AHS
Advances in Horticultural Science

# Effect of different packaging materials on shelf life and postharvest quality of tomato (*Lycopersicum esculentum* var. Srijana)

**S. Poudel [1 (*)], P. Aryal [1], M. Basnet [2]**

[1] *Tribhuvan University, Institute of Agriculture and Animal Science, Lamjung Campus, Sundarbazar-07, Lamjung, Nepal.*

[2] *Tribhuwan University, Institute of Agriculture and Animal Science, Paklihawa Campus, Siddharthanagar-1, Paklihawa, Rupandehi, Nepal.*

OPEN ACCESS

(*) **Corresponding author:**
saritapaudel12345@gmail.com

**Citation:**
POUDEL S., ARYAL P., BASNET M., 2022 - *Effect of different packaging materials on shelf life and postharvest quality of tomato (Lycopersicum esculentum var. Srijana).* - Adv. Hort. Sci., 36(2): 127-134.



**Data Availability Statement:**
All relevant data are within the paper and its Supporting Information files.

**Competing Interests:**
The authors declare no competing interests.

Received for publication 12 February 2022
Accepted for publication 4 April 2022

*Key words*: HDPE, LDPE, modified atmosphere, permeability.

**Abstract: Tomatoes, being highly perishable, experience extreme post-harvest losses due to improper packaging materials. Experimentation was done to investigate the effect of different packaging materials on shelf life and quality traits of tomato var. Srijana at the horticulture laboratory of the Institute of Agriculture and Animal Science, Lamjung Campus under a completely randomized design. Seven treatments viz. no packaging (control), unperforated low-density polyethylene (LDPE) bag, perforated (4 holes of 2 mm) LDPE bag, unperforated high-density polyethylene (HDPE) bag, perforated HDPE bag, unperforated non-woven fabric bag, and perforated non-woven fabric bag with 3 replications were used. Tomatoes were evaluated for weight loss, color development, total soluble solids, titratable acidity, pH, and shelf life. Among the treatments, the lowest percentage of weight loss (0.66%) was observed on tomatoes packed in an unperforated HDPE bag, however, it had a higher fungus attack. No packaging group showed rapid shriveling of fruits with the highest percentage of weight loss (14.70%). Although packaging in a non-woven fabric bag was better than control, it showed a higher percentage of weight loss than plastic packaging due to its high permeability to gases and water vapor. The TSS and pH values were found to be higher and TA to be lower in no packaging compared to other packagings. The longest shelf life of tomatoes was observed in perforated LDPE (24 days), followed by HDPE (23 days) whereas the lowest was observed in control (16 days). Overall, the perforated plastic packaging was found best among all treatments with no significant variation among perforated HDPE and perforated LDPE for maintaining qualities of tomatoes and longer shelf life.**

## 1. Introduction

Tomato (*Lycopersicon esculentum* Mill.) is considered as one of the widely grown horticultural crops across the world that ranks second in importance to potato. (FAO, 1989). The area under tomato cultivation in

Nepal occupies about 21,747 ha giving a total production of 413,761 mt (MOALD, 2019/2020). Despite this production, post-harvest loss in tomatoes accounts for about 30-33% of total production. (Tiwari *et al*., 2020). This loss has been attributed to a broad number of factors among which improper packaging, storage facilities, and poor means of transportation and roads constitute a major part. Reduction of post-harvest losses of any perishables is of utmost importance as it is hard to increase a 10% production than to reduce a 10% loss without laying additional land for cultivation (Bhattarai and Gautam, 2006).

Post-harvest quality maintenance is of great challenge in developing countries like Nepal where post-harvest technologies are not so far developed or available in every part of the country. Even the availabilities of some costly technologies are not affordable to smallholder consumers, sellers and farmers. So, there is a need to explore every possible cost-effective way to minimize the prevailing post-harvest losses. One of the better alternative and viable options for improving shelf life and reducing quality degradation of the produce inexpensively is Modified Atmospheric Packaging (MAP) (Kader *et al*., 1989). MAP is achieved by using various packaging materials like LDPE, HDPE that result in alteration of the gaseous environment inside the packages by manipulating the levels of $O_2$, $CO_2$, $N_2$, and $C_2H_4$. The permeability of film decides the level of $O_2$ and $CO_2$ inside it. If the film is of correct permeability, a preferable equilibrium modified atmosphere can be entrenched where the $O_2$ and $CO_2$ transmission rate via package can balance the product's respiration (Day, 2001). Reduced $O_2$ and/or elevated $CO_2$ levels can reduce respiration, retard ethylene production and ripening, impede textural softening and slow down biochemical changes associated with ripening and thus ultimately resulting in an extension of shelf life (Farber, 1991).

Low-density polyethylene (LDPE) and High-density polyethylene (HDPE) are the materials that are commonly used for MAP. The non-woven fabric bag is the packaging material that has recently evolved in the Nepalese market and has been replacing plastic packages. These packaging materials are easily available and purchasable in the Nepalese market. Different studies suggest that the use of improper packaging and storage has significantly shortened the shelf-life of tomatoes. Hence, to extend the storage life coupled with quality maintenance cost-effectively, this research is focused on identifying the most suitable and effective packaging for tomatoes.

## 2. Materials and Methods

*Description of the study area*

The research was conducted in the horticultural laboratory of the Institute of Agriculture and Animal Science (IAAS), Lamjung Campus located in Lamjung, Nepal. It lies at an elevation of 800 meters with 28.127°N latitude and 84.4167°E longitude. The mean annual rainfall of the area is 700 mm. Within a year, the average maximum temperature occurs during June at around 35.7°C whereas the average minimum temperature occurs during January at around 14.5°C.

*Experimental materials*

Breaker stage defect-free tomato fruits of Srijana variety were harvested from the field of lamjung campus during morning time and taken to the horticultural lab of lamjung campus. The harvesting was done by handpicking with leaving a small pedicel above the fruit. The fruits were free from defects such as sun scorch, bruises, and pest or disease damage. Then, these tomatoes were cleaned, washed, and dried before preparing each sample.

*Environmental parameters*

The maximum temperature of the experimental lab varied from 33-28°C, minimum temperature from 17-22°C, and relative humidity from 48-75% (Fig. 1).

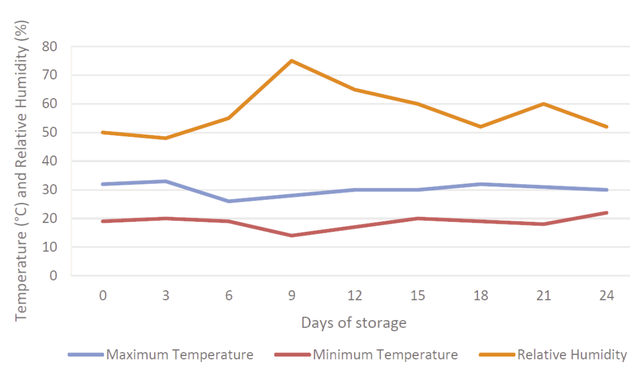


Fig. 1 - Graphical representation of temperature and relative humidity during storage period of tomato.

*Treatments and experimental design*

The experiment was carried out with seven treatments elaborated be laid in a completely randomized design with three replications. Thus, the overall experimental units were 21. The washed tomato fruits were divided into 21 groups each with a half kilogram then subjected to various treatments and kept in the ambient environment for its post-harvest quality assessment and physiological weight loss. Each plastic bag was of 25-micron thickness and 20 x 15 cm size while the non-woven fabric bag was single-layered spun-bond polypropylene non-woven fabric with 50 gsm and 0.520 mm thickness. The rubber band was used for sealing the mouth of packages each of the same size. 4 perforations of 2 mm diameter were made in perforated packages with a heated wall nail.

Treatments detail:

T1= No packaging or control;
T2= Unperforated Low-Density Polyethylene (LDPE);
T3= Perforated Low-Density Polyethylene;
T4= Unperforated High-Density Polyethylene (HDPE);
T5= Perforated High-Density Polyethylene;
T6= Unperforated Non-woven fabric bag (NW fabric);
T7= Perforated Non-woven fabric bag.

*Data collection*

Data for physiological weight loss was observed at every three days of storage whereas the qualitative data was observed every six days.

*Weight loss (%)*

The fruit was weighed using the electronic digital balance on successive intervals and the loss in weight at each interval was calculated by using the following formula:

Weight loss, % = [(initial weight - final weight )/Initial weight] x 100

*Color development*

The color development was observed visually. USDA standard color chart (Fig. 2) was used for observation of various maturity stages of tomatoes.

Mature Green = Complete green color on the surface of the tomato;
Breaker = Distinct break in color from green to tarnish-yellow, pink or red on not more than 10% of the surface;
Turning = Change in color from green to tannish-yellow, pink, red up to 10-30% of the surface;
Pink= Pink or red color on 30% to 60% of the surface.
Light red = Pinkish red or red color on 60% to 90% of the surface;
Red = Red color on more than 90% of the surface.

The color changes were determined by using a numerical rating scale from 1-7 where 1= green, 2= breaker, 3= pink, 4= turning, 5= light red, 6=red, and 7= deep red.

Fig. 2 - Standard tomato ripening color chart.

*Total soluble solids (°Brix)*

To determine the total soluble solids, tomato fruit was squeezed and a few drops of juice were added onto the prism plate of the refractometer (ERMA INC-JAPAN) and TSS (°Brix) was recorded. The prism plate of the refractometer was cleaned after each test with distilled water and soaked up with soft cotton.

*Titratable acidity (%)*

TA was determined by titrating the 10 ml of tomato juice with 0.1% NaOH which was placed in the burette. A few drops of phenolphthalein were added to the juice as the indicator. The mouth of the burette was opened to allow NaOH to drop down until the color of the juice changed to pink for about 10 seconds. The volume of NaOH required was recorded and titratable acidity was calculated by using the following formula that is expressed as % of citric acid.

TA (%) = [($N_B$ x $V_B$ x $M_{eq.}$ of acid)/volume of sample] x d.f. x 100

Where, $N_B$ = Normality of base (NaOH), $V_B$= Volume of the base, d.f. = Dilution factor, and $M_{eq}$.= Milliequivalent weight of predominant acid i.e. citric acid = 0.064.

*The pH of the juice*

The pH reading was measured by using a digital pH meter from the juice extracted for titration. The pH meter was placed in the juice and left for a certain time until the reading become stable and the stable pH value was noted.

*Shelf life*

The shelf life of fruits was recorded by judging the non-marketability parameters such as damage by fungus attack, shriveling, etc. It was detected when 50% of tomatoes of each treatment were non-marketable.

*Data analysis*

The collected data entry and analysis on various parameters were done using the computer software package, Microsoft Excel (2016) and R (agricolae v.1.3-2). The analyzed data were subjected to LSD for mean comparison.

## 3. Results

*Weight loss*

Statistically, significant variation was found concerning the weight loss of tomatoes among different treatments. The higher rate of weight loss was observed in no packaging (open) and the lower was in unperforated HDPE that was statistically at par with unperforated LDPE at all days of the storage.

The perforated packages showed a higher weight loss than any unperforated packaging material (Table 1).

One of the important factors that determine the shelf life of the tomato is weight loss and it was found to increase with the increase in permeability of the packaging material. The non-woven fabric bag has a high permeability to gases and water vapor as compared to the plastic film resulting in higher weight loss.

*Color development*

The color development was observed to be rapid with the increase in permeability of the packaging material. Extremely slow development of the color was observed in unperforated polyethylene storage and rapid in open tray storage (Table 2).

*Total soluble solids*

The TSS of the tomato increased under all the packaging material up to 18 days of storage. There was no significant difference in the TSS value of the tomato under different packaging materials on the 6$^{th}$ day of storage. However, the significant difference among the treatments began to appear from the 12$^{th}$ day of storage. The highest TSS was observed in no

Table 2 - Effect of packaging materials on color development

| Treatments | Color development | | |
|---|---|---|---|
| | 6DAS | 12DAS | 18DAS |
| T1 | 4.17 a | 6.33 a | 6.80 a |
| T2 | 2.17 a | 3.00 d | 4.33 d |
| T3 | 3.33 cd | 5.33 c | 6.10 c |
| T4 | 2.10 e | 3.16 d | 4.16 d |
| T5 | 3.17 d | 5.10c | 6.13 c |
| T6 | 3.5 c | 5.76 b | 6.46 b |
| T7 | 3.93 b | 6.03 b | 6.60 ab |
| Grand Mean | 3.19 | 4.96 | 5.80 |
| LSD | 0.17 *** | 0.29 *** | 0.31 *** |
| CV | 3.05% | 3.38% | 3.01% |

Means in the column followed by similar letters are not statistically different at p=0.05 by LSD.
Color Score (1 Green, 2 Breakers, 3 Turning, 4 Pink, 5 Light Red, 6 Red, 7 Deep Red).
DAS=Days after Storage, LSD=Least significant difference, CV=Coefficient of variance, NS=Non significant, * significant at 5%, ** significant at 1%, ***significant at 0.1% level of significance.

Table 1 - Effect of packaging materials on physiological weight loss (%)

| Treatments | Weight loss (%) | | | | | |
|---|---|---|---|---|---|---|
| | 3DAS | 6DAS | 9DAS | 12DAS | 15DAS | 18DAS |
| T1 | 2.67 a | 3.08 a | 4.95 a | 8.12 a | 12.18 a | 14.70 a |
| T2 | 0.09 d | 0.21 e | 0.30 e | 0.37 e | 0.50 e | 0.81 e |
| T3 | 0.41 c | 0.82 d | 1.29 d | 1.62 d | 2.07 d | 2.77 d |
| T4 | 0.04 d | 0.19 e | 0.26 e | 0.30 e | 0.40 e | 0.66 e |
| T5 | 0.038 c | 0.78 d | 1.22 d | 1.37 d | 1.85 d | 2.58 d |
| T6 | 1.84 b | 2.34 c | 3.47 c | 6.08 c | 9.07 c | 11.54 c |
| 7 | 1.94 b | 2.62 b | 3.86 b | 6.55 b | 9.87 b | 12.37 b |
| Grand Mean | 0.994 | 1.435 | 2.198 | 3.488 | 5.134 | 6.49 |
| LSD | 0.1397 *** | 0.2256 *** | 0.3190 *** | 0.3588 *** | 0.4662 *** | 0.7020 *** |
| CV% | 8.02% | 8.97% | 8.32% | 5.87% | 5.18% | 6.18% |

Means in the column followed by similar letters are not statistically different at p=0.05 by LSD.
DAS= Days after Storage, LSD = Least significant difference, CV = Coefficient of variance, * significant at 5%, ** significant at 1%, *** significant at 0.1% level of significance.

packaging on all days of the storage and the lowest was in unperforated HDPE (Table 3).

Table 3 - Effect of different packaging materials on TSS content of tomato

| Treatments | TSS of tomato | | |
|---|---|---|---|
| | 6DAS | 12DAS | 18DAS |
| T1 | 4.016 a | 4.533 a | 5.100 a |
| T2 | 3.850 a | 4.067 d | 4.301 d |
| T3 | 3.867 a | 4.183 bc | 4.550 c |
| T4 | 3.850 a | 4.083 cd | 4.301 d |
| T5 | 3.867 a | 4.177 bcd | 4.533 c |
| T6 | 3.867 a | 4.233 b | 4.750 b |
| T7 | 3.933 a | 4.277 b | 4.77 b |
| Grand mean | 3.893 | 4.222 | 4.614 |
| LSD | NS | 0.1106 *** | 0.1079 *** |
| CV(%) | 2.64% | 1.49% | 1.33% |

Means in the column followed by similar letters are not significantly different at p=0.05 by LSD.
DAS=Days after Storage, LSD=Least significant difference, CV=Coefficient of variance, NS= Non significant, * significant at 5%, ** significant at 1%, ***significant at 0.1% level of significance.

*Titratable acidity (TA)*

TA of the tomato decreased with an increase in the period of storage in all the packaging materials used. The lowest TA was observed in no packaging storage while the unperforated plastic packaging showed significantly higher TA (Table 4).

Table 4 - Effect of different packaging materials on TA content of tomato

| Treatments | TA of tomato | | |
|---|---|---|---|
| | 6 DAS | 12DAS | 18DAS |
| T1 | 0.697 e | 0.613 e | 0.303 d |
| T2 | 0.987 a | 0.863 a | 0.563 a |
| T3 | 0.750 c | 0.640 cd | 0.367 b |
| T4 | 0.990 a | 0.853 a | 0.550 a |
| T5 | 0.767 b | 0.670 b | 0.353 b |
| T6 | 0.713 d | 0.647 c | 0.326 c |
| T7 | 0.703 de | 0.627 de | 0.323 c |
| Grand mean | 0.80 | 0.701 | 0.398 |
| LSD | 0.013 *** | 0.016 *** | 0.016 *** |
| CV(%) | 0.9% | 1.28% | 2.33% |

Means in the column followed by similar letters are not statistically different at p=0.05 by LSD.
DAS=Days after Storage, LSD = Least significant difference, CV = Coefficient of variance, * significant at 5%, ** significant at 1%, ***significant at 0.1% level of significance.

*The pH of the juice*

The pH of the tomato increased with the increase in the storage days for all the packaging material. The pH was found more in open tray conditions and low in unperforated polyethylene. The higher the barrier to the gases through the packaging film, the lower was the PH (Table 5).

*Shelf life*

The longest shelf life was observed in perforated LDPE (24 days) and the shortest in no packaging (16 days) (Fig. 3).

## 4. Discussion and Conclusions

The weight loss of the tomatoes is primarily due to the loss of water from transpiration and respiration (Singh, 2010). Lower weight loss in all the pack-

Table 5 - Effect of different packaging materials on PH content of tomato

| Treatments | PH of tomato | | |
|---|---|---|---|
| | 6DAS | 12DAS | 18DAS |
| T1 | 4.13 a | 4.30 a | 4.53 a |
| T2 | 3.80 d | 4.03 c | 4.20 d |
| T3 | 3.95 b | 4.17 b | 4.30 bc |
| T4 | 3.83 cd | 4.00 c | 4.20 d |
| T5 | 3.93 b | 4.17 b | 4.26 cd |
| T6 | 3.90 bc | 4.00 c | 4.33 bc |
| T7 | 4.10 a | 4.12 ab | 4.37 b |
| Grand mean | 3.95 | 4.12 | 4.31 |
| LSD | 0.074 *** | 0.114 *** | 0.076 *** |
| CV(%) | 1.07% | 1.59% | 1.01% |

Means in the column followed by similar letters are not statistically different at p=0.05 by LSD.
DAS= Days after Storage, LSD= Least significant difference, CV= Coefficient of variance, * significant at 5%, ** significant at 1%, *** significant at 0.1% level of significance.

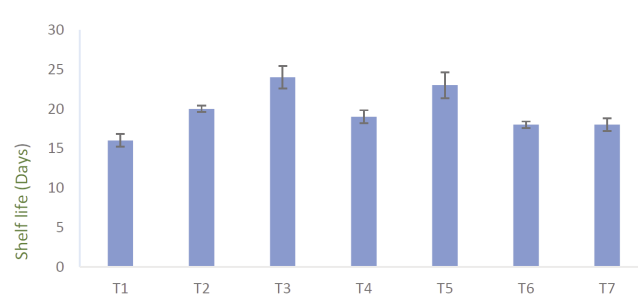


Fig. 3 - Effect of different packaging material on shelf life of tomato.

aged fruits as compared to control could be due to a lower rate of transpiration and counteraction of excessive moisture loss which was similar to the results presented by Gonzalez *et al*. (1990) and Nath *et al.* (2011). The difference in weight losses of fruits among different films could also be largely due to differences in transmission rates of water vapor through the packaging film (Batu and Thompson, 1998). Here the lower transmission rate of polyethylene packages might contribute to the development of higher relative humidity inside the package thereby reducing weight loss (Thompson, 2001). Batu and Thompson (1998) also found less weight loss in sealed packed tomatoes after 60 days of storage at 13°C. A modified atmosphere is created around the fruits due to the permeable nature of the film. During the storage, the $CO_2$ concentration accumulates inside MAP restricting the respiration of the produces thereby reducing weight loss and prolonging the shelf life (Selçuk *et al*., 2020). Similarly, higher weight loss was observed in macro-perforated packages than any of the unperforated packages due to higher permeability to gases and water vapor (Van Der Steen *et al*., 2002). Similar might be the case for non-woven packages where the bag itself has a low barrier to the exchange of gases even without any perforations resulting the higher weight loss.

Lycopene pigment is the primary reason for the development of the color in tomatoes. As the ripening proceeds, lycopene content increases. However, in presence of low oxygen, the formation of lycopene is inhibited resulting in the slow development of color. Due to low $O_2$, high $CO_2$, or the suitable combination of these two gases, there could be retardation of color change in tomato fruits (Kidd and West, 1930). Yang and Chinnan (1987) also found that there Is less accumulation of lycopene in sealed packaged tomatoes with fewer chroma values than that of control treatment. Lycopene formation was found to be completely inhibited at 1% $O_2$ and 99% N2 for 50 days of storage (Yang *et al*., 1987). Ethylene is responsible for triggering the ripening of tomatoes and it is associated with a sudden change in the physiology of tomatoes at the onset of ripening. $CO_2$ concentration affected the development of color in tomatoes by suppression of ethylene production (Kubo and Inaba, 1989). While exposing the tomatoes to high levels (20, 40, and 60%) of $CO_2$, color development was inhibited in tomatoes (Buescher, 1979).

The TSS content of fruit determines its overall taste (Baldwin *et al*., 1998). Getinet *et al*. (2008) have reported a low total soluble solid at the color breaker stage but higher when tomato fruits were harvested at the pink mature stage. The increase in TSS with the increase in maturity could be attributed to the breakdown of starch to simple sugars or the hydrolysis of cell wall polysaccharides (Crouch, 2003). The lower TSS in packed tomatoes as compared to the open storage could be due to a slower rate of respiration and metabolic activities that slow down the ripening process in packed tomatoes (Gharezi *et al*., 2012). However, the higher TSS observed in non-woven treatment might be attributed to the relatively faster rate of respiration resulting by the comparatively higher air permeability of the bag. The more TSS is related to more ripen of fruit (Dhakal *et al*., 2020). However, the rapid increment in TSS is not desirable as it causes rapid shriveling and decreases the shelf life.

Priyankara *et al*. (2017) also found the titratable acidity reaching the peak at the color breaker stage and decreasing along with the advancement of fruit ripening. Since the acidity of the fruit is due to the presence of various organic acids, the amount of organic acid is usually found decreasing during maturity as being a substrate of respiration (Albertini *et al*., 2006). The slow rate of decrement of TA in unperforated plastic packaging could be attributed to the reduced $O_2$ and increased $CO_2$ inside the packages that result in the slow rate of respiration (Mathooko, 2003); thus, it may impede the loss of organic acids (Wang, 1990). Even so, the rapid decrement of TA in non-woven packages could be ascribed to the exchange of gases good enough to deplete the organic acid. Every factor that is responsible for reducing cellular respiration and catabolism prevent the reduction of organic acid in the product (Feizi *et al.*, 2020). De Castro *et al*. (2005) also reported the decrement in acidity with maturity evolution.

The difference in the pH and TA in different packages is attributed to the variations in respiration rate and enzyme activities (Feizi *et al*., 2020). Organic acid being an intermediate of carbon metabolism increase the pH of the produce. The higher pH under the open tray could be associated with the faster utilization of acids for sugar catabolism. For a similar reason, pH is higher in the non-woven bag as compared to others owing to increased $O_2$ inside the packages engendered by the air enterable nature of the bag. The significantly lower pH values of unperforated packaged fruits could be explained by the relatively reduced respiration rate due to reduced $O_2$ inside the packages. The increase in the PH of the fruits during storage was also observed by Batu and Thompson

(1998).

The difference in the shelf life was due to the difference in marketability of fruits due to the decaying of fruits by fungus or shriveling of the fruits unacceptably. Unperforated plastic packaging showed the highest percentage of fungus attacks that could be probably due to higher relative humidity inside the packages. The non-woven fabric bag allows access to air sufficient enough to escape the modified atmospheric condition resulting relatively higher shriveling and weight loss ensued from faster ripening and transpiration and ultimately over-ripening.

The beneficial effect of perforated plastic packaging could be attributed to the well-modified atmosphere created inside the package along with the reduction in water loss. Lower rate of respiration and ethylene production inhibited ethylene action, delayed ripening and senescence, impeded growth of decay-causing pathogens and insects due to gaseous modification inside the package could be the probable reason to extend the shelf life of fruits (Kader and Rolle, 2004). Ben-Yenonshuna (1985) also reported the delayed ripening and softening in the case of packaging of climacteric fruits in low-density polyethylene bags and hence improving marketability.

Thus, packaging significantly affected various quantitative and qualitative post-harvest properties. All the packaging system was found to be better than open tray storage. The permeability of packaging material had a huge influence on the composition of the internal atmosphere and the creation of optimal storage conditions. Very low permeability would induce fungal growth due to high relative humidity and high permeability would result in higher weight loss due to faster respiration. Therefore, it is necessary to establish an optimal condition that may be an equilibrium-modified atmosphere that avoids both of these problems. Based on the result of this experiment, perforated plastic bag (both HDPE and LDPE) was discovered to be best among all packaging treatments for reducing weight loss, avoiding fungal growth, and maintaining a better quality of tomatoes for a longer duration.

## References

ALBERTINI M.V., CARCOUET E., PAILLY O., GAMBOTTI C., LURO F., BERTI L., 2006 - *Changes in organic acids and sugars during early stages of development of acidic and acidless citrus fruit.* - J. Agric. Food Chem., 54: 8335-8339.

BALDWIN E.A., EINSTEIN J.W., MALUNDO M.A., CARR T.M.M., 1998 - *Relationship between sensory and instrumental analysis of tomato flavor*. - J. Biol. Chem., 193: 265-275.

BEN-YENONSHUNA S., 1985 - *Individual seal packaging of fruits and vegetables in plastic film new postharvest technique.* - J. Hort. Sci., 20: 32-37.

BHATTARAI D.R., GAUTAM M.D., 2006 - *Effect of harvesting method and calcium on postharvest Physiology of Tomato*. - Nepal Agric. Res. J., 4(7): 37-41.

BUESCHER R.W., 1979 - *Influence of Carbondioxide on Postharvest Ripening and Deterioration of Tomatoes*. - J. Amer. Soc. Hort. Sci., 104(4): 545-547.

CROUCH I., 2003 - *1-Methylcyclopropene (SmartfreshTM) as an alternative to modified atmosphere and controlled atmosphere storage of apples and pears*. - Acta Horticulturae, 600: 433-436.

DAY B.P.F., 2001 - *Modified atmosphere packaging of fresh fruit and vegetables - An overview*. - Acta Horticulturae, 553: 585-590.

DE CASTRO L.R., VIGNEAULT C., CHARLES M.T., CORTEZ L.A., 2005 - *Effect of cooling delay and cold-chain breakage on 'Santa Clara' tomato*. - J. Food, Agric. Environ., 3: 49-54.

DHAKAL A., PAHADI K., ADHIKARI S., GHIMIRE P., SUBEDI S., GHIMIRE D., 2020 - *Effect of different plastic packaging on postharvest quality of tomato* (Lycopersicon Esculentum *Mill).* - Tropical Agroecosystems, 1(1): 21-24.

FAO, 1989 - *Document repository, prevention of post-harvest food losses. Fruits, vegetables and root crops: A training manual.* - Forest Finance Working Paper 17-2.

FARBER J.M., 1991 - *Microbiological aspects of modified-atmosphere packaging technology. A review*. - J. Food Prot., 54(1):58-70.

FEIZI H., KAVEH H., SAHABI H., 2020 - *Impact of different packaging schemes and transport temperature on post-harvest losses and quality of tomato (*Solanum lycopersicum l.*)*. - J. Agric. Sci. Techn., 22(3): 801-814.

GETINET H., SEYOUM T., WOLDETSADIK K., 2008 - *The effect of cultivar, maturity stage and storage environment on quality of tomatoes.* - J. Food Engin., 87: 467-478.

GHAREZI M., JOSHI N., SADEGHIAN E., 2012 - *Effect of postharvest treatment on stored cherry tomatoes*. - J. Nutrition Food Sci., 2(8): 1-10.

GONZALEZ G., YAHIA E.M., HIGUERA I., 1990 - *Modified atmosphere packaging (MAP) of mango and avocado fruit.* - Acta Horticulturae, 269: 1-12.

KADER A.A., ROLLE R.S., 2004 - *The role of postharvest management in assuring the quality and safety of horticultural produce.* - FAO, Rome, 152: 1010-1365.

KADER A.A., ZAGORY D., KERBEL E.L., 1989 - *Modified atmosphere storage of fruits and vegetables.* - CRC Critical Rev. Food Sci. Nutrition, 28: 1-30.

KIDD F., WEST C., 1930 - *The gas storage of fruit. II. Optimum temperatures and atmospheres.* - J. Pomol. Hort. Sci., 8: 67-83.

KUBO Y., INABA A., 1989 - *Effects of High $CO_2$ on respiration in various horticultural crops.* - J. Japan. Soc. Hort. Sci., 58(3): 731-736.

MATHOOKO F.M., 2003 - *A comparison of modified atmosphere packaging under ambient conditions and low temperatures storage on quality of tomato fruit*. - Afr. J. Food Agric. Nutr. Dev., 3: 20-27.

MOALD, 2019/2020 - *Statistical Information on Nepalese Agriculture*. - MOALD, Ministry of Agriculture and Livestock Development, Singha Durbar, Kathmandu, Nepal.

NATH A., DEKA B.C., SINGH A., PATEL R.K., PAUL D., MISRA L.K., OJHA H., 2011 - *Extension of shelf life of pear fruits using different packaging materials.* - J. Food Sci. Techol., 49: 556-563.

PRIYANKARA G.G.D.S., KARUNARATHNE C.L.S.M., SARANANDA K.H., ARIYARATNE M., 2017 - *Effect of maturity stage on ripening and quality characters of four tomato (*Solanum lycopersicum L*.) varieties of Sri Lanka.* - Tropical Agric. Res., 28(4): 496.

SELÇUK E.G., ÜNAL S., KÜÇÜKBASMACI SABIR F., 2020 - *Influence of modified atmosphere packaging on the postharvest quality and chilling injury of tomato harvested at different maturity stages*. - Selcuk J. Agric. Food Sci., 34(2): 148-153.

THOMPSON A.K., 2001 - *Controlled atmosphere storage of fruits and vegetables*. - CAB International, Wallingford, Oxfordshire, UK, pp. 272.

TIWARI I., SHAH K.K., TRIPATHI S., MODI B., SHRESTHA J., PANDEY H.P., BHATTARAI B.P., RAJBHANDARI B.P., 2020 - *Post-harvest practices and loss assessment in tomato (*Solanum lycopersicum L.) *in Kathmandu, Nepal.* - J. Agric. Natural Resources, 3(2): 335-352.

VAN DER STEEN C., JACXSENS L., DEVLIEGHERE F., DEBEVERE J., 2002 - *Combining high oxygen atmospheres with low oxygen modified atmosphere packaging to improve the keeping quality of strawberries and raspberries*. - Postharvest Biol. Technol., 26: 49-58.

WANG C.Y., 1990 - *Alleviation of chilling injury of horticultural crops*, pp. 281-302. - In: C.Y. WANG (eds.) *Chilling injury of horticultural crops.* CRC Press, Boca Raton, Florida, USA, pp. 328.

YANG C.C., BRENNAN P., CHINNAN M.S., SHEWFELT R.L., 1987 - *Characterization of tomato ripening process as influenced by individual seal-packaging and temperature.* - J. Food Quality, 10(1): 21-33.

YANG C.C., CHINNAN M.S., 1987 - *Computer modeling of color development of tomatoes in modified atmosphere storage*. - Trans. Amer. Soc. Agric. Eng., 30: 548-553.