores that are covering the fresh harvested produce and allowed to dry at room temperature and then the fruits were dipped in the given concentrations of edible coatings and total treated combinations were examined. After coating, samples of all treated and untreated fruits were packed in single layer in cardboard boxes and kept in cold storage at 8±1°C with 80-85% RH for 24 days. Following parameters were studied.

***Physical parameters*:** Weight loss of fruits was determined in each treatment by selecting 6 random fruits per treatment and placing separately to record the weight loss on fixed intervals of three days until 24th day of the storage and calculations were made to determine weight loss percentage i.e. {(W1 -W2)/ W1} × 100; where W1 = Weight of pepper fruit (g) on harvest day, and W2 = Weight of fruit (g) after interval. Firmness of fruits was hedonically measured by using 1-9 scale described by Miller *et al*. (1984) i.e. 1 = extremely soft; 2 = very soft; 3 = moderately soft; 4 = slightly soft; 5 = neither hard nor soft; 6 = slightly hard; 7 = moderately hard; 8 = very hard; 9 = extremely hard. Skin colour of bell peppers was determined by using Chroma Meter CR-400 (Konica Minolta Sensing, Inc., Japan) to measure the L* and a* values of fruit skin color during storage period at three days interval from the two opposite sides. The external appearance of treated fruits and the presence of disease or decay were visually observed.

***Chemical parameters*:** Total soluble solids of fruit juice were evaluated according to AOAC (1990) by the use of hand refractrometer at room temperature. pH of pepper fruit juice was measured by use of the digital pH meter (model: Knick 646) (AOAC, 1990).

Titratable acidity of freshly extracted juice was recorded by using standard process of AOAC (1990). Well shaked pepper juice of 10 ml was poured into volumetric flask of 100 ml and diluted with distilled water up to the mark. 10 ml of diluted sample of juice was then taken in a conical flask and added 1-2 drops of phenolphthalein as indicator. The titration of juice containing solution was done with 0.1 N NaOH until stable light pink color appeared. Consecutive three readings were recorded for each sample and percent acidity (as citric acid) was noted by using the formula TA (%) = (N x T x 0.0064) x 100/ S x D, Where: N = Normality of NaOH, T = ml of 0.1 N NaOH used, D = ml of sample taken for dilution, S = ml of diluted sample taken for the titration with constant factor of 0.0064.

Ascorbic acid contents of fruit were recorded as per procedure described by Hans (1992). A 5g sample was taken randomly from five fruits and blended with 1.0% (w/v) HCl (5 ml) and centrifuged (10 minutes) at 10,000 rpm. Supernatant fluid from centrifuge tubes was taken to evaluate ascorbic acid contents. Absorbance at (243 nm) of the extracted supernatant was computed by use of a spectrophotometer (Optima, SP 3000-plus). Ascorbic acid contents were measured as mg/100g of the fresh fruit. Total and reducing sugars of juice were estimated by the method described by Hortwitz (1960).

Electrolyte leakage of fruit was measured by employing the method of Wang *et al*. (2005) with a little modification. Concentrations of chlorophyll *a* and *b* were calculated by use of method described by Nagata and Yamashita (1992). Fruit sample (1g) was taken from the equator of each of fruit and kept at -16°C for a period of 24 h and defrosted. The solvent, acetone-hexane (4:6) 10-20 ml was used to extract the pigments. After homogenization of mixture, measurement of optical density of the supernatant was done at 663 and 645 nm by the use of spectrophotometer (Optima, SP 3000-plus). Chlorophyll *a* and *b* were recorded in accordance with equations given below:

Chlorophyll *a* (mg/100 ml) = 0.999 A_{663} - 0.0989 A_{645} and Chlorophyll *b* (mg/100 ml) = -0.328 A_{663} + 1.77 A_{645}

***Statistical analysis*:** Experimental data were analyzed by using a 2 factor factorial design, including concentrations of chemicals/UV-C and storage period. All treatments were replicated 3 times with 80 fruit as an experimental unit. Data were subjected to analysis of variance (ANOVA) using Statistix 8.1 software. The effects of various treatments were assessed within ANOVA for various parameters and least significant differences (LSD) were calculated to analyze the difference between treatments and intervals at 95% confidence level of each variable (Chase and Bown, 1997).

RESULTS

Physical Parameters:

Weight loss: Significant reduction in weight loss was noted in fruit treated with UV-C and edible coatings (Fig. 1A). Weight loss increased with the advancement in storage period, as maximum weight loss was recorded near the end of storage (Fig. 1A). Maximum weight loss (3.51%) was observed in control while minimum in UV-C for 5 min (1.18 %) followed by UV-C 3 min (1.41 %) treated fruit (Fig. 1A).

***Firmness*:** Results in Fig. 1B project a decreasing trend of fruit firmness with passage of time after harvest in all treatments. Loss in firmness gradually progressed till the end of storage period and maximum loss in firmness retention happened due to ongoing metabolic activities within fruit pericarp. Untreated fruits exhibited maximum loss in firmness (66%) while it was lowest (48%) in fruits received UV-C for 5 minutes and for 3 minutes. At the end of storage fruits receiving UV-C for 5 min exhibited 1.23 times higher firmness compared with untreated fruits.

***Colour*:** Fruit skin lightness (*L**) values in treated and untreated fruits decreased and reached to the lowest after 24 days of storage (Fig. 2A). Treated fruit significantly lowered the changes in fruit skin color. On 24th day of storage period, maximum fruit brightness (43.04) was observed with UV-C for 5 minutes followed by 1% chitosan (42.75) and 1.5% *Aloe* gel (42.68). Minimum fruit brightness (L*) value was

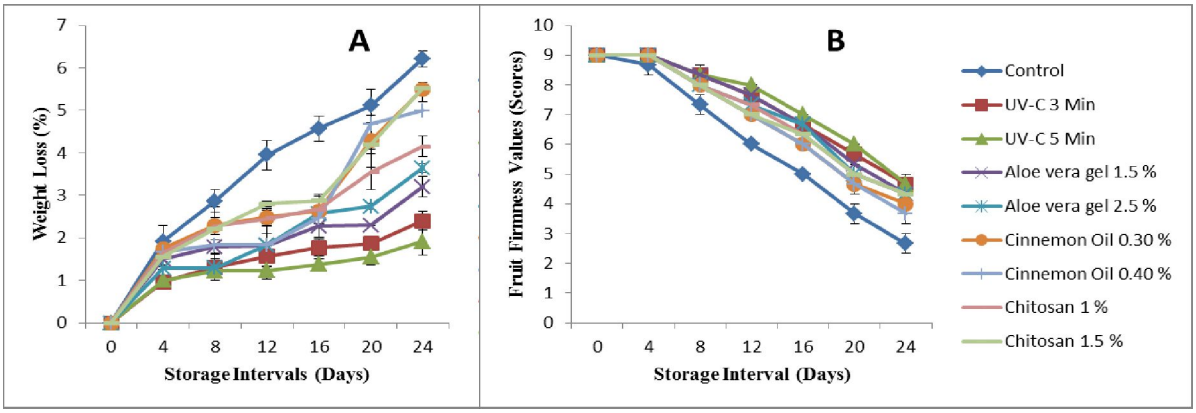

Figure 1. Effect of UV-C and edible coatings on fruit weight loss (A) and fruit firmness (B) during low temperature storage. *Bars represent SE of mean (n =3).*

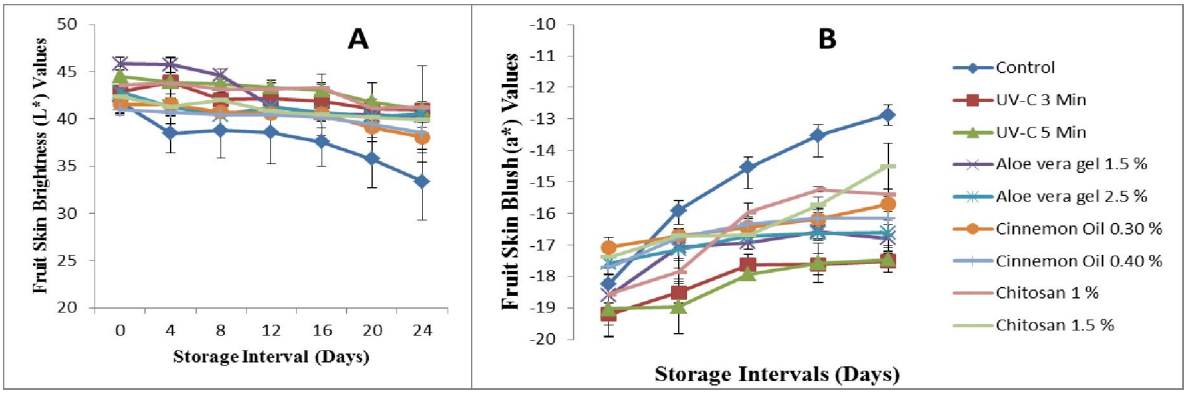

Figure 2. Effect of UV-C and edible coatings on fruit skin brightness (A) and fruit skin blush values during low temperature storage. *Bars represent SE of mean (n =3).*

recorded in control (37.75). Similarly the minimum increase in skin blush color (*a**) value (15%) was observed in UV-C for 5 minutes while the maximum increase (38%) in control (Fig. 2B).

Chemical Parameters:

***Total soluble solids (TSS), Titratable acidity (TA) and pH*:** TSS gradually increased and TA decreased significantly for all the treatments during storage at 8±1°C (Fig. 3A, B). However, changes in these chemical parameters were significantly low in treated fruits than the control which exhibited higher level of TSS (5.78 °Brix) while in fruits which were coated with 2.5% *Aloe* gel (4.96 °Brix) showed minimum TSS value followed by 1.5% *Aloe* gel treatment (4.99 °Brix) (Fig. 3A).

***Total Sugars and Ascorbic acid contents*:** Total sugar of fruits increased with the advancement of storage period in all treatments (Fig. 4A). Highest value (7.87%) was recorded in control. While total sugars were significantly lower in all the treatments (Fig. 4A). The minimum total sugars were found in the fruits treated with 1.5% *Aloe* gel coating (6.58%) followed by 2.5% *Aloe* gel (6.62%) and 1.5% chitosan (6.70%) treatments, which were statistically identical. Treated fruits maintained relatively higher level of ascorbic acid throughout the storage period (Fig. 4B) that showed a significant decrease in ascorbic acid reaching final level of 21.88 and 38.50 mg/100g in untreated and 2.5% *Aloe* gel treatments respectively.

Figure 3. Effect of UV-C and edible coatings on fruit juice TSS (A), titratable acidity (B) and pH (C) during low temperature storage. *Bars represent SE of mean (n =3)*

TA showed a gradual decreasing trend with passage of time during storage in all treatments at low temperature for 24 days (Fig. 3B) but the decline was rapid in control compared to treated fruits**.** At the end of storage, significantly higher values of TA were recorded in all treatments. The treatment of 1.5% *Aloe* gel coating showed the maximum value (0.15%) followed by UV-C 5 min treatment (0.14%). The control got the lowest value (0.13%) at the end of the storage (Fig. 3B).

An increasing trend of pH was observed during storage period (Fig. 3C). The maximum pH (5.61) was recorded in control while the minimum in UV-C 5 min (5.51). The treatments of UV-C and *Aloe* gel were at par.

Figure 4. Effect of UV-C and edible coatings on total sugars (A) and ascorbic acid (B) contents during low temperature storage. *Bars represent SE of mean (n =3).*

***Electrolyte leakage (EL), disease/decay incidence and chlorophyll contents*:** A significant reduction of electrolyte leakage of stored fruits was recorded in UV-C and edible coating treatments compared with control (Fig. 5A). The maximum EL (76.81%) was observed in control while the minimum (72.21%) in UV-C 5 minutes followed by UV-C 3 minutes (72.39%). From the data it is clear that Aloe gel and

cinnamon oil treatments were statistically identical sharing the same letter.

Data in Fig. 5B shows that all treatments significantly minimized the incidence of disease and decay of stored fruits over control. The treatments were effective in two ways i.e. reduced the incidence and delayed the time for the incidence of disease and decays (Fig. 5B). The maximum level of disease was recorded in the untreated fruit (37.57%) while it was lowest (7.33%) in UV-C 5 min followed by UV-C 3 min (8.29%) treatment.

Disease and decay: Data showed that all treatments significantly minimized the incidence of disease and decay of store fruits over control (Fig. 13). The treatments were effective in two ways i.e. reduced the incidence and delayed the time for the incidence of disease and decay (Fig. 13). The maximum level of disease was recorded in the untreated fruit (37.57 %) while it was lowest (7.33 %) in UV-C 5 min followed by UV-C 3 min (8.29 %) treatment.

Figure 5. Effect of UV-C and edible coatings on fruit electrolyte leakage (A) and disease/decay incidence (B) during low temperature storage. *Bars represent SE of mean (n =3).*

The data showed a decreasing trend of chlorophyll *a* and *b* in fruits during storage (Fig. 6A,B), as different treatments significantly reduced the degradation which was higher in control compared to all treatments with the value of chlorophyll a 0.902 mg/100 ml after 24 days. The maximum chlorophyll *a* was observed in treatment of UV-C 5 minutes (1.20 mg/100 ml) followed by 1.5% *Aloe* gel coating (1.13 mg/100 ml). The data showed the lowest value of chlorophyll *b* (1.26 mg/100 ml) in control while the maximum in UV-C 5 min (1.62 mg/100 ml) followed by 1.5% *Aloe vera* gel treatments (1.53 mg/100 ml).

Figure 6. Effect of UV-C and edible coatings on chlorophyll a (A) and chlorophyll b (B) contents during low temperature storage. *Bars represent SE of mean (n =3).*

DISCUSSION

Water contents of fruits and vegetables are major factors in maintaining the quality of horticultural produce. Post-harvest life is important for long term storage, thus low rate of weight loss and delay in softening of bell pepper are important factors to maintain quality over longer duration (Maalekuu *et al*., 2003). Bell peppers are delicate experiences a series of problems mainly including flaccidity (loss of water during storage), shriveling and decay due to highly perishable nature of fruit (Terry and Joyce, 2004). In present studies the loss of fruit weight was significantly higher in control as compared with treated fruits during 24 days of storage; the minimum weight loss appeared in UV-C (5 min) treated fruits. Fig.1A shows increase in weight loss in all treatments with progress in storage time but control

exhibited the maximum weight loss till the end of storage. Weight loss is mainly associated with respiration and transpiration of moisture, and bell peppers having thin skin are more prone to rapid water loss, resulting in shrivelage and deterioration. In the study, lower weight loss was recorded in the fruits treated with UV-C and edible coatings that might be attributed to cell membrane integrity and lower electrolyte leakage of fruit tissues. Comparable results of weight loss have also been reported in tomato, kiwifruit, red and yellow pepper and strawberry (Obande *et al*., 2011). Coating also reduced the respiration by formation of semi-permeable barrier to water vapors and gases, thus extended the shelf life of fruits based on the mechanism of hygroscopic properties (Ni *et al*., 2004).

Deformation of fruit was influenced by both postharvest treatments and storage period, thus firmness decreased with prolonged storage (Fig. 1B). The softening that occurs in any fruit is primarily due to a change in cell-wall carbohydrate metabolism, resulting in a net decrease in certain structural components (Labavitch, 1981). The changes in cell-wall composition result from the action of hydrolytic enzymes produced by the fruit (Payasi *et al*., 2009). At the end of storage, the maximum firmness was observed in fruits treated with UV-C 5 minutes and the minimum in control. The increased level of firmness of UV-treated fruit could be linked with increased level of polyamines (PAs) compared to untreated fruits (Maharaj *et al*., 1999). UV light lowered the activity of cell wall degrading enzymes (CWDE), suggesting that CWDE might be the main target of UV-C light. Jiang *et al*. (2010) proved that UV-C maintained firmness and the shelf life of mushroom during storage at 20°C. Similarly reports depicted that Aloe gel reduced the activity of some CWDE responsible for fruit softening in pineapple (Adetunji *et al*., 2012).

In the present studies, UV-C light and edible coatings significantly lowered the changes in *L** and *a** of stored bell peppers that might be attributed to alteration of chemical composition of epicuticular wax and the consequent ultra-structural properties. The changes in epicuticular wax can alter the light reflectance properties of fruit surface which might be the reason for brightness in fruits treated with UV-C 5 min compared to control. *Aloe* gel can also have a positive effect on (*L**) value of color attributing to modified atmospheric effects, thus delayed degradation of chlorophyll and carotenoid synthesis. Another reason for maintaining higher L* values is reduction of water loss from treated fruits, keeping healthy and fresh compared to control. Fig. 2B illustrated the increasing trend of *a** value (-greenness to + redness) in peppers during storage as negative value moved towards positive *a** value, depicting chlorophyll degradation in all treatments. This parameter is confirmed with the evidence that higher losses of green color might be due to the synthesis of lycopene and ß-carotene, whereas increased breakdown of chlorophyll pigments occur during fruit ripening (Nyalala and Wainwright, 1998). Therefore, UV-C and edible coatings maintained a* and b* values at lower level. Cantos *et al*. (2002) reported less change in color of table grape berries treated with *Aloe vera*. Similar results were ascertained by Xing *et al*., (2010) who applied cut lotus root with chitosan solution (1.2%) placing in cold store at 4°C for 10 days, thus retained (*b**) value of color during storage for acceptable quality.

UV-C and edible coatings in this study significantly kept lower level of TSS in stored peppers. The increased TSS is due to loss of moisture and hydrolysis of polysaccharides, modifications in structural carbohydrates, conversion of organic acids and protein degradation. However, TSS level was significantly low in *Aloe* gel treated fruits under same conditions. Non-significant results appeared among different UV-C and *Aloe* gel treatments but were significant compared to control. UV-C irradiation reduced the moisture loss which might be the reason of maintaining low TSS.

Loss of titratable acidity (TA) at fruit ripening might be attributed to decline of organic acids being the main substrates of respiration and conversion of acids into sugars. These acids are considered to decrease as being the reserve source of energy during ripening (Tucker, 1993). In our findings, the acidity loss in control might be due rapid increase in metabolic activity as a fast ripening process. There were high values of TA observed in UV-C irradiated fruits supported by Eivazi *et al*. (2011), who reported significantly higher level of TA in irradiated fruit as compared to control. The changes in TA were significantly higher towards the end of storage period in all fruits regardless of treatment that ought to be linked for more demand of energy to overcome the stress. Opposite to TA, the constant increase in fruit pH might be due to biochemical, structural and physiological changes leading to loss of organic acids of fruits during storage. On last day in store, the minimum pH value was observed in fruits treated with UV-C 5 min as confirmed by Charles *et al*. (2005) working on irradiated tomatoes. In present studies lower values of pH obtained for fruits treated with 1.5 % Aloe gel compared to control, speculating that *Aloe* gel coating on fruit might have changed the internal fruit atmosphere leading to change in endogenous CO_2 and O_2 concentrations resulting in retardation of fruit ripening, hence maintaining higher levels of organic acids.

Data in Figure 4B showed the decreasing trend of ascorbic acid in peppers during storage. Highest ascorbic acid was noted at the day of harvest while least was at the last day of storage. The losses in ascorbic acid may be attributed to the activity of oxidase and phenol-oxidase enzymes. The treatment of 1.5% *Aloe* gel proved the most effective in decreasing the ascorbic acid loss during storage compared to other treatments that might be because of low permeability of *Aloe* gel for oxygen.

Sucrose, glucose and fructose are present in bell pepper fruit as the main components of soluble neutral sugars. The increasing trend of sugars in peppers during ripening could be due to conversion of fruit starch into sugars. Our results showed that the use of 1.5% *Aloe* gel kept significantly low level of sugars in peppers which is supported by Adetunji *et al*., (2012). This might be because of creation of modified atmosphere by the *Aloe* gel that decreases respiration rate and eventually maintains the level of sugars.

Electrolyte leakage (EL) mainly depends on membrane permeability that increases with the onset of ripening (Elkashif and Huber, 1988). The results showed an increase in EL in peppers with the passage of storage period regardless of the treatments whereas, lower EL was observed in treatment of UV-C 5 min and control showed higher EL because of more damage to the cellular membranes. The UV-C treatment might have induced biological stress which can trigger defense mechanism (Mercier *et al.,* 2000) and prevention of membrane damage by initiating the accumulation of polyamines in fruit tissue (Gonzalez-Aguilar *et al*., 2007). As the results showed an increase in the electrolyte leakage throughout storage period, however, a significantly slow rate of increase in *Aloe* gel treated fruits were observed which are in confirmation with the findings of Ahmed *et al*. (2009).

The crucial factor of quality degradation in bell peppers during storage for a long time is the development of decay, primarily caused by *Alternaria alternata* and *Botrytis cinerea*.In this study, the rate of disease and decay increased in all treatments with storage time and was the maximum after 24 days. Control fruits were most affected by disease and decay after 24 days in storage and the least were fruits treated with UV-C 5 min. this effect of UV-C treatment might be due to induction of resistance against pathogens by increasing the level of PAs, in addition to its direct germicidal effects because of involvement in shifting the electrons of DNA (Stevens *et al*., 1996). The UV-C irradiation is a non-thermal technique for food preservation and our studies proved its effectiveness for increasing the storage life of fruits at low doses in support similar to reducing the green mold rot development in citrus (Gonzalez-Aguilar *et al*., 2007), brown rot in peaches, sour and stem end rot in tangerine, bitter and rot in apples (Stevens *et al*., 1996). Present study on bell peppers also showed significantly positive results for *Aloe* gel on reduction of disease and decay in fruit at low temperature storage which could be due to the presence of certain components in *Aloe* gel such as acemannan, saponins and anthraquinones derivatives recognizing for antibacterial activity (Ferro *et al*., 2003). Our results elucidate that 1% chitosan has significant effects in controlling disease and decay of fruits attributing to film forming and antimicrobial property of chitosan by acting as a barrier and protect the fruits from infections (Meng *et al*., 2008).

The fruits of sweet bell pepper (*Capsicum annuum* L.) are non-climacteric with respect to respiratory pattern. Total chlorophyll contents is one of the most important quality attributes of green bell peppers. Figure 6A and 6B shows chlorophyll a and b decreased in all treatments with progress in storage time and reached minimum level after 24 days. Control exhibited the lowest levels of chlorophyll a and b after 24 days in store. Carotenoid and other color pigments are synthesized with the onset of ripening (capsanthin and capsorubin) along with a rapid degradation in chlorophylls because of conversion of chloroplast into chromoplast. The role of enzyme, chlorophyllase during the degeneration process appears to be crucial being a triggering or modulating factor for the synthesis of carotenoid pigments. The synthesis of chlorophyllase is linked with senescence and maturation, thus decrease in chlorophyll contents in control might be due advancement in senescence that continued rapidly after harvest (Hornero-Mendez and Minguez-Mosquera, 2002).

***Conclusion*:** The various dozes of UV-C irradiation and edible coatings (Aloe gel, cinnamon oil and chitosan) had significant effectiveness in maintaining the fruit quality of bell peppers (*Capsicum annuum*) during cold storage, which was accompanied by reduction in softening, weight loss and changes in fruit chemical characteristics. Further studies are necessitated to know the mechanism of action by which UV-C lowered the changes during storage. The results vividly suggest that both UV-C and edible coatings have potential application of postharvest for maintaining quality and improving the health benefits of bell pepper fruit.

REFERENCES

Adetunji, C.O., O.B. Fawole, S.S. Afolayan, O.O. Olaleye and J.B. Adetunji. 2012. Effects of *Aloe vera* gel coatings on shelf life of Citrus sinensis fruits stored at ambient temperature. An oral presentation during 3rd NISFT western chapter half year conference/general meeting (Ilorin, 2012) May 14-16th, 2012.

Ahmed, M.J., Z. Singh and A.S. Khan. 2009. Postharvest *Aloe vera* jel-coating modulates fruit ripening and quality of 'Arctic Snow' nectarine kept in ambient and cold storage. Int. J. Food. Sci. Tech. 44:1024-1033.

AOAC. 1990. Official Methods of Analysis. Association of Analytical Chemists. 15th Ed., Virginia, Arlington, USA.

Baka, M., J. Mercier, R. Corcuff, F. Castaigne and J. Arul. 1999. Photochemical treatment to improve storability of fresh strawberries. J. Food Sci. 64:1068-1072.

Cantos, E., J.C. Espin and F.A. Tomas-Barberan. 2002. Varietal differences among the polyphenol profiles of seven table grape cultivars studied by LC-DAD-MS-MS. J. Agric. Food Chem. 50:5691-5696.

Cha, D.S and M. Chinnan. 2004. Biopolymer-based antimicrobial packaging: a review. Crit. Rev. Food Sci. Nutr. 44:223-237.

Charles, M.T., R. Kalantari, R. Corcuff and J. Arul. 2005. Postharvest quality and sensory evaluation of UV-treated tomato fruit. Acta Hort. 682:537-542.

Chase, W. and F. Bown. 1997. General statistics 3rd Ed. John Willey & Sons. Inc. NY; pp.491-523.

Cheng, S.S., J.Y. Liu, K.H. Tsai, W.J. Chen and S.T. Chang. 2004. Chemical composition and mosquito larvicidal activity of essential oils from leaves of different *Cinnamomum osmophloeum* provenances. J. Agric. Food Chem. 52:4395−4400.

Eivazi, A., H. Karimi and H. Yusef-Zadeh. 2011. The Effects of UV-C irradiation and Kitosan concentrations on post harvest traits of Apricot (*Prunus armeniaca* L.) fruit. Tech. J. Engin. App. Sci.1:111-117.

El-Ghaouth, A., J. Arul, R. Ponnampalam and M. Boulet. 1991. Use of chitosan coating to reduce water loss and maintain quality of cucumber and bell pepper fruits. J. Food Process. Preserv. 15:359-368.

Elkashif, M.E. and D.J. Huber. 1988. Electrolyte leakage, firmness, and scanning electron microscope studies of watermelon fruit treated with ethylene. J. Amer. Soc. Hort. Sci. 113:378–381.

Ferro, V.A., F. Bradbury, P. Cameron, E. Shakir, S.R. Rahman and W.H. Stinson. 2003. In vitro susceptibilities of *Shigella flexneri* and Streptococcus pathogenes to inner gel of *Aloe barbadensis* Miller. Antimicrob. Agents Ch. 47:1137–1139.

Gonzalez-Aguilar, G.A., R. Zavaleta-Gatica and M.E. Tiznado-Hernandez. 2007. Improving postharvest quality of mango Haden by UV-C treatment. Postharvest Biol. Technol. 45:108–116.

Hans, W.S.H. 1992. The guide book of food chemical experiments, Pekin Agricultural University Press, Pekin. (n.p).

Hortwitz, W. 1960. Official and tentative methods of analysis, 9th Ed., Association of Official Agricultural Chemists, Washington, DC; pp.314-320.

Hornero-Mendez., D. and M.I. Minguezz-Mosquera. 2002. Chlorophyll disappearance and chlorophyllase activity during ripening of *Capsicum annuum* L. fruits. J. Sci. Food Agric. 82:1564-1570.

Howard, L.R., R.T. Smith, A.B. Wagner, B. Villalion and E.E. Burns. 1994. Provitamin A and ascorbic acid content of fresh pepper cultivars (*Capsicum annuum*) and processed jalapenos. J. Food Sci. 59:362-365.

Jiang, T., M.M. Jahangir, Z. Jiang, X. Lu and T. Ying. 2010. Influence of UV-C treatment on antioxidant capacity, antioxidant enzyme activity and texture of postharvest shiitake (*Lentinus edodes*) mushrooms during storage. Postharvest Biol. Technol. 56:209-215.

Kim, H.O., S.W. Park and H.D. Park. 2004. Inactivation of Escherichia coli O157: H7 by cinnamic aldehyde purified from *Cinnamomum cassia* shoot. Food Microbiol. 21:105-110.

Labavitch, J.M. 1981. Annu. Rev. Plant Physiol. 32: 385.

Lopez-Malo, A., J. Barreto-Valdivieso, E. Palou and F.S. Martin. 2006. *Aspergillus flavus* growth response to cinnamon extract and sodium benzoate mixtures. Food Control. 18:1358−1362.

Maalekuu, K., Z. Elkind, S. Tuvia-Alkalai, Y. Shalom and E. Fallik. 2003. Quality evaluation of three sweet pepper cultivars after prolonged storage. Adv. Hort. Sci. 17:187-191.

Maharaj, R., J. Arul and P. Nadeau. 1999. Effect of phytochemical treatment in the preservation of fresh tomato (*Lycopersicon esculentum* cv Capello) by delaying senescence. Postharvest Biol. Technol. 15:13–23.

Meng, X., L. Boqiang, L. Jia and T. Shiping. 2008. Physiological responses and quality attributes of table grape fruit to chitosan preharvest spray and postharvest coating during storage. J. Food Chem. 106:501-508.

Mercier, J., D. Roussel, M.T. Charles and J. Arul. 2000. Systemic and local responses associated with UV-induced and pathogen-induced resistance to *Botrytis cinerea* in stored carrot. Phytopathol. 90:981–986.

Miller, W.R., S D.H. Palding, L.A. Rosse, and V. Chew. 1984. The effects of animazalil-impregnated film with chloride and imazalil to decay of bell peppers. Proc. Fla. State Hort. Soc. 97:108-111.

Nagata, M. and I. Yamashita. 1992. Simple method for simultaneous determination of chlorophyll and carotenoids in Tomato fruit. J. Japan. Soc. Food Sci. Technol. 39:925-928.

Ni, Y., D. Turner, K.M. Yates and I. Tizard. 2004. Isolation and characterization of structural components of *Aloe vera* L. leaf pulp. Int. Immunopharmacol. 4:1745-1755.

Nyalala, S.P.O. and H. Wainwright. 1998. The shelf life of tomato cultivars at different storage temperatures. Trop. Sci. 38:151-154.

Obande, M.A., G.A. Tucker and G. Shama. 2011. Effect of preharvest UV-C treatment of tomatoes (*Salanum lycopersicon* Mill.) on ripening and pathogen resistance. Postharvest Biol. Technol. 62:188-192.

Payasi, A., N.N. Mishra, A.L.S. Chaves and R. Singh. 2009. Biochemistry of fruit softening: an overview. Physiol. Mol. Biol. Plants. 15:103–113.

Stevens, J.L., C.L. Wilson, J.Y. Lu, V.A. Khan, E. Chalutz, S. Droby, M.K. Kabwe, M.Z. Haung, O. Adeyeye, P.L. Pusey, M.E. Wisniewski and M. West. 1996. Plant hormesis induced by ultraviolet light- C for controlling postharvest diseases of tree fruits. Crop Prot. 15:129–134.

Terry, L.A. and D.C. Joyce. 2004. Elicitors of induced disease resistance in postharvest horticultural crops: a brief review. J. Postharvest Biol. Technol. 32:1-13.

Tucker, G.A. 1993. Respiration and energy, p.3. In: G.B. Seymour, J.E. Taylor and G.A. Tucker (eds.), Biochemistry of fruit ripening, Chapman and Hall, London, UK.

Wang, S.Y., P.F. Chen and S.T. Chang. 2005. Antifungal activities of essential oils and their constituents from indigenous cinnamon (*Cinnamomum osmophloeum*) leaves against wood decay fungi Bioresour. Technol. 96:813–818.

Xing, Y., X. Li, Q. Xu, J. Yun, Y. Lu and Y. Tang. 2010. Effects of chitosan coating enriched with cinnamon oil on qualitative properties of sweet pepper (*Capsicum annuum* L.). J. Food Chem. 124:1443- 1450.