Proc. Fla. State Hort. Soc. 119:350-352. 2006.

A REFEREED PAPER

EFFECT OF EDIBLE COATINGS ON QUALITY OF MANDARINS CV. *CLEMENULES*

MARIA LL. NAVARRO-TARAZAGA AND MARIA B. PÉREZ-GAGO*
Postharvest Department
Instituto Valenciano de Investigaciones Agrarias
Moncada, Spain

Additional index words. Edible composite coatings, hydroxypropyl methylcellulose, beeswax, solid content

Abstract. **Polysaccharide-lipid edible composite coatings can extend fruit shelf-life by providing a barrier to gas and water vapor exchange between the fruit and its environment, reducing respiration rate and weight loss. Among other factors, coating barrier properties depend on coating composition and thickness, which depends on the solid content of the formulations. The objective of this work was to study the effect of hydroxypropyl methylcellulose (HPMC):beeswax (BW) ratio and solid content (SC) of HPMC:BW composite coatings on the quality of 'Clemenules' mandarins. HPMC of two different molecular weights were used to prepare emulsion coatings at three HPMC:BW ratios (1:1, 1:3, 1:30), with 4% and 8% SC and similar viscosity. After coating, mandarins were stored up to four weeks at 4°C (39.2°F) followed by one week at 20°C (68°F). Fruit quality analysis was done periodically during storage. Coatings reduced weigh loss and improved texture of mandarins compared to uncoated samples. Weight loss and texture were not affected by SC. However, as SC increased, internal CO_2, ethanol and off flavor increased and fruit appearance worsened. Increasing the BW content reduced weight loss, CO_2, ethanol levels and off flavor. However, coatings with 1:30 HPMC:BW ratio presented a whitish appearance.**

Weight loss and off-flavor development are the most important factors limiting citrus postharvest quality. Edible coatings can reduce weight loss and respiration rate by providing a barrier to moisture and gas transfer. However, a high gas barrier can induce anaerobic conditions and off-flavor development in the fruit (Baldwin, 1994).

Water and gas barrier of edible coatings depend, among other factors, on coating composition. In edible composite coatings based on a hydrocolloid (protein or polysaccharide) and a lipid, the lipid reduces water permeability, while the hydrocolloid reduces gas permeability and improves the mechanical integrity of the coatings. For a specific coating formulation, the gas barrier offered by the coating is related to coating thickness (Banks et al., 1993), which depends on solid content (SC), viscosity, and density of the coating formulation (Park et al., 1994). Therefore, changes in the ratio of hydrocolloid:lipid and/or in the SC of the formulations could improve the performance of the coatings, and thus reduce weight loss and the off-flavor incidence. However, these factors could also adversely affect coating integrity and fruit appearance, reducing coating performance.

The objective of this work was to study the effect of hydroxypropyl methylcellulose (HPMC):beeswax (BW) ratio and solid content (SC) of HPMC:BW composite coatings on the quality of 'Clemenules' mandarins.

Materials and Methods

Coating formulations. Emulsion coatings consisted of HPMC (Dow Chemical Co., Midland, Mich.) and BW (Brillocera S.A., Valencia, Spain) as the hydrophilic and lipophilic phases, respectively, suspended in water. HPMC of two different molecular weights (60,000 and 100,000) were used to prepare emulsion coatings at three HPMC:BW ratios (1:1, 1:3, 1:30), with 4% and 8% SC and similar viscosity. Stearic acid and glycerol (both from Panreac Quimica S.A., Barcelona, Spain) were added as emulsifier and plasticizer, respectively. BW:Stearic acid ratio and HPMC:glycerol ratio were kept constant in all formulations. Table 1 shows the coating treatments.

Sample preparation and coating application. 'Clemenules' mandarins from a local grove in Valencia (Spain) were selected for size, color, and absence of physical damage, and then dipped for 1 min in 2,500 ppm imazalil (Tecnidex, Valencia, Spain), a fungicide solution, followed by air drying. Mandarins were randomly divided into 7 groups, which corresponded to 6 coating treatments and 1 uncoated control. Fruits were dip-coated by immersion in the coating solutions for 60 s, drained of excess coating, and dried in a tunnel at 45-50°C (113-122°F) for 3 min. After coating, fruit were stored for 2, 3 and 4 weeks at 4°C (39.2°F) and 75-80% RH, followed by one additional week at 20°C (68°F) and 85-90% RH, simulating retail handling conditions.

Quality parameters. Lots of 30 fruits per treatment were used to measure weight loss. The results were expressed as the percentage loss of initial weight.

Firmness of 20 fruits per treatment was determined at the end of each storage period using an Instron Universal Testing Machine (Model 3343; Instron Corp., Canton, Mass.). The instrument gave the deformation (length) after application of a load of 1 kg (2.2 lb) to the equatorial region of the fruit at a rate of 5 mm/min (0.2 in/min). Results were expressed as the % deformation related to the initial diameter.

Table 1. Coatings treatments.

Code	HPMC:BW ratio	Solid content (%)	HPMC[z] molecular weight
HPMC:BW (1:1) 4%SC	1:1	4	60,000
HPMC:BW (1:3) 4%SC	1:3	4	60,000
HPMC:BW (1:30) 4%SC	1:30	4	100,000
HPMC:BW (1:1) 8%SC	1:1	8	60,000
HPMC:BW (1:3) 8%SC	1:3	8	60,000
HPMC:BW (1:30) 8%SC	1:30	8	100,000

[z] HPMC with higher MW was used when the amount of HPMC was lower to keep viscosity constant for all formulations.

This research was supported by the Spanish Ministerio de Ciencia y Tecnología through the project AGL 2002-00560. Maria Llanos Navarro-Tarazaga was also supported with a scholarship from the Spanish Ministerio de Ciencia y Tecnología.

*Corresponding author; e-mail: mbperez@ivia.es

Table 2. Weight loss and firmness of coated and uncoated mandarins cv. 'Clemenules'.[z]

	Weight loss (%)			Firmness (% deformation)		
Treatment	2w4°C + 1w20°C	3w4°C + 1w20°C	4w4°C + 1w20°C	2w4°C + 1w20°C	3w4°C + 1w20°C	4w4°C + 1w20°C
HPMC:BW (1:1) 4%SC	8.35 bc	8.34 bc	11.51 c	7.90 a	8.08 ab	8.85 bc
HPMC:BW (1:3) 4%SC	8.49 bc	8.00 b	10.30 b	8.72 bc	7.69 a	8.52 abc
HPMC:BW (1:30) 4%SC	8.08 ab	7.66 ab	9.35 a	8.69 bc	8.15 ab	8.11 a
HPMC:BW (1:1) 8%SC	8.99 cd	9.76 e	11.36 c	8.35 ab	8.43 bc	8.36 ab
HPMC:BW (1:3) 8%SC	8.15 b	8.99 cd	11.58 c	8.00 a	7.94 ab	8.49 abc
HPMC:BW (1:30) 8%SC	7.47 a	7.02 a	9.42 a	8.54 abc	7.72 a	8.73 bc
Control	9.51 d	9.14 de	10.92 bc	9.15 c	8.86 c	8.98 c

[z]Mean within each storage time with the same letter are not different by LSD test at 5% confidence level.

Internal CO_2 concentrations were evaluated in 10 fruits per treatment. Concentrations of each sample were obtained by withdrawing 1 mL internal gas sample from the mandarin cavity with a syringe while the fruit was submerged under water. The gas sample was then injected into a Thermo Electron Gas Chromatograph (Model Trace GC Ultra; Waltham, Mass.) with the conditions described by Perez-Gago et al. (2002). Peak areas obtained from standards gas mixtures were determined and results were expressed as percentages according to standard values.

Ethanol concentration in juice was determined by headspace gas chromatography according to the method described by Ke and Kader (1990). Ten fruits each in 3 replicates per treatment were juiced and analyzed. Five mL of juice was transferred to 10-mL vials with crimp-top caps and TFE/silicone septum seals and frozen until analysis. Ethanol was analyzed and identified by comparison of retention times with standards. Results were expressed as $mg \cdot 100\ mL^{-1}$ juice.

Sensory evaluation was assessed by 10 judges trained to recognize off flavor in citrus and for use of the 5-point scale. Panelists rated off-flavor on a 5-point scale, where 0 represented absence of off-flavor and 5 high presence of off-flavor. One sample consisted of whole segments taken from about 4 individual fruits. The effect of the treatments on external quality (appearance) was also evaluated. One set of 5 fruits per treatment was presented to panelist for appearance evaluation. Panelist rated appearance of overall fruit as 1 = bad, 2 = acceptable, and 3 = good.

Statistical analysis was performed using STATGRAPHICS Plus 4.1 (Manugistics, Inc., Rockville, Md.). Specific differences between means were determined by least significant difference (LSD). Significance of differences was defined at $P \leq 0.05$.

Results and Discussion

Table 2 shows weight loss of coated and uncoated mandarins. The composite coatings reduced weight loss compared to control, except when formulated at 8% SC with HPMC:BW ratios of 1:1 and 1:3 after 3 and 4 weeks in cold storage followed by 1 week at room temperature, and for the 4% SC at 1:1 and 1:3 ratios after 4 weeks in cold storage followed by 1 week at room temperature. This indicates that the BW content in these formulations was not enough to reduce weight loss after prolonged storage at room temperature. An increase in BW content of the coatings (i.e., 1:30 vs 1:3 and 1:1) resulted in a decreased in weight loss, more so at 8% SC than at 4% SC, and after 4 weeks in cold storage followed by 1 week at room temperature. SC level did not affect weight loss of coated mandarins.

Coatings improved firmness of mandarins compared to uncoated samples (Table 2). Even though there were differences among treatments, no consistent effect of coating composition was observed in fruit firmness.

Table 3 shows the internal CO_2 and ethanol content in juice of coated and uncoated mandarins. HPMC:BW ratio showed an effect in both quality parameters. For the 1:30 HPMC:BW coatings the internal CO_2 (%) and ethanol contents were decreased by nearly 50% (Table 3). These decreases produced reductions between 50 and 60% in the off-flavor (Table 4). For the 1:1 and 1:3 HPMC:BW coatings, formulation SC affected internal CO_2 level and ethanol content in juice. As SC decreased from 8% to 4%, internal CO_2 (%) and ethanol contents were decreased by nearly 30%. These decreases produced reductions around 40% in off-flavor (Table 4). However, SC did not affect internal CO2 (%) and ethanol contents for the 1:30 HPMC:BW coatings, which indicates

Table 3. Internal CO_2 and ethanol content in juice of coated and uncoated mandarins cv. 'Clemenules'.[z]

	Internal CO_2 (%)			Ethanol (mg/100mL)		
Treatment	2w4°C + 1w20°C	3w4°C + 1w20°C	4w4°C + 1w20°C	2w4°C + 1w20°C	3w4°C + 1w20°C	4w4°C + 1w20°C
HPMC:BW (1:1) 4%SC	2.06 b	2.67 b	3.61 c	48.03 b	42.54 b	62.07 bc
HPMC:BW (1:3) 4%SC	2.09 b	2.32 b	2.23 b	26.56 a	39.75 b	38.85 a
HPMC:BW (1:30) 4%SC	0.86 a	1.21 a	1.48 a	25.20 a	30.66 a	32.41 a
HPMC:BW (1:1) 8%SC	3.74 d	3.42 c	3.99 cd	70.61 c	56.25 c	104.28 d
HPMC:BW (1:3) 8%SC	2.70 c	3.37 c	4.57 d	50.85 b	53.30 c	63.00 c
HPMC:BW (1:30) 8%SC	1.68 b	1.60 a	1.54 ab	26.42 a	26.71 a	38.64 a
Control	1.11 a	1.15 a	2.15 ab	24.71 a	28.51 a	40.52 ab

[z]Mean within each storage time with the same letter are not different by LSD test at 5% confidence level.

Table 4. Off-flavor and appearance of coated and uncoated mandarins cv. 'Clemenules'.[z]

	Off-flavor			Appearance		
Treatment	2w4°C + 1w20°C	3w4°C + 1w20°C	4w4°C + 1w20°C	2w4°C + 1w20°C	3w4°C + 1w20°C	4w4°C + 1w20°C
HPMC:BW (1:1) 4%SC	1.25 c	1.71 bc	2.07 c	3.00 c	2.6 c	2.5 bc
HPMC:BW (1:3) 4%SC	0.50 ab	1.29 ab	1.14 a	3.00 c	3.0 d	2.6 cd
HPMC:BW (1:30) 4%SC	0.40 a	0.57 a	1.36 ab	1.00 a	1.8 b	1.3 a
HPMC:BW (1:1) 8%SC	2.00 d	2.15 c	2.48 d	1.75 b	1.4 b	1.4 a
HPMC:BW (1:3) 8%SC	2.14 d	0.86 a	1.58 b	2.00 b	1.0 a	2.1 b
HPMC:BW (1:30) 8%SC	0.63 ab	1.29 ab	1.38 ab	1.00 a	1.0 a	1.0 a
Control	1.06 b	1.04 ab	1.54 b	3.00 c	3.0 d	3.0 d

[z]Mean within each storage time with the same letter are not different by LSD test at 5% confidence level.

that for this formulation the driving factor affecting coating behavior was the proportion of both HPMC and BW components, and not the overall SC content.

The appearance (Table 4) and gloss (data not shown) of the coated mandarins decreased as BW content increased. At 1:1 and 1:3 HPMC:BW ratios, a SC increase decreased fruit appearance and gloss. Formulations with 1:30 HPMC:BW ratio formed brittle coatings with a whitish appearance, reducing the appearance score for this coating at both SC (Table 4).

The results show that the HPMC:BW ratio had an effect on weight loss, internal atmosphere and appearance of the mandarins, whereas SC had only an effect on internal atmosphere and fruit appearance. The effect of SC on coating performance could be related to changes on coating thickness. These edible coatings were formed by a continuous matrix of HPMC with the BW particles dispersed in it. An increase in coating thickness with increasing SC implies an increase in the amount of HPMC on the mandarin surface. Since HPMC is a good gas barrier, this might result in a higher modification of the internal atmosphere of the fruit. However, the water vapor barrier is not affected by SC, even though there is a higher deposition of the BW on mandarin surface. This could be due to the fact that the diffusion of water vapor through the HPMC:BW system takes place through the HPMC matrix, avoiding the dispersed lipid particles. Similarly, a decrease in BW content translates into an increase in the HPMC hydrophilic matrix, increasing the gas barrier of the system; whereas, the water barrier decreases. Other works show similar results to our results (Cisneros-Zevallos and Krochta, 2003; Park et al., 1994).

The results indicate the need to control SC to avoid the overproduction of volatiles associated with anaerobic conditions. To determine the appropriate HPMC:BW ratio for citrus coatings, it is necessary to make a compromise between barrier properties and coating appearance. HPMC:BW coatings should be optimized for citrus applications in order to obtain coatings with appropriate barrier properties and good appearance.

Literature Cited

Baldwin, E. A. 1994. Edible coatings for fresh fruit and vegetables: past, present and future, pp. 25-64. In J. M. Krochta, E. A. Baldwin, and M. O. Nisperos-Carriedo (eds.). Edible coatings and films to improve food quality. Technomic Publishing Co., Lancaster, PA.

Banks, N., B. Dadzie, and D. Cleland. 1993. Reducing gas exchange of fruits with surface coatings. Postharvest Biol. Technol. 3:269-284.

Cisneros-Zevallos, L., and J. M. Krochta. 2003. Dependence of coating thickness on viscosity of coating solution applied to fruits and vegetables by dipping method. J. Food Sci. 68:503-510.

Ke, D., and A. A. Kader. 1990. Tolerance of 'Valencia' oranges to controlled atmosphere as determined by physiological responses and quality attributes. J. Am. Soc. Hort. Sci. 115:770-783.

Park, H., J. Bunn, P. Vergano, and R. Testin. 1994. Gas permeation and thickness of the sucrose polyester Semprefresh coatings on apples. J. Food Proc. Preserv. 8:349-358.

Pérez-Gago, M. B., C. Rojas, and M. A. del Rio. 2002. Effect of lipid type and amount of edible hydroxypropyl methylcellulose-lipid composite coatings used to protect postharvest quality of mandarins c.v. Fortune. J. Food Sci. 67:2903-2910.