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Influence of hydroxypropyl methylcellulose edible coating on fresh-keeping and storability of tomato*

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Abstract: The effect of application of cellulose-based edible coating, hydroxypropyl methylcellulose (HPMC) to mature-green tomatoes on the firmness and color was investigated. Tomatoes were stored at 20℃ for up to 18 days. Firmness decreased as storage time increased in all treatments. However, application of HPMC edible coating delayed softening of tomatoes during 18 days of storage at 20℃. At days 7, 13 and 18, the firmness of tomatoes coated with HPMC was significantly ($P \leqslant 0.05$) greater than the firmness of uncoated tomatoes. The study also confirmed that HPMC coatings could significantly ($P \leqslant 0.05$) delay the changes in color of tomatoes stored at 20℃. The ripening of tomatoes from the pink stage to the red stage was successfully retarded. HPMC coating could extend the shelf life of fresh tomatoes. The retardation of the rate of loss of firmness could reduce the economic loss that would result from spoilage by mechanical injury during transportation of tomatoes.

Key words: Hydroxypropyl methylcellulose, Edible coating, Tomato, Fresh-keeping, Storage
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INTRODUCTION

Discarded non-degradable plastic films widely used in food packaging cause "white pollution" to the environment. In recent years, the use of plastic packing for food is restricted or prohibited in some developed countries. So "green packaging", including edible packaging are becoming more widely used than before since it does not cause any environmental pollution problem.

Edible films and coatings generally can be defined as thin layers of edible material applied on (or even within) foods by wrapping, immersing, brushing or spraying in order to impose a barrier against the transmission of gases, vapors and solutes while also giving mechanical protection (Donhowe et al., 1994). Compared with plastic films, edible films and coatings generally have lower oxygen and carbon dioxide permeabilities (Park et al., 1994); and so, have been used successfully for preserving fresh fruits and vegetables. By inhibiting water loss and controlling the rate of oxygen and carbon dioxide migration, edible coatings can retain fresh produce quality and extend shelf life. Edible films can also be used to retard changes in textural properties.

Applications and properties of proteins, carbohydrates, and lipids used as bases for edible-film formulations were reviewed by Kester et al. (1986) and Guilbert (1986). Protein and polysaccharide coating can be used as barriers to oxygen and carbon dioxide transmission, but are poor barriers to moisture transfer. Covering fresh fruits and vegetables with waxes and lipids to retard desiccation is an accepted practice. In the 12th century, the Chinese were already using wax for coating oranges and lemons to retard water loss (Hardenberg, 1967; Labuza et al., 1981). Mixtures of sucrose fatty acid esters had been used in coatings to extend the shelf life of fresh fruits and vegetables by reducing the rate of postharvest physiological activities and thus delaying changes in color and firmness (Banks, 1984; Santerre et al., 1989; Smith et al., 1984).

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Park et al. (1992; 1994) reported that coating tomatoes with a corn-zein film reduced the respiration rate. This technique would result in a delay of the ripening of tomatoes and maintain firmness, and also could retard the ripening of tomatoes from the pink stage to the red stage. The storage life of tomatoes could be prolonged by about 6 days.

The half-ripe to fully-ripe tomatoes can be eaten without cooking. However, due to rapid ripening in the climacteric phase of respiration they have a short shelf life under normal commercial conditions. Thus, tomatoes transported and stored commercially should be harvested at mature-green stage of maturity and ripened during postharvest storage by treatment with ethylene. The quality of ripened mature-green tomatoes is close to that of those fully ripened on the plant (Ye, 1992); so mature-green tomatoes were used as material in this study.

Cellulose derivatives of methylcellulose (MC), hydroxypropyl methylcellulose (HPMC), and hydroxypropyl cellulose (HPC), have excellent film-forming characteristics. HMPC is easier to prepare than HPC and so was used in this study to coat mature-green tomatoes. The objective of this study was to determine the effects of the edible coatings on the firmness and color changes of tomatoes during storage.

MATERIALS AND METHODS

1. Preparation of hydroxypropyl methylcellulose films and dipping solutions

HPMC is easy dissolved in ethanol solution. Coating solutions were prepared by dissolving 9 g of HPMC (Aldrich Chemical Company, Inc, Milwaukee, WI) in 300 ml of 63% or 72% ethanol; 1 ml of polyethylene glycol 400 was added as a plasticizer. The film solutions were mixed for 20 min with a T-Line Stirrer (Model # 105, Talboys Instrument Corp., Emerson, NJ) set at 1 550 r/min while the solution was kept at 50℃ in a water bath. 63% or 72% ethanol dipping solutions were also prepared. The solutions were equilibrated to 20℃ before application to tomatoes.

2. Tomatoes and coating treatment

Mature-green tomatoes (*Lycopersicon esculentum*, cv. Sunny) were picked by hand from fields of commercial growers near Homestead, FL and delivered to the University of Georgia within 48 hours. The tomatoes, weighing 120 to 150 g each, were held at 30℃ for 10 – 12 hours before dipping in edible film solutions. Batches of 10 tomatoes were submerged and constantly agitated in 2 liters of edible film solution, or 63%, 72% ethanol solution (20℃) for 2 minutes respectively, and air dried at ambient temperature (22℃) for 4 hours. After the HPMC coating formed a thin transparent layer on the surface of the tomatoes, they were stored at 20℃ for up to 18 days. The without dipping group was the control.

3. Firmness measurement

On each sampling day, 10 tomatoes from each treatment were analyzed for firmness using an Instron Universal Testing Machine (Model 1122, Canton, MA) set to operate at a full-scale load of 2 kg, a cross-head speed of 0.2 mm/min and a chart speed of 100 mm/min. The method followed was a nondestructive technique described by Chinnan et al. (1990) which was adapted from that of Bourne (1982). Force (*N*) readings were recorded at 2% constant deformation at one point on the circumference of each of 10 tomatoes from coated and uncoated groups.

4. Color determination

On each sampling day, after the firmness measurement, the surface color (L^*, a^*, b^*) of 10 tomatoes from each treatment was determined using a Gardner XL-845 colorimeter (Gardner Laboratory Division, Bethesda, MD). The mean of L^*, a^*, and b^* coordinates were obtained from 4 different points on the circumference of each of 10 tomatoes. A standard pink calibration tile ($L^* = 69.1$, $a^* = 23.4$, $b^* = 9.3$) was used as a reference for making color measurements. These coordinates were converted to hue angles. A correction factor to offset the effect of the coating on instrumental color readings was obtained using a separate batch of tomatoes (23, Yang et al., 1987). Color measurements before and after washing were used to calculate the correction factor for L^*, a^*, and b^*. The parameters of Hunter color values are: L^*: white to black (100 to 0); a^*: green

(–) to red (+) axis; b^* : blue(–) to yellow (+) axis.

5. Statistical analysis

Experiments were done in triplicate. Data were subjected to analysis of variance (ANOVA) and Duncan's multiple range test using PROC GLM and to linear regression analysis using PROC REG of SAS procedures (SAS Institute Inc, 1985).

RESULTS AND DISCUSSION

1. Firmness

The tissue of tomatoes become soft during ripening; so the extent of postharvest ripening could be determined by measurement and comparison of the firmness.

No interaction between dip treatment and storage time was observed. Table 1 shows the results of Duncan's multiple range test for statistical differences between means of treatment on each day of storage. In all cases, firmness decreased as storage time increased. However, application of edible coating delayed softening of tomatoes during 18 days of storage at 20℃. At days 7, 13 and 18, the firmness of tomatoes coated with HPMC (containing 63% or 72% ethanol) was significantly ($P \leqslant 0.05$) greater than the firmness of uncoated tomatoes. The level of ethanol in HPMC did not have significant effect on change in firmness.

The exocarp adjacent to the core tissue of the control tomatoes shrivelled by day 13. The tomatoes looked less fresh. This phenomenon was not observed in coated tomatoes. Although transpiration of tomatoes subjected to various treatments in our experiments was not measured, it is likely that application of HPMC reduced the transpiration rate of tomatoes, thus retarding change in firmness. The surface of the peel of tomatoes coated with HPMC was smooth and flexible.

Table 1 Changes in firmness of coated and uncoated tomatoes stored at 20℃ for up 18 days

Treatment	Force(N)[1]				
	Time of storage (days)				
	0	4	7	13	18
Control (not dipped)	5.35 A	3.54 A	2.43 B	1.28 B	0.87 C
Ethanol (63%)	5.54 A	4.50 A	2.87 B	1.28 B	0.81 BC
Ethanol (72%)	5.73 A	4.56 A	2.96 AB	1.28 B	0.74 B
HPMC (63% ethanol)	6.07 A	4.00 A	4.31 A	2.20 AB	1.43 A
HPMC (72% ethanol)	5.49 A	4.47 A	3.97 A	2.89 A	1.79 A

[1] Mean force (N) values in same column not followed by the same letter are significantly different ($P \leqslant 0.05$); $n = 18$.

2. Color

The appearance and pigmentation of the tomato reflects the extent of its ripening. According to the change of the color, the period of ripening of tomato could be divided into mature-green, slight ripening, half ripening, ripening, fully ripening, excessive ripening phases. The color of these stages was green, breaker, orange, turning pink, light red, and red respectively.

The HPMC coating formed an achromatic and thin transparent layer on the surface of the tomatoes. Correction factors (the intercept and slope values from regression analysis) for L^*, a^*, and b^* used for estimating Hunter color coordinates of HPMC-coated tomatoes are given in Table 2. In the regression analysis, the dependent variable was the Hunter color coordinate of the HPMC-coated tomato and the independent variable was the Hunter color coordinate of the same tomato with the coating removed.

Values for HPMC treatments are shown in Table 3 were obtained by applying appropriate correction factors from Table 2. No interaction between dip treatment and storage time was observed. During ripening of tomatoes, the chlorophyll content decreases and there is an accumulation of carotenoid, particularly lycopene (Khudairi, 1972). Table 3 shows that mature-green tomatoes undergo color change from green to breaker, turning pink, light red, and red stages as indicated by decreasing hue angle

(Cheng et al.，1988). The hue angle changed much faster in uncoated tomatoes and tomatoes dipped in 63% or 72% ethanol than in coated tomatoes. The uncoated tomatoes reached the red stage at day 13 of storage at 20 ℃，while coated tomatoes reached the pink and the light red stages only after 18 days of storage. The ethanol content in HPMC did not influence change in the hue angle value of tomatoes.

Hunter L^*，an indication of lightness of color，was unaffected by dipping tomatoes in 63% or 72% ethanol. Tomatoes coated with HPMC (containing 63% or 72% ethanol) were significantly ($P \leqslant 0.05$) lighter on day 4，7，13，and 18 compared to tomatoes that were not coated.

The result confirmed that HPMC coatings could significantly ($P \leqslant 0.05$) delay the changes in color of tomatoes stored at 20℃.

Table 2 Linear regression analysis of Hunter color coordinates for HPMC-treated tomatoes for obtaining correction factors

Treatment	Color coordinate	Intercept	Slope	R^2_{adj}
HPMC (63% ethanol)	L^*	−1.843	1.025	0.804
	a^*	−0.440	1.028	0.986
	b^*	6.114	0.733	0.625
HPMC (72% ethanol)	L^*	0.779	0.979	0.906
	a^*	−0.355	1.067	0.990
	b_*	7.890	0.704	0.777

Table 3 Hue angle and Hunter L* values of HPMC-coated and uncoated tomatoes stored at 20℃ for up to 18 days

Treatment	Hue angle[1]				
	Time of storage (day)				
	0	4	7	13	18
Control	112 B	67 B	54 B	38 B	32 B
63% ethanol	112 B	84 B	57 B	38 B	32 B
72% ethanol	112 B	88 B	56 B	38 B	34 B
HPMC (63% ethanol)	112 B	104 A	96 A	65 A	50 A
HPMC (72% ethanol)	115 A	111 A	108 A	75 A	48 A
	Hunter L^* values[1]				
Control	64 A	57 B	52 B	47 C	46 B
63% ethanol	61 B	57 B	54 B	45 C	46 B
72% ethanol	62 B	57 B	53 B	45 C	44 B
HPMC (63% ethanol)	64 A	62 A	59 A	51 B	46 B
HPMC (72% ethanol)	63 AB	62 A	60 A	54 A	49 A

[1] Mean values in same column not followed by the same letter are significantly different ($P \leqslant 0.05$); $n = 18$.

CONCLUSIONS

In this study，a cellulose-based edible film，hydroxypropyl methylcellulose was coated on mature-green tomatoes which were then stored for up to 18 days at 20℃. In all the treatments，firmness decreased as storage time increased. However，application of HPMC edible coating delayed softening of tomatoes during 18 days of storage at 20℃. At days 7，13，and 18，the firmness of tomatoes coated with HPMC (containing 63% or 72% ethanol) was significantly ($P \leqslant 0.05$) greater than the firmness of uncoated tomatoes. The level of ethanol in HPMC did not have significant effect on change in firmness. The study also confirmed that HPMC coatings could significantly ($P \leqslant 0.05$) delay the changes in color of tomatoes stored at 20℃; and that ripening of tomatoes from the pink stage to the red stage could be successfully retarded.

The exocarp of tomato is a very thin cellular layer easily injured during transportation after harvest. HPMC edible coating for tomatoes can provide an additional protective layer and thereby reduce quality degradations and quantity losses by modification of the internal atmosphere of the fresh tomatoes. Since HPMC has low oxygen and carbon dioxide permeablities, it could prevent oxygen coming into the tissue of the constantly respirating tomato; during which oxygen inside the tissue is consumed and CO_2 is released; so CO_2 would predictably accumulate inside the packaging during tomato storage. This accumulation would decrease ethylene synthesis and reduce the respiration rate, which would in turn delay ripening as evidenced by slower changes in firmness and color. The retardation of the rate of loss of firmness could reduce the economic loss that would result from spoilage by mechanical injury during transportation of tomatoes. Also, the HPMC edible coating did not adversely affect the flavor of the stored tomatoes.

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