

Investigation of Active Modified Atmosphere and Nanoparticle Packaging on Quality of Tomatoes

M. Ghasemi-Varnamkhasti, S. H. Yoosefian, A. Mohammad-Razdari

Abstract—This study investigated the effects of Ag nanoparticle polyethylene film and active modified atmosphere on the postharvest quality of tomatoes stored at 6 °C. The atmosphere composition used in the packaging was 7% O₂ + 7% CO₂ + 86% N₂, and synthetic air (control). The variables measured were weight loss, firmness, color and respiration rate over 21 days. The results showed that the combination of Ag nanoparticle polyethylene film and modified atmosphere could extend the shelf life of tomatoes to 21 days and could influence the postharvest quality of tomatoes. Also, existence of Ag nanoparticles caused preventing from increasing weight loss, a*, b*, Chroma, Hue angle and reducing firmness and L*. As well as, tomatoes at Ag nanoparticle polyethylene films had lower respiration rate than Polyethylene and paper bags to 13.27% and 23.50%, respectively. The combination of Ag nanoparticle polyethylene film and active modified atmosphere was effective with regard to delaying maturity during the storage period, and preserving the quality of tomatoes.

Keywords—Ag nanoparticles, modified atmosphere, polyethylene film, tomato.

I. INTRODUCTION

INCREASING growth in the consumption of fresh fruits and vegetables has created a demand for improving storage and prevent disease and maintain quality [1]. Tomato is the second most important vegetable crops in Iran and is an important agricultural commodity due to its high nutritional value. Tomato consumption is high due to its effect on reducing cancer [2]. The most important quality factors for marketing include size, strength, color, taste and nutritional content [3].

Packaging process has a special position in the food industry. Researchers evaluated different types of polymers as base film for production type of packaging. Polyethylene used in many cases has a wide range of physical properties. The main reason for its compliance with various application, it lies in the configuration of semi-crystalline and molecular variables that can control the process during packaging [4]. Today, added metal materials, micro and nanostructure polymers in contact with food for increasing mechanical properties and improving barrier properties and to avoid reducing photo degradation rubber [4]-[6]. Among the metal cautions, Ag ion has the highest antimicrobial activity against

a wide variety of microorganisms [7]. It has long-term antimicrobial activity and it can be added to plastics [8].

Modified atmosphere packaging (MAP) [9], [10] and controlled atmosphere (CA) storage of fresh produce have long been used as a means to prolong shelf-life by reducing the overall physiological activity in tomatoes. Depleted O₂ and/or enriched CO₂ levels can reduce respiration, delay ripening, decrease ethylene production, retard textural softening, and slow down compositional changes associated with ripening, thereby resulting in an extension of shelf life [3]. Generally, 3-8% CO₂ and 2-5% O₂ are recommended for fruits and vegetables for MAP storage [11].

The aim of this study was to determine the influence of MAP specifications on respiration, ethylene production rates and overall physical and chemical quality of tomatoes using Ag nanoparticles polyethylene film.

II. MATERIALS AND METHODS

A. Harvest and Storage Condition

Tomatoes (Roma variety) used in the experiments were harvested from a local place in Hamadan, Iran in 2015. Fresh samples were selected from visual defects or damage and uniform size, color and then packaged into paper bags. Before each experiment, tomatoes were selected according to size within 20–30 mm diameter, red color (more than 80% of the surface showed red color).

The samples were stored at 6 °C in refrigerator and all of the tests were done for three weeks during storage. During the storage period, the relative humidity (RH) of the atmosphere ranged to 65±4%. For each day of analysis, three packages were used. All experiments and analyses were carried out in triplicate [12].

B. Film Fabricating

In this work, medium density polyethylene from Iran Polymer and Petrochemical Institute was used. Ag nanoparticles in size of 35-nanometer were purchased from Notrino China Company. In order to mix the raw materials and making nanopolymer film, extrusion process was used for extruder. The different extruder zones temperature from the feeder to the output was prepared 125, 145, 155, 170, 185, 195, 195 and 200 °C, respectively. Extruder pressure was 12.5 bar and the melting temperature was 200 °C. Ensuring from path clean and creation of appropriate conditions, polyethylene and metal nanoparticle (in the percentage of weight 0.5 and 1%) well mixed together, and was feed through the hopper into the chamber extruded. Materials pass through the extruder and melt mixed completely by imposing shear

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forces and pressure together. The melt was passing out from extruder terminal and then was inserted to cold water pool. At this level, prepared granules were inserted from the feeder into the machine and after heating and mixing, as a thin film on a

roll at the same time playback and multi-roller cooling with cold sequential extraction and were rotated at the end of the tubular device. The extruder temperature of different parts was 239, 239, 223, 223, 218, 215, 185 °C, respectively [13].

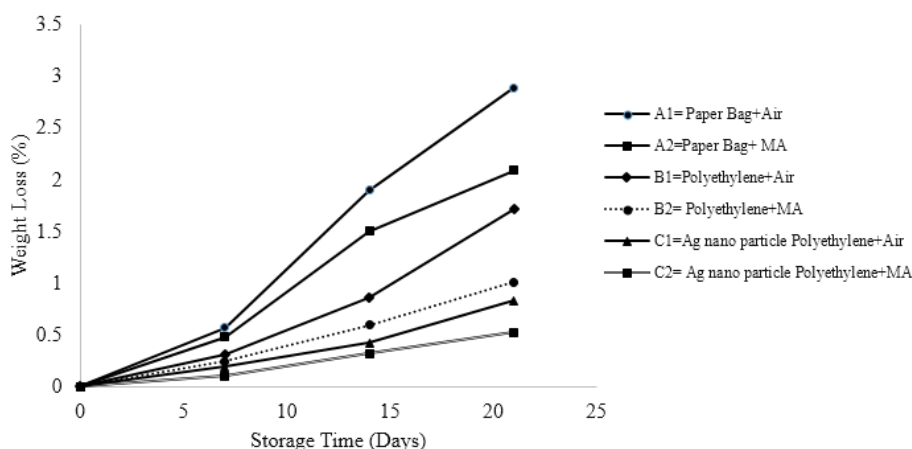


Fig. 1 Weight loss of tomatoes under MAP (7% O₂, 7% CO₂, and 86% N₂) and air (control) in nanoparticle Polyethylene film for 21 days at 6 °C

1. Headspace Gases and Packaging

For the MAP of the tomatoes, the headspace gases used were 7% CO₂, 7% O₂ and 86% N₂ obtained from Glove Box (VBOX 2 – HSM) and air (as a control). The mixed gases had a purity of 99.9%. For the sake of simplicity, they will be referred to as: A1 = paper bag + air; A2 = paper bag + 7% CO₂, 7% O₂ and 86% N₂; B1 = Polyethylene Film+ air; B2 = Polyethylene Film + 7% CO₂, 7% O₂ and 86% N₂; C1 = Ag nanoparticle Polyethylene Film + air; C2 = nanoparticle Polyethylene Film + 7% CO₂, 7% O₂ and 86% N₂.

2. Weight Loss

To calculate weight loss, the difference between initial and final samples weight was considered as total weight loss during each storage interval and calculated as percentages on a fresh-weight basis by the standard AOAC (2005) method [14]. Tomato samples were weighed non-destructively on days 0, 7, 14 and 21 days.

3. Surface Color

The surface tomato color was measured with a portable colorimeter (HP-200, China). Standard white plate (CR-A43) was used to calibrate colorimeter. CIE color space coordinates L* (Lightness), a* (red-green), b* (yellow-blue), Chroma and Hue angle were recorded by using colorimeter.

4. Firmness

Compression force was determined using a digital texture analyzer Instron (500 N, Xforcehp, Germany) with following conditions: test speed of 3 mm/s, pre-test speed of 20 mm/s and strain of 25%. Then, the curve of force versus time was depicted by texture exponent software and firmness and resilience parameters of the tomatoes were automatically calculated using same software.

5. Respiration Rate

Headspace gases CO₂ and O₂ were measured using portable gas analyzer (Checkmate 9900, Ringsted, Denmark) after removal from refrigerator. Interned injector device into bags, then closed suction 5 ml of gas in the device and report automatically oxygen and carbon dioxide gas concentration inside the packages. Gas samples were analyzed from three replicates of each non-destructive sample. The respiration rates of O₂ consumption and CO₂ evolution were obtained from a CO₂ and O₂ concentrate. A computer program was developed using the MATLAB software (Mathworks Inc., USA) to determine the respiration rates using the model proposed by Lee et al. [15] according to (1):

$$r_{O_2} = -\frac{d[O_2]}{100dt} \left(\frac{V}{m} \right) + \frac{SP_{O_2} (0.21 - [O_2/100]) p}{mL} \quad (1)$$

where r_{O_2} is the respiratory rates for O₂ consumption expressed as mg kg⁻¹ s⁻¹, [O₂] is the concentrations of O₂ expressed as %, L is the thickness of the film in m, S is the area of the bag (m²), PO₂ is the permeability of the film for O₂, respectively (mL m⁻² s⁻¹ Pa⁻¹), t is the time in h, V/m is the free volume in the bag (mL) and m is the mass of product in the bag (kg).

6. Statistical Analysis

Analysis of variance (ANOVA) was performed using general linear model in SAS 9.1.3. Statistical Software and LSD test for the parameters weight loss, firmness, color parameters and respiration rate (significance level p < 0.05). The study was repeated three for each replicate.

III. RESULTS AND DISCUSSION

A. Weight Loss

Fig. 1 shows the weight loss of tomatoes stored in Ag nanoparticles Polyethylene films and modified atmosphere containing 7% O₂, 7% CO₂, and 86% N₂ and atmosphere containing synthetic air (control) for 21 days at 6°C. According to the results, using packaging, the weight losses after 21 days of storage for A1 (Paper bag + air); A2 (Paper bag + 7% CO₂, 7% O₂ and 86% N₂); B1 (Polyethylene Film + air); B2 (Polyethylene Film + 7% CO₂, 7% O₂ and 86% N₂); C1 (Ag nanoparticle Polyethylene Film + air); C2 (nanoparticle Polyethylene Film + 7% CO₂, 7% O₂ and 86% N₂) treatments were around 3.4%, 2.10%, 1.82%, 1.5%, 1.2% and 0.78%, respectively. For all of treatments, weight loss increased throughout the storage period; however, it was lower than the values obtained in the previous studies for unpackaged tomatoes. According to results, Polyethylene films influenced on weight loss of tomatoes that's because its tissue with increasing of storage time and their interstitial water has been dried. Of course, due to biological activity breathing decreased moisture content but Polyethylene film prevent decreasing [16].

B. Color

Color change is an indication of the shelf life and maturity of fruits and vegetables. Table 1 shows the results obtained for the color of tomatoes. Changes in the parameter a* occurred after 21 days of storage for A1 (Paper bag + air); A2 (Paper bag + 7% CO₂, 7% O₂ and 86% N₂); B1 (Polyethylene Film + air); B2 (Polyethylene Film + 7% CO₂, 7% O₂ and 86% N₂); C1 (Ag nanoparticle Polyethylene Film + air); C2 (nanoparticle Polyethylene Film + 7% CO₂, 7% O₂ and 86% N₂) to 25.68, 25.13, 23.18, 21.93, 21.63 and 21.70, respectively, that indicating increased red coloration. According to results, a* changes are lower for tomatoes at nanoparticle Polyethylene Film with modified atmosphere. Control samples showed significant changes ($p < 0.05$) in all parameters. Also, L parameter decreased to 27.10, 27.39, 29.14, 29.34, 31.27 and 31.56 for A1, A2, B1, B2, C1, C2, respectively. Such changes indicate a significant increase in red color throughout the storage period. Color changes were more pronounced for the control samples. The difference between the Chroma (C) values during storage for control samples can indicate slight saturation of red color of samples, although Chroma is not a good indicator of tomato ripening because it essentially is an expression of the purity or saturation of a single color.

C. Firmness

Firmness of cherry tomatoes stored in MAP for 25 days at 5°C is shown in Fig. 2. The Firmness decreased over storage for samples stored for all of samples. Samples stored at Ag nanoparticles Polyethylene films with modified atmosphere (7% CO₂, 7% O₂ and 86% N₂) have more firmness than Polyethylene films with modified atmosphere and paper bags with modified atmosphere to 2.3% and 3.7%, respectively. These results indicate that Ag nanoparticles the modified

atmosphere and reduced fruit softening and maintained firmness throughout storage compared to the control. In the literature, firmness is known to be related to cell turgor pressure, cell size, cell wall strength and intercellular adhesion in the cells [17]. In general, for samples into polyethylene bags and with metal nanoparticles retarded the loss of tomatoes firmness compared to other treatments. Control and samples into polyethylene and paper bags and without metal nanoparticles tomatoes had the lower firmness values during storage.

D. Respiration Rate

The values for respiration rate of tomatoes stored in Ag nanoparticles Polyethylene films in modified atmosphere containing 7% O₂, 7% CO₂, and 86% N₂ and atmosphere containing synthetic air (control), for 21 days at 6°C are shown in Fig. 3. In the first hours of product storage, the respiration rate is high due to the greater amount of O₂ available. In the following hours, the respiration rate decreases due to the reduction of the amount of O₂ available for consumption by the fruit. The respiration rate (consumption rate of oxygen) for samples A1, A2, B1, B2, C1 and C2 decreased to 2.37, 2.34, 2.15, 2.06, 2.00 and 1.79 $\times 10^{-3}$ mgkg⁻¹s⁻¹. Odriozola-Serrano et al. [18] reported a significant reduction in O₂ concentration in the package headspace over time when fresh-cut tomatoes were preserved at 5°C compared with those stored under elevated temperatures [18]. Similar values were found by Goyette et al. [19].

TABLE I
COLOR INDICES OF TOMATOES STORED IN MODIFIED ATMOSPHERE AND
ATMOSPHERE CONTAINING SYNTHETIC AIR (CONTROL) IN TREATMENT FOR
21 DAYS AT 6 °C

Treatment	Storage Time (Days)	a*	b*	L*	Chroma	Hue Angle
A ₁	0	17.53 ^a	17.30 ^a	32.18 ^a	25.60 ^a	43.80 ^a
	7	22.69 ^b	20.56 ^b	29.07 ^a	26.79 ^b	45.27 ^b
	14	23.73 ^a	22.70 ^a	28.27 ^a	27.14 ^a	46.39 ^b
	21	25.68 ^a	23.31 ^a	27.10 ^a	29.09 ^b	48.12 ^a
A ₂	0	17.30 ^a	17.83 ^b	31.81 ^{ab}	24.82 ^a	42.93 ^a
	7	22.19 ^{ab}	20.73 ^{ab}	29.13 ^b	26.72 ^a	44.63 ^{ab}
	14	23.49 ^{ab}	22.35 ^{ab}	28.70 ^b	27.91 ^b	45.93 ^{ab}
	21	25.13 ^a	23.12 ^a	27.39 ^{ab}	29.61 ^{ab}	47.52 ^{ab}
B ₁	0	17.64 ^a	18.52 ^a	31.15 ^{ab}	25.29 ^a	43.51 ^{ab}
	7	20.10 ^b	19.49 ^{ab}	30.19 ^a	26.41 ^a	44.63 ^b
	14	22.72 ^b	19.98 ^a	29.31 ^a	27.38 ^{ab}	45.61 ^b
	21	23.18 ^a	22.24 ^{ab}	29.14 ^a	28.31 ^b	46.39 ^b
B ₂	0	18.07 ^a	18.43 ^a	31.72 ^{ab}	24.94 ^b	44.05 ^a
	7	19.34 ^a	19.31 ^b	30.43 ^{ab}	25.37 ^a	45.21 ^a
	14	20.39 ^b	19.97 ^b	29.73 ^{ab}	26.79 ^{ab}	46.17 ^{ab}
	21	21.93 ^a	22.49 ^{ab}	29.34 ^a	28.67 ^{ab}	47.43 ^{ab}
C ₁	0	17.96 ^a	17.89 ^a	33.91 ^a	25.16 ^a	44.13 ^{ab}
	7	18.75 ^{ab}	18.28 ^a	33.20 ^b	26.41 ^a	44.76 ^{ab}
	14	20.17 ^a	20.46 ^a	33.09 ^b	26.97 ^a	45.61 ^{ab}
	21	21.63 ^{ab}	21.83 ^a	31.27 ^a	27.76 ^{ab}	46.58 ^{ab}
C ₂	0	17.47 ^a	18.53 ^b	33.16 ^a	25.12 ^a	43.91 ^{ab}
	7	18.12 ^a	18.93 ^{ab}	33.05 ^b	25.83 ^a	44.37 ^a
	14	19.07 ^a	20.37 ^a	32.52 ^b	26.34 ^b	44.98 ^a
	21	21.70 ^b	20.79 ^a	31.56 ^{ab}	27.49 ^a	45.73 ^a

The respiration rate of the tomatoes in the Ag nanoparticles Polyethylene films packaging material controls the gas composition in the packages. Also, Ag nanoparticles prevent

changes due to tissue fungus and destroy and it also helps to prevent Intermolecular changes. Both A nanoparticle and Polyethylene film factors are, in the next turn influenced by temperature and the initial gas composition [20].

In Table I, a-b means in the same column with different letters are significantly different according to LSD multiple comparison test ($p \leq 0.05$) applied after an ANOVA. A1 (Paper bag + air); A2 (Paper bag + 7% CO₂, 7% O₂ and 86% N₂); B1 (Polyethylene Film + air); B2 (Polyethylene Film + 7% CO₂, 7% O₂ and 86% N₂); C1 (Ag nanoparticle Polyethylene Film + air); C2 (nanoparticle Polyethylene Film + 7% CO₂, 7% O₂ and 86% N₂)

IV. CONCLUSION

Results of this study showed that the Ag nanoparticles Polyethylene film with combination modified atmosphere which can be beneficial for tomatoes stored at 6 °C differ

markedly from when fruit are stored at paper package with air. For all of treatments, weight loss and firmness increased and decreased throughout the storage period; however, it was lower than the values obtained for tomatoes in paper bags and with atmosphere air. Also, color changes indicate a significant increase in a*, b*, Chroma and Hue angle throughout the storage period and L* decreased, too. Color changes were more pronounced for the control samples. In the first hours of product storage, the respiration rate is high due to the greater amount of O₂ available. In the following hours, the respiration rate decreases due to the reduction of the amount of O₂ available for consumption by the fruit. Ag nanoparticles prevent changes due to tissue fungus and destroy and it also helps to prevent Intermolecular changes. Finally, according to results, combination of Ag nanoparticles Polyethylene films packaging with modified atmosphere is a suitable method for preservation of tomatoes for transportation and exporting.

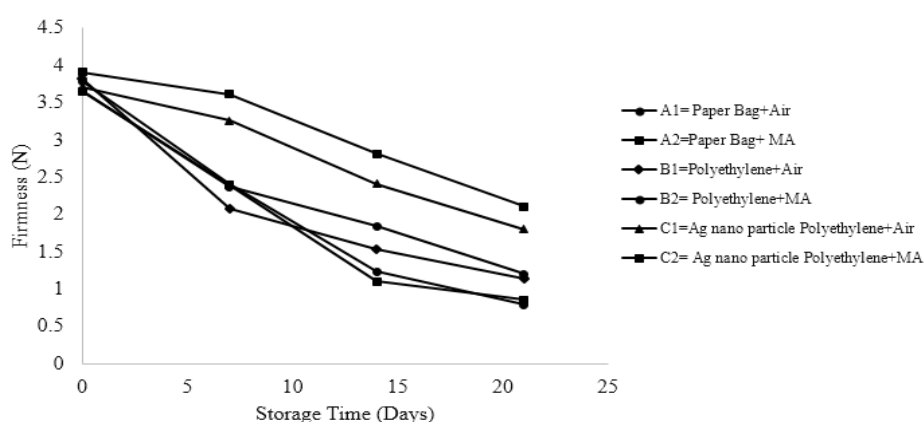


Fig. 2 Firmness of tomatoes stored in modified atmosphere and atmosphere containing synthetic air (control) in A1, A2, B1, B2, C1 and C2 for 25 days at 5°C

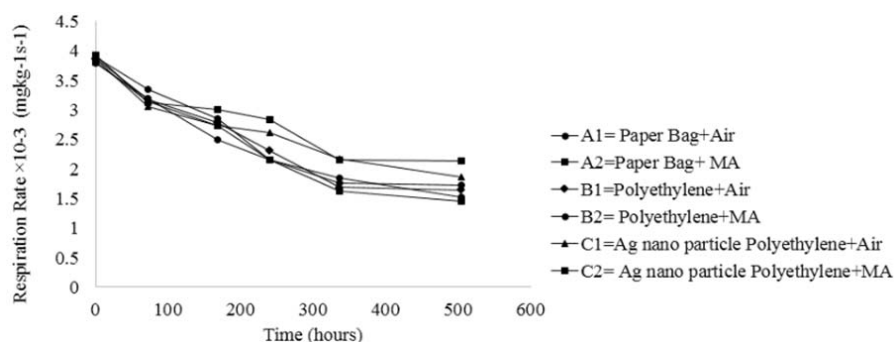


Fig. 3 Respiration rate based on O₂ consumption of tomatoes stored in Ag nanoparticles Polyethylene films with modified atmosphere and atmosphere containing synthetic air (control), for 21 days at 6 °C

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