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ACTIVE PACKAGING USING ETHYLENE ABSORBER TO EXTEND SHELF-LIFE

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ABSTRACT

Ethylene gas is a plant hormone which is produced by fruits and vegetables during ripening and it is also found in the environment. It plays an essential role in normal ripening, but excessive exposure can radically reduce the shelf-life of the product, in some cases inducing undesirable reactions such as development of bitter flavors and loss of chlorophyll (yellowing of greens). The objectives of our work were (1) to test an active packaging of poly vinyl alcohol (PVA) for apple stored; (2) to test the effect of ethylene absorber agent, impregnated in plastic film, to reduce decay of fresh apple; (3) to study the influence of radiation on the barrier properties, mechanical properties and biodegradability of PVA films. This study evaluated the effect of coating produced from PVA and polyol (glycerol and sorbitol) as plasticizer on apple conservation (75°F (24°C); 70%RH). The coated product was analyzed for mass loss, color alterations and fungi. The PVA films were produced by casting process (dehydration of a filmogenic solution on Petri plastic dishes) and were irradiated at low doses of 2, 5 and 10 kGy, commonly used in food irradiation. The resulting films were transparent and homogeneous. The active packaged fruits presented higher acceptance, lower microbiological growth, less alterations in acidity, lower weight loss rate during the storage time and an extended shelf-life as compared to the control fruits (without plastic films).

1. INTRODUCTION

Recently, new food-packaging systems have been developed as an answer to trends in consumer preferences towards mildly preserved, fresh, tasty and convenient food products with a prolonged shelf-life. Active packaging changes the condition of the packaged food to extend shelf-life or improve food safety or sensory properties, while maintaining the quality of the packaged food [1]. Nowadays much attention has been paid to biodegradable polymers, such as the biodegradable poly vinyl alcohol (PVA), a non-toxic synthetic polyester that presents high tensile strength and flexibility, as well as high oxygen and aroma barrier properties [2,3].

Ethylene gas, a plant hormone, is produced by fruits and vegetables during ripening and is also found in the environment. It plays an essential role in normal ripening, but excessive exposure can radically reduce the shelf-life of the product, in some cases inducing undesirable reactions such as development of bitter flavors and loss of chlorophyll (yellowing of greens).

The objectives of our work were (1) to test an active packaging of PVA for apple stored; (2) to test the effect of ethylene absorber agent to reduce decay of fresh apple and (3) to study the solubility, water vapor permeability and the mechanical properties of PVA films with different irradiation doses (2, 5 and 10 kGy).

2. EXPERIMENTAL

2.1. Materials

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The following materials were used to prepare the film: poly vinyl alcohol (PVA) (synth), glycerol (synth), sorbitol (synth) and polyethylene film for domestic use (fischer S.A).

2.2. Methods

2.2.1. Sample Preparation. The PVA films were produced by casting process (dehydration of a filmogenic solution) from solutions of PVA (2.5g) in water (100mL) on Petri plastic dishes. The solution was heated to 140ºF (60°C) to dry and then a transparent film was formed.

2.2.2. Gamma Irradiation. Samples were irradiated at room temperature in air, in a Co-60 irradiator (model JS7500) of 700.000 Ci, operating at 5.0kGy/h (total doses of (2±0.4); (5±1) and (10±2) kGy).

2.2.3. Water Vapor Transmission (WVT). The WVT was determined according to ASTM E96-80 [4] modified by Gontard et al. [5]. A container with silica gel was closed with a sample of film firmly fixed on top. Then the container was placed in a desiccator with distilled water at a temperature of 25.0 ^{o}C. The films were weighed daily on a Mettler analytical balance during 10 days. Water vapor transmission (WVT) was calculated according to equation 1:

$$WVT = \frac{w.x}{A} \qquad (1)$$

Where WVT is Water Vapor Transmission (g H_2O. mm.cm^{-2}), x is the average thickness of the film (0.055 ± 0.010 mm) and A is the permeation area (23.76 cm^{2}).

2.2.4. UV-Vis Spectroscopy. UV-Vis spectra were obtained on a UV-Vis spectrometer Shimadzu UV-2401 model at a range 200-800nm.

2.2.5. Mechanical Properties. Tensile strength and percentage elongation were measured according to ASTM-D D412-98a (ASTM, 1998) [6] using a Mechanical Universal Testing Machine Instron 4400R, with a 50 N load cell and at a velocity of 1.0 mm/s. Test samples were cut in dumb-bell Die F dimensions according to the ASTM standard method. The films have been equilibrated at a 25ºC and 60% relative humidity (RH) for 2 days prior to measurement. A commercial polyethylene film was also measured to compare the mechanical properties to PVA films. The results are the average of four samples.

2.2.6. Solubility in water. Solubility was measured by submerging two pre-weighed film samples for 15minutes at room temperature. Afterwards, the films were dried to constant weight at 131ºF (55°C). The solubility of each film was determined according to the expression (2):

$$\%MS = \frac{M_i - M_f}{M_i} x100 \qquad (2)$$

Where %MS is percentage of soluble mass, M_i is initial mass of the film and M_f is final mass of the film.

2.2.7. Biodegradability. Samples (63.0cm^2) of PVA films (0 and 10kGy) were weighed and buried in compost of municipal solid waste (pH=8.0) at 66ºF (19ºC). Biodegradation films were monitored every 2 or 5 days for two months by measuring the mass retention. The mass retention was determined according to the expression (3):

$$M_r = \frac{M_f}{M_0}.100 \qquad (3)$$

Where M_r is mass retention, M_0 is initial mass of the film and M_f is final mass of the film.

3. RESULTS AND DISCUSSION

This work reports the influence of radiation on the barrier properties (water vapor permeability (WVP) and solubility), mechanical properties and biodegradability of PVA films alone or with ethylene absorber agent. These films were prepared by casting from solution. The PVA, PVA/sorbitol and PVA/glycerol films are transparent enough, with good mechanical properties and potential application for food packaging. PVA films with ethylene absorber agent showed more yellowing. Solubility, tensile strength and percent elongation of PVA films with different irradiation doses and glycerol and sorbitol concentrations are shown in Table 1. A commercial polyethylene film was also measured to compare the mechanical and barrier properties to PVA films.

As it can be seen in table 1, the mechanical characteristics (tensile strength and elongation) and barrier properties (solubility and WVP) are influenced by irradiation dose: an increase in radiation dose resulted in a considerable increase of the tensile strength and elongation of the films, whereas WVT and solubility can be significantly reduced applying low gamma radiation doses (Fig. 2). Addition of polyol (glycerol and sorbitol) to the PVA films resulted in plasticization of the polymer matrix as reflected by lower strength but higher elongation values (table 1). Tensile strength and percent elongation of PVA films (30.5±1.0MPa, 53.2±1.2%) were lower than the ones of the PE film (40.98±0.4MPa, 71.0±0.5%). However, applying low gamma radiation doses to the PVA/glycerol and PVA/sorbitol (2 and 5kGy) films resulted in improvement of the mechanical properties and also of the tensile strength and percent elongation. There were no significant difference of the tensile strength and percent elongation when compared to the PVA/glycerol (2kGy) (42.2±0.8MPa, 69.7±0.6%) and PE films (40.98±0.4MPa, 71.0±0.5%).

PVA films had been reported to be ineffective moisture barriers due to their hydrophilic nature [7], [8]. In the present work, PVA films were irradiated at low doses of 2, 5 and 10 kGy, commonly used in food irradiation, in an attempt to improve the water-resistance properties of PVA film. As it can be seen in Fig. 1, WVP of films decreased significantly by irradiation.

Table 1. Mechanical properties and solubility of the gamma irradiated PVA films.

Irradiation Dose (kGy)	PVA	Glycerol	Sorbitol	Water	Tensile strength (MPa)	Elongation (%)	Solubility (%)
0	2.5%	-	-	97.5%	30.5±1.0	53.2±1.2	95.3±1.8
	2.5%	1%	-	96.5%	40.2±0.8	64.7±0.6	
	2.5%	-	1%	96.5%	35.9±1.2	60.7±0.4	
	2.5%*	-	-	97.5%	32.2±0.7	50.8±1.0	29.5±1.6
2	2.5%	-	-	97.5%	36.5±1.0	60.2±1.2	50.5±1.0
	2.5%	1%	-	96.5%	42.2±0.8	69.7±0.6	
	2.5%	-	1%	96.5%	35.9±1.2	62.7±0.4	
5	2.5%	-	-	97.5%	36.5±1.0	65.2±1.2	57.3±1.5
	2.5%	1%	-	96.5%	51.2±0.8	68.7±0.6	
	2.5%	-	1%	96.5%	38.9±1.2	64.7±0.4	
10	2.5%	-	-	97.5%	20.5±1.0	36.2±1.2	66.7±2.1
	2.5%	1%	-	96.5%	36.2±0.8	40.7±0.6	
	2.5%	-	1%	96.5%	28.9±1.2	41.7±0.4	

* with ethylene absorber agent (0,02%)

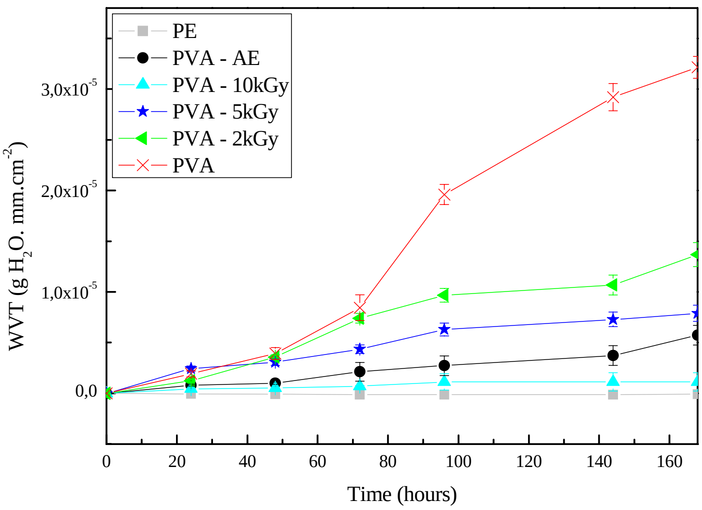

Figure 1. Barrier properties of PVA films (0, 2, 5 and 10 kGy), PVA-AE (PVA with ethylene absorber agent) and PE (commercial polyethylene film). WVP = water vapor permeability.

PVA films, prepared by casting process, were examined for biodegradation by composting over 60 days (Fig. 2).

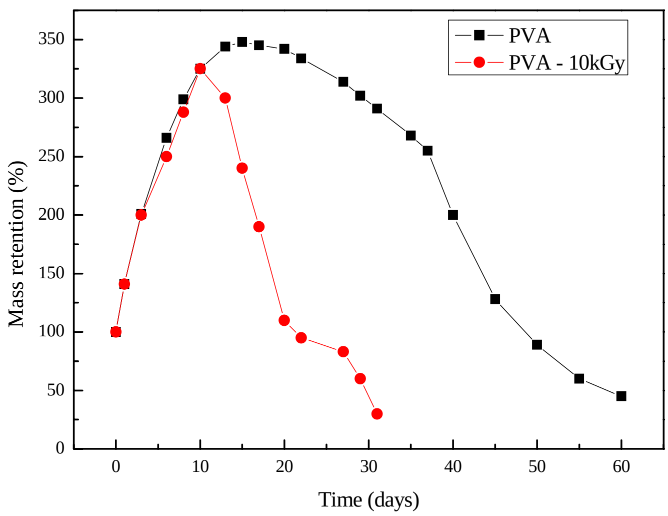

Figure 2. Biodegradation curves of PVA films (0 and 10kGy) in simulated soil.

Biodegradation of non-irradiated PVA was relatively slower, with losses of 45% after 60 days compared to the PVA irradiated with 10kGy (30% after 30 days). This is probably due to the film degradation at this level dose. The gamma radiation effect on the mechanical properties of PVA was also evident as demonstrated previously (table 1). Tensile strength and percent elongation of PVA films irradiated with 10kGy (20.5±1.0MPa; 36.2±1.2%) were significantly lower when compared to the PVA non-irradiated film (30.5±1.0MPa; 53.2±1.2%).

Fresh apples stored under atmospheric conditions had a shelf life of only 20 days (in PE packaging) which was mainly limited by its sensory acceptance and microbial spoilage. In the present work, we tested the effect of ethylene absorber agent, impregnated in plastic film of PVA (0kGy) to reduce decay of fresh apple. Fresh apples were stored without plastic films (control fruits) and in PVA, PVA-AE (PVA film with ethylene absorber agent) and PE packagings at 75°F (24°C) and 70%RH during 40 days. The thickness of PE, PVA-AE and PVA packaging were 0.055 ± 0.010 mm. The active packaged fruits presented higher acceptance, lower microbiological growth, showed less alterations in acidity, lower weight loss rate during the storage time and an extended shelf-life, as compared to the control fruits (without plastic films). The apples packaged under PVA films with ethylene absorber agent presented shelf life of 30 days showing good sensory acceptance throughout the storage period. The results from measurements of weight loss of fresh apples stored in PVA films, PE film and without plastic films are given in Fig. 3.

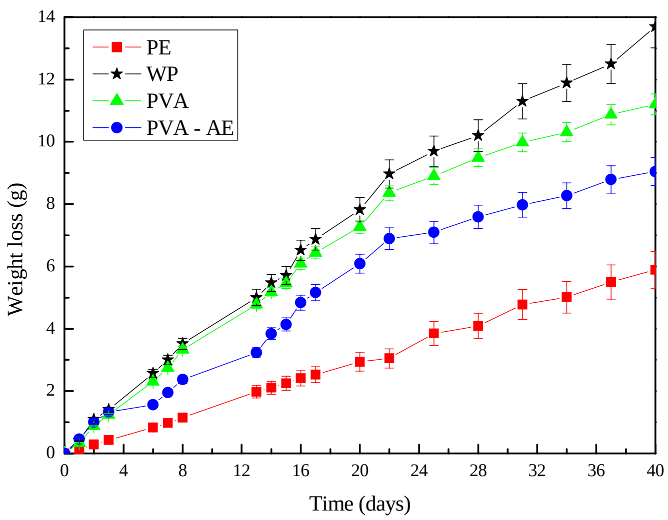

Figure 3. Weight loss rate during the storage time of fresh apples in polyethylene film (PE), without plastic film (WP), in PVA film and in PVA film with ethylene absorber agent (PVA-AE). Thickness of films were 0.055 ± 0.010 mm.

The apples stored in PE had less mass loss than the ones wrapped in PVA, PVA-AE films and also when compared to the ones with no packaging at all. The PVA-AE films are the most effective in apple storing because they are less permeable to water vapor when compared to the PVA films (Fig. 1). It explains why the apples wrapped with PVA-AE had less mass loss and still presented the active ingredient that extends the apples shelf-life. In 40 days, in room temperature, a significant increase in the humidity of apples in polyethylene was observed while no significant differences were noted with PVA packaging.

3. CONCLUSIONS

Gamma irradiation can be a useful tool as a cross-linking agent of PVA.

Adding of glycerol (1%) or sorbitol (1%) and irradiation with 2kGy was estimated as the optimum value.

Addition of polyol (glycerol or sorbitol) to the PVA films resulted in plasticization of the polymer matrix as reflected by higher percent elongation and lower tensile strength values.

PVA film with ethylene absorber agent was able to extend the shelf-life of fresh apples in 10 days.

We intend to test the effect of ethylene absorber agent, impregnated in PVA films irradiated at 2 and 5kGy.

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