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REGULAR ARTICLE

Tomato quality as influenced by different packaging materials and practices

Zewdie Tsegahun Mekonnen*

Department of Food Engineering, Bahir Dar Institute of Technology, Bahir Dar, Ethiopia.

Abstract

In this study, the effect of retailing packaging material on tomato quality was investigated. Specifically, non-defective tomato fruits were selected after harvest and packed in four different packaging materials; open market bag, open box, sealed box and Xtend bag. A total of six treatments were prepared by storing the packaged fruits at 4 or 17°C for 10 days. Quality attributes of tomatoes such as calyx freshness, weight loss, fruit firmness, total soluble solids (TSS), colour and physiological damage were assessed. Generally, both packaging material and storage temperature affected the quality of the tomato fruits. The quality of tomato fruits stored at 40C was generally superior to those stored at 17°C.Calyx of tomato fruits stored in open market bag (stored at 17°C) and open box (stored at 17°C) were very dry after storage compared to the tomato fruits stored at 4°C. Tomato fruits packed in Xtend bag and sealed box were firmer than those packed in open box and open market bag. The carbon dioxide (CO_2) concentration in sealed box was substantially higher (8.25%) than that in Xtend bag (2.07%). In contrast, the oxygen (O2) concentration in the Xtend bag was higher (18.90%) than that in the sealed box (14.75%). Tomatoes packed in Xtend bag and sealed box had minimal changes in colour intensity (C*), showed lower TSS values compared to tomato fruits packed in other packaging materials. Xtend bag and sealed box seems to be better packaging material for storing tomato fruits for a period of 10 days.

Key words: Retailing packaging materials, tomato quality, physiological damage, storage temperature, calyx freshness

Introduction

Tomato (*Lycopersicon esculentum* Mill. or *Solanum lycopersicum*) is an important fruit vegetable consumed all over the world. The consumption of tomato in recent time has increased due to the associated benefits of some phytochemicals including carotenoids. Carotenoids are responsible for the colour in tomatoes which are synthesized massively during fruit ripening (Guil-Guerrero and Rebolloso-Fuentes, 2009). Other notable component of tomatoes is vitamin C. Depending on variety and growing conditions, the vitamin C content of tomatoes may vary between 39-263 mg/100 g (Guil-Guerrero and Rebolloso-Fuentes, 2009). For instance, tomatoes grown on organic substrates were found to contain significantly more Ca and vitamin C than tomatoes grown on hydroponic media (Premuzic et al., 1998). Tomatoes may be eaten either raw or cooked.

Fresh produce quality generally decreases after harvest. The decrease in quality could be attributed to the respiratory activity that continues after harvest. Since there is a

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*Corresponding Author

Zewdie Tsegahun Mekonnen

Department of Food Engineering, Bahir Dar Institute of Technology, Bahir Dar, Ethiopia

Email: tsegmek@yahoo.com

growing demand for fresh fruits and vegetables, due to the increased consumption of these commodities, many industries are employing different methods to improve the quality of fresh produce. Several methods including temperature control, use of efficient packaging materials, product pre-treatment and the use of fruits with initial good quality are being used to maintain or reduce the postharvest losses of fresh commodities. Tomato is an important commodity both for the fresh and processing markets (Fagundes et al., 2015). The shelf life of tomatoes is relatively short (Hoeberichts et al., 2002) due to different postharvest physiological, physical and chemical changes that occurs during storage (Fagundes et al., 2015). These changes are triggered by the production of ripening hormone called ethylene (Carrari and Fernie, 2006). Hence, postharvest handling of tomatoes is essentially targeted at reducing the rate of respiration and the concomitant control of the ethylene production (Fagundes et al., 2015; Martínez-Romero et al., 2007). Many strategies and techniques are being investigated to reduce these changes in fruits and to enhance the keeping quality.

Being a climacteric and perishable vegetable, tomatoes have a very short lifespan, usually 2 to 3weeks (Sibomana et al., 2015). Hence, tomato fruits must be properly handled after harvest in order to maintain quality and enhance consumer appeal during sale. The quality of tomato is determined by appearance, firmness, flavour and the nutritive value. These quality parameters are affected by several factors including, variety, agronomic practices, method of harvesting, time of harvesting, postharvest handling techniques, packaging materials and storage conditions. Packaging generally helps to protect and retain the quality of fresh horticultural produce and reduces damage during transport. Sammi and Masud (2009) reported that packaging can significantly reduce fruit weight loss of tomatoes when sealed in plastic films and can extend the marketable life. Since consumers are interested in produce with good quality and long shelf life, it is important to package fresh commodities in materials that will meet these requirements. In general, packaging material will not only hold the food substance, but will also protect it from contamination. They also extend the marketable life of the product (Sammi and Masud, 2007). However, the type or quality of packaging material may also influence the product quality. For example, tomato packed in polyethylene bags showed significantly lower weight loss (approx. 10%) compared to tomato fruits packed in grease free papers, which showed approximately 20% weight loss after 28 days of storage at ambient temperature of 32±2°C (Shahnawaz et al., 2012). Commercially, different packaging materials are used in the wholesale and retail market for the sale of fresh produce such as tomatoes. As stated above, the properties of these packaging materials may influence the product quality. Hence, this study investigates the influence of retail packaging; open box, open market bag, Xtend bags and sealed box on the quality of freshly harvested tomato fruits.

Materials and Methods

Materials and chemicals

Fresh matured pink tomatoes as identified using a color chart (Fig. 1) with uniform color and sizes and without bruises or signs of infection were collected from the Postharvest laboratory. The tomatoes were sorted, cleaned and packaged in open box, open market bag, Xtend bags and sealed box (Fig. 2). Distilled water was used for cleaning purposes and calibration of equipment.

Methods

Weight loss

The individual weight of tomatoes used for the experiment was taken using a digital analytical balance. After weighing and performing other analysis on the fruits, the tomatoes were transferred to the storage room in different packaging materials. The weight loss was calculated as shown in Equation 1

$$\% \text{ weight loss} = \frac{W_o - W_t}{W_o} \times 100 \qquad \text{Equation 1}$$

W_o= Average weight of the tomatoes at day 0
W_t= Average weight of the tomatoes after storage

Fig. 1. Colour classification of tomatoes (Based on Jones, 2007)

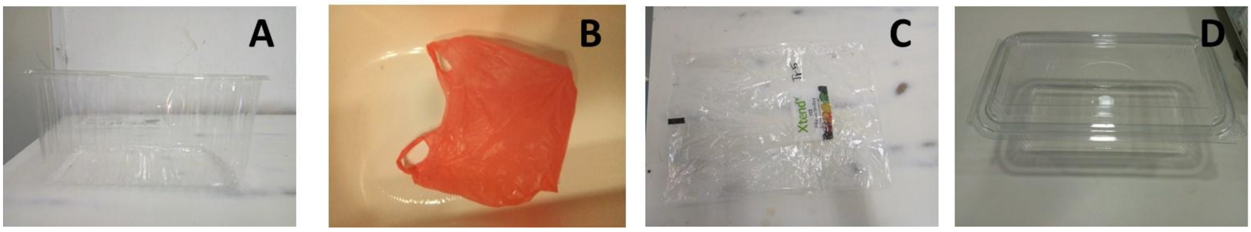

Fig. 2. Packaging materials. A: Open box, B: Open market bag, C: Xtend bag, D: Sealed box.

Firmness

Fruit firmness was determined using a hand pressure gauge by pressing the probe of the gauge against the fruits. The pressure gauge was applied around the circumference of the fruits on opposite sides. Firmness was determined using the scale 0-20 (very soft), 20-30 (soft), 30-40, (flexible), >50 (very firm).

Colour

Tristimulus L*, C* and h parameters of the tomatoes were determined using a colorimeter after calibration. Snapshots in triplicates were taken and values were read directly from a digital print.

Decay

Tomatoes were checked for decay by visualization before and after storage.

Calyx freshness

The freshness of the calyx was observed physically and graded as very fresh or less fresh with values ranging from 5 to 1 (1= very fresh, 2=fresh, 3=not fresh, 4= dry with some green, 5= dry

Total soluble solids (TSS)

The measurement was done using both dilute and non-diluted methods as suggested by Laure (2001) and as explained by Abdul-Rahaman and Peter (2017). The TSS of the tomatoes was determined using a digital refractometer after calibration using distilled water. Tomato fruits were cut with a sterile knife and the juice from the pulp squeezed out using gauze. The juice was placed on the surface of the refractometer and the value read directly from the instrument. The same procedure was repeated for the stored samples.

Storage

All the tomatoes in the primary packages were transferred into a secondary package (Fig. 2), a box and stored at 4 or 17^{o}C for 12 days. Thereafter, the analyses described above were repeated to check for changes in quality.

Sensory evaluation

Tomato fruits were cleaned and sliced thinly and presented to taste panel members comprising of five panelists. The fruits were assessed for sweetness, sourness, off-flavour, texture and overall acceptability on a scale ranging from 1 to 5.

Results

Physical damage

Tomato fruits used before the experiment had no bruises. However, after the storage period, some of the samples showed evidence of bruises. Some tomato fruits packed in open box and open market bag (stored at 17ºC) and those packed in open market bag and sealed box (stored at 4ºC) had bruises as shown in Fig. 4. There were no bruises in any of the samples packed in open box (stored at 4ºC) and those packed in Xtend bag (stored at 4ºC).

Calyx freshness

The calyx of all the tomato fruits prior to storage were very fresh as observed using a scale of 1 (very fresh) to 5 (very dry). However, after packing and storage at different temperatures of 4 and 17ºC, there were differences in their calyx freshness. Tomato fruits packed in open market bag (stored at 4ºC) and Xtend bag (stored at 4ºC) had values of 2 suggesting that they were fresh after storage (Fig. 5). Samples packed in open box (stored at 17ºC) and open box (stored at 4ºC) were dry but still had some green (value of 4). However, tomato fruits packed in sealed box (stored at 4ºC) had intermediate value of 3, which indicated that they were not fresh.

Physiological damage

There was no evidence of decay in the tomato fruits packaged in all the packaging materials used except the open market bag stored at 17ºC (Fig. 5).

Fig. 3. Tomato fruits showing sections of physical damage or bruise.
Tr_1: open box stored at 17ºC, Tr_2: open market bag stored 17ºC, Tr_3: open box stored at 4ºC
Tr_4: open market bag stored at 4ºC, Tr_5: Xtend bad stored at 4ºC, Tr_6: sealed box stored at 4ºC

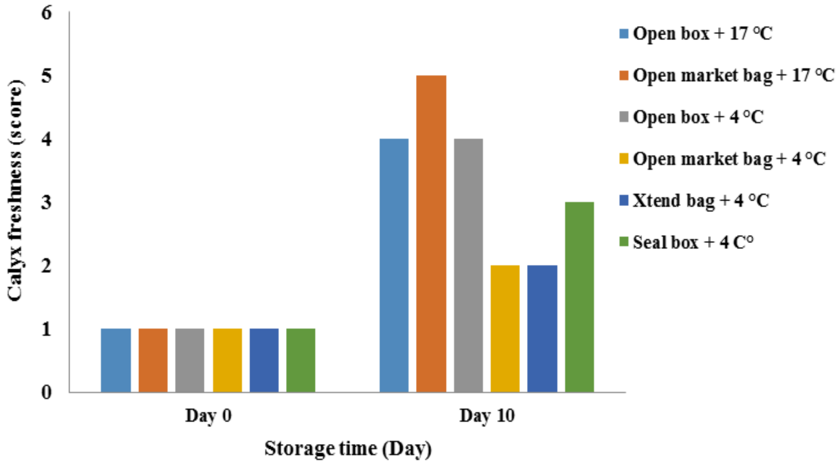

Fig. 4. Calyx freshness of tomato fruits packed in different packaging materials stored at 4 or 17ºC.

Fig. 5. Evidence of physiological damage for tomato fruit packed in open market bag (17°C).

Firmness

The average initial firmness of the tomato fruits was 43.25 N (Table 1). However, the firmness generally decreased after storage. Tomato fruits packed in Xtend bag (stored at 4°C) were firmer (42.67 N) than samples packed in other packaging materials (32.56-40.50 N). The reduction in firmness of the tomatoes occurred slowly at lower temperatures (4°C) than at higher temperature (17°C), for the same period of storage (10 days).

Weight loss

Tomato fruits packed in open box stored at 4 or 17°C showed higher weight loss than other samples (Table 1).

Total soluble solids (TSS)

The average TSS of the tomato fruits was 3.90°Brix (Table 1). TSS in all treatments increased after storage and varied from 3.99-4.53 °Brix for tomatoes packed in Xtend bag (stored at 4°C) and tomatoes packed in open box (stored at 17°C) (Table 1). Tomatoes stored at 4°C had lower TSS values (3.99-4.08 °Brix) compared to those stored at 17°C (4.11-4.53°Brix).

Gas composition

In order to understand the influence of respiration on changes in tomato quality, the gas compositions in Xtend bag (stored 4°C) and sealed box (stored 4°C) containing tomato fruits were determined. Other packaging materials were opened; hence, the gas compositions were not determined. The carbon dioxide (CO_2) concentration in sealed box was substantially higher (8.25%) than that in Xtend bag (2.07%) (Fig. 6). In contrast, the oxygen concentration in the Xtend bag was higher (18.90%) than that in the sealed box (14.75%).

Colour

Generally, the lightness (L*) and hue (H) angle values of tomatoes in different packaging materials at 4 and 17°C decreased after storage (Table 2). However, the Chroma (C*) values increased

Sensory evaluation

The tomato fruits were subjected to organoleptic assessment to ascertain the sweetness, sourness, off-flavour, texture and overall acceptability after storage. Tomato fruit packed in open box stored at (17°C) had higher rating for sweetness, while samples in sealed box (stored at 4°C) had the lowest rating (Table 3). The tomatos packed in sealed box (stored at 4°C) were very sour compared to other treatments. All the treatments had similar ratings of 0 for off-flavour. Texture ratings for all the tomatoes stored at 17°C were softer than samples stored at 4°C. In the overall sensory evaluation, the rating for overall acceptability was not very different.

Table 1. Weight loss, firmness and total soluble solids of packaged tomato fruits stored at 4 or 17°C.

T	ST	Packaging	Weight loss (%)		Firmness (N)		TSS (°Brix)	
			D 0	D 10	D 0	D 10	D 0	D 10
1	17	Open box	0.00	5.14 ± 0.99	43.25 ± 6.72	32.56 ± 5.82	3.90± 0.17	4.53 ± 0.23
2	17	Open market bag	0.00	1.02 ± 0.58	43.25 ± 6.72	34.44 ± 4.61	3.90± 0.17	4.11 ± 0.15
3	4	Open box	0.00	4.10 ± 1.10	43.25 ± 6.72	38.44 ± 3.72	3.90± 0.17	4.08± 0.25
4	4	Open market bag	0.00	0.60 ± 0.31	43.25 ± 6.72	39.17 ± 4.02	3.90± 0.17	4.05± 0.32
5	4	Xtend bag	0.00	0.64 ± 0.25	43.25 ± 6.72	42.67 ± 2.67	3.90± 0.17	3.99± 0.14
6	4	Seal box	0.00	0.51 ± 0.13	43.25 ± 6.72	40.50 ± 2.28	3.90± 0.17	4.01± 0.23

T: Treatments, ST: Storage Temperature, TSS: total soluble solids.

Table 2. Colour changes of tomato fruits packaged in different packaging materials stored at 4 or 17°C.

T	ST	Packaging	L*		C*		Hue angle	
			D 0	D 10	D 0	D 10	Day 0	D 10
1	17	Open box	50.06 ± 1.96	46.10 ± 1.68	16.69 ± 2.59	19.47 ± 2.09	81.35 ± 10.25	36. 57 ± 7.29
2	17	Open market bag	50.55 ± 2.63	46.22 ± 2.10	18.01 ± 2.82	20.97 ± 1.91	80.24 ± 17.49	40.13 ± 7.62
3	4	Open box	50.4 ± 1.76	49.54 ± 2.13	17.56 ± 2.47	18.07 ± 2.42	85.95 ± 13.18	66.23 ± 10.85
4	4	Open market bag	49.66 ± 1.06	47.26 ± 1.04	15.85 ± 1.91	20.16 ± 2.41	83.32 ± 8.13	66.71 ± 6.53
5	4	Xtend bag	49.40±1.28	49.39 ± 1.31	15.91 ± 2.53	16.29 ± 2.86	78.02 ± 16.70	60.33 ± 7.70
6	4	Seal box	50.04 ± 1.97	48.78 ± 2.87	15.40 ± 1.90	17.83 ± 2.39	71.93 ± 14.73	59.75 ± 8.35

T: Treatments, ST: Storage Temperature

Table 3. Mean sensory scores of tomato fruits packaged in different packaging materials stored at 4 or 17°C

T	ST	Packaging	Sweetness (1-5)	Sourness (1-5)	Off-flavour (0-3)	Texture (1-5)	Overall (1-5)	Preference
1	17	Open box	4	2	0	1	4	
2	17	Open market bag	3	1	0	2	3	
3	4	Open box	3	3	0	4	3	
4	4	Open market bag	3	2	0	4	3	
5	4	Xtend bag	3	2	0	4	4	
6	4	Seal box	2	5	0	4	3	X
			Very sweet -5 No sweet -1	Very sour -5 No sour -1	High off flavor -3 No off flavor -0	Very firm -5 Soft -1	Very good -5 bad -1	X

T: Treatments, ST: Storage Temperature

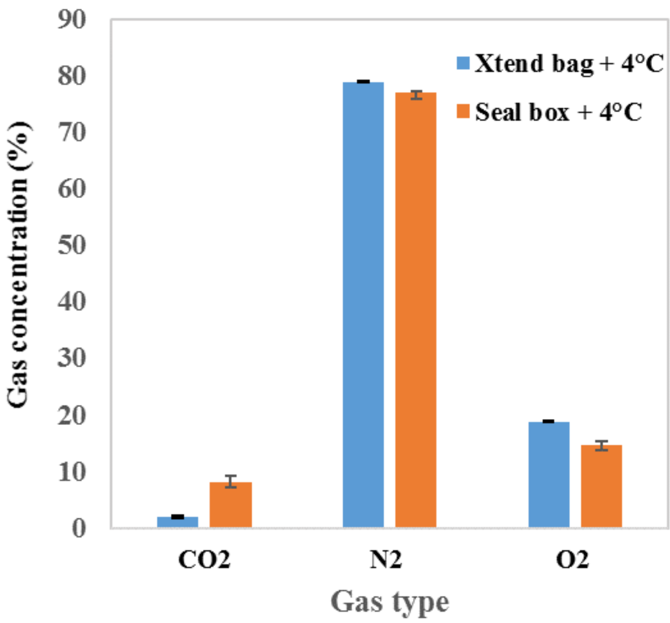

Fig. 6. Gas composition of tomato fruits packed in Xtend bag and sealed box stored at 4°C.

Discussion

Packaging can create modified gas atmospheres around the product which slows down the respiratory activity of fruits including tomatoes. Tomato is a climacteric fruit that is very perishable and requires adequate packaging and control of temperature to extend its shelf life. In this study, four retail packaging were used to pack tomato fruits and the packaging materials were stored at refrigeration (4°C) or ambient temperature (17°C). Generally, packaging material and storage temperature both influenced the quality of the tomato fruits. However, storage temperature contributed significantly to the maintenance of calyx freshness to some extent than did packaging materials. This seems plausible since the calyx of tomato fruits stored in open market bag (stored at 17°C) and open box (stored at 17°C) were very dry after storage compared to the tomato fruits stored at 4°C. Similarly, it was observed that temperature significantly influenced the extent of decay in the tomato fruits. Only tomato fruit stored in open market bag at 17°C showed evidence of decay. This possibly suggests the impact of temperature in reducing the growth of microorganisms during storage, since decay may be associated with the growth of microorganisms.

The firmness of the tomato fruits was significantly affected by packaging material and temperature of storage (Table 1). Firmness is an important parameter used by the consumer to determine the final quality of tomato fruits. Tomato fruits packed in Xtend bag and sealed box were firmer than those packed in open box and open market bag. The lower firmness of tomato fruits packed in open box and open market bag may be attributed to two major factors. Firstly, these packaging materials are open and samples may lose water rapidly, leading to reduction in firmness. Another factor that could cause reduced firmness is the extent of tissue softening due to enzymatic degradation of pectic substances by pectinmethylesterase and polygalacturonase. According to Vu et al. (2004), pectin degradation results in drastic changes in texture with an evident softening of the tomato tissues. These degradative enzymes are sensitive to oxygen. Thus, the availability of oxygen in the open box and open market bag may have enhanced the degradative process of pectin breakdown, leading to reduction in firmness. Furthermore, temperature also seems to play significant role in the reduction in the firmness of the tomato fruits. Irrespective of the packaging material, tomatoes stored at 4°C were firmer than those stored at 17°C (Table 1). This could be associated with the influence of temperature on the rate of reaction, suggesting higher water loss and higher enzyme activity at elevated temperature. Pinheiro et al. (2013), used that Arrhenius model to describe the effect of temperature on changes in firmness and weight loss of stored tomato fruits. Previous research also associated higher weight loss in stored tomato at room temperature to increased transpiration rate (Getinet et al., 2008; Javanmardi and Kubota, 2006).

In order to understand the influence of respiration on changes in tomato quality, the gas compositions in Xtend bag (stored 4°C) and sealed box (stored 4°C) containing tomato fruits were determined. Other packaging materials were opened; hence, the gas compositions were not determined. The carbon dioxide (CO_2) concentration in sealed box was substantially higher (8.25%) than that in Xtend bag (2.07%) (Fig. 6). In contrast, the oxygen (O_2) concentration in the Xtend bag was higher (18.90%) than that in the sealed box (14.75%). Fresh commodities are living tissue which continue to use up available $O_2$for respiration after harvest. Thus, the lower CO_2 with corresponding higher O_2 in the Xtend bag suggest that the Xtend bag is capable of reducing the rate of respiration in tomato fruits and thus extend it shelf life. Changes in colour of tomatoes during storage were minimal in Xtend bag compared to other packaging materials (Table 2). The result suggests that Xtend bag is capable of controlling the exchange gases to maintain the quality of tomato fruits, especially at low temperature. Tomatoes packed in Xtend bag and sealed box were firmer (Table 1) and had minimal changes in colour intensity (C*) (Table 2) compared to tomato fruits packed in other packaging materials. The colour result correlates with the TTS result of the tomato fruits. TSS is one of the quality indices used to assess the sweetness in tomatoes. It appeared that the Xtend bag and sealed box were able to delay the ripening process during storage since the tomatoes packed in these packaging materials showed lower TSS values (Table 1) and minimal changes in colour intensity (C*) (Table 2) compared to tomato fruits packed in other packaging materials.

Conclusions

Packaging material type and storage temperature both significantly influenced the calyx freshness, colour, firmness and sensory quality of tomato fruits. Tomato stored at low temperatures of 4°C generally had better firmness, colour and calyx freshness than those stored at room temperature (17°C). Among the packaging materials, Xtend bag and sealed box seems to be better packaging material for storing tomato fruits for a period of 10 days.

Recommendation

Tomato fruit may be stored using Xtend bag or sealed box at 4°C for up to 10 days without significant changes in quality, since these conditions retained fruit firmness, delay fruit ripening and had no signs of decay during storage. Future studies using these packaging materials should focus on extended storage period up to one month to evaluate the possible occurrence of physiological changes such as chilling injury and changes in lycopene and ascorbic acid contents. Weight loss, decay and rapid deterioration are major factors that determine the storage conditions of tomato fruits.

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