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Quality Retention and Shelf-life Extension in Mediterranean Cucumbers Coated with a Pectin-based Film

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Abstract

Edible coating is a simple and inexpensive concept for extending post-harvest life of fruits and vegetables. In this study, cucumbers were coated with different pectin-based emulsions to preserve the fruit quality and extend the post harvest shelf life. The formulations consisted of pectin, beeswax, sorbitol, water, and an emulsifying agent. By monitoring the physiological and quality parameters, the coating effects on the storability of cucumber fruits at 23°C and 40% RH (display cabinet), and 12°C and 85% RH (cold room) were determined. The parameters included weight loss, respiration rate, firmness, color, soluble solids and chlorophyll content. The coating markedly reduced weight loss and respiration rate at both temperatures. In addition, the coating reduced loss of firmness, color, chlorophyll and total soluble solids, and extended the storage life of cucumber fruits at both storage conditions.

Keywords: Editble film, coating, shelf-life, cucumber, quality, postharvest

1. Introduction

The cucumber (*Cucumis sativus L.*) is a widely cultivated plant in the family *cucurbitaceae*. It is grown throughout tropics and subtropics but has also become important in cooler latitudes where it is grown under glass or plastic (Snowdon, 1990). World's cucumber production is over 40,000 tonnes, with China being the leading producer (FAO, 2005). Cucumbers usually have a short storage life, about 10 to 14 days, at optimum temperatures of 10 to 12°C and RH of more than 80% (Snowdon, 1990). Cucumber is harvested at a physiologically immature state and the metabolic activity is extremely high (Kader, 1983).

Several treatments have been developed for prolonging the post-harvest life of these vegetables. Temperature control, controlled atmosphere storage (CA), and use of waxes and/or other coatings are among the most important techniques for maintaining vegetable quality after harvest (Baldwin, 2003). Since cucumber is a tropical crop, low temperature storage (below 10°C) causes chilling injury (Kader, 1983). Ryall & Lipton (1983) reported that CA conditions (5% O_2 plus 5% CO_2) can be expected to retard yellowing of cucumbers and extend their shelf-life. However, CA storage is expensive and may be uneconomical for cucumbers because of their short shelf life (Krochta & Mulder-Johnston, 1997; Smith et al., 1987). Shrink-wrapping or individual seal packaging in high density polyethylene film is another effective way of extending shelf life of cucumbers (Ben-Yehoshua et al., 1985; Snowdon, 1990).

Waxing of fruits and vegetables has been traditionally used to retard their transpiration and respiration. Coating fruits with semi-permeable films is another effective method used to delay senescence and extend the storage life of produce. Such coatings can create beneficial modified atmosphere within the product. El Ghaouth et al. (1991) studied the effect of chitosan coating (1.0% and 1.5% w/v) on the storability of cucumbers and bell peppers stored at 13 and 20°C (RH 85%). At both temperatures, the coating was reported to markedly reduce their weight loss. In addition, they also reduced the respiration rate, loss of color, wilting, and fungal infection. Kaynas &

Ozelkok (1999) investigated the effect of 0.8% and 1.0% coating (Semperfresh) on post harvest quality of two varieties of cucumber (*Niz 760, Hana*). Their results showed that the coating did not retard water loss on *Niz 760* variety; however, at 1.0% level, it was effective on *Hana*, and reduced respiration rate and increased marketable characteristics of the fruits. High methoxy pectins can be used to form an effective semi-permeable film as shown by Maftoonazad and Ramaswamy (2008) who evaluated barrier, optical, and mechanical properties of pectin films using a response surface methodology. Their results showed that the coating hindered the ripening of avocado fruits and improve all related quality parameters by lowering the rate of loss of firmness, color changes, weight loss, and chemical changes, and hence extending the shelf life to over a month at 10°C.

The objective of the study was to evaluate the effect of a pectin-based emulsion coating on physical, chemical, and physiological changes in cucumber during storage at two temperatures.

2. Materials and Methods

2.1 Fruit Preparation

Cucumbers (*Cucumis sativus L. cv. Mediterranean*) were obtained from local supermarket and the fruits were sorted for uniform size, to be free from physical damage and fungal infection. They were kept at 12°C (lowest safe temperature for cucumbers) until the next day. Prior to the study, the fruits were washed with water to remove any loose soil, surface sterilized in 1% sodium hypochlorite solution for 15 min, washed again and surface dried in a slow air draft. The fruits were then randomly distributed into four lots. The first two lots were stored without coating and constituted the control. The other two lots were coated with a pectin-based emulsion composite coating.

2.2 Preparation of Coating

Coating emulsions were prepared by using high-methoxy pectin (a hydrophilic polymer), beeswax (hydrophobic phase), a plasticizer (sorbitol), an emulsifying agent, and water. Preliminary experiments were carried out to find the suitable formulation for coating cucumbers. Ten coating formulations (as evaluated by Maftoonazad et al., 2007) were used for the preliminary experiments and details of their composition are given in Table 1. Lack of any adverse effect including wilting and decay were the indices for selecting the suitable formulations for the study. Based on their performance, formulation A1 was found best and employed for further studies. The details of preparation of this formulation was as follows: 6.5 g pectin (HM rapid set powder, TIC GUMS, Belcamp, MD) was rehydrated in 500 ml distilled water for 18 h at 20°C, to which 3 g sorbitol as plasticizer (Sigma, Oakville, ON) was added and thoroughly mixed. Melted beeswax (2.6 g) (Sigma, Oakville, ON) and 0.78 g emulsifying agent (ADM, Decatur, IL) were added to this mixture. To get uniformly dispersed emulsion, the mixture was homogenized using a homogenizer (PowerGen 700, Fisher Scientific, and Pittsburg, PA) for 4 min and then cooled.

Table 1. Compositions of formulations initially evaluated for this study, and the effect of their coating on quality and decay of cucumber stored at 23°C for 4 days

Code	Pectin (%)	Sorbitol (%) based on pectin dry weight	Beeswax (%) based on pectin dry weight	Visual quality [1]	Decay [2]
A1	1.3	45	40	+ + + +	-
A2	1.3	45	50	+ + +	+
A3	2	35	30	+ +	+ +
A4	2	35	50	+ +	+ +
A5	2	55	30	+ +	+ +
A6	2	55	50	+ +	+ +
A7	2	35	57	+ +	+ +
A8	2	55	23	+ +	+ +
A9	2	55	40	+ +	+ +
A10	3	62	40	+	+ + +

[1]Visual quality rating: + + + + + = excellent, + + + + = good, + + + = moderate, + + = acceptable, + = non-acceptable

[2] Decay: - = none, + = slight, + + = moderate, + + + = severe

2.3 Coating Application

Cucumbers were dipped in the coating solution for 1 min at 20°C, the excess solution was drained and the coated fruits were air-dried. After drying, the fruits were packaged in plastic trays with perforations. Test samples (coated and control) were stored at conditions: a) 12°C and 85% RH, and b) 23°C and 40% RH to simulate cold storage and display marketing of cucumbers. At regular intervals the fruits were removed and analyzed.

2.4 Weight Loss

During storage, the weight loss was measured by weighing the fruit on each day of the experiment. Weight loss was determined by dividing the weight change during storage by the original weight using the following equation:

$$WL\ (\%) = 100 \times (W_A - W_B)/W_A$$

where W_A is the weight on the first day and W_B the weight in the test day

2.5 Respiration Rate

Cucumbers (a known quantity) were placed in an air-tight Plexi-glass chamber (18cm x 12cm x 27cm). To monitor change in CO_2 concentration, a CO_2 sensor (ACR Systems Inc., St-Laurent, PQ) connected to a data logger (Smart Reader plus 7, Data Logger Analysis Software, Version 1.0 for Windows, ACR Systems Inc., St-Laurent, PQ) was placed inside the chamber. The data logger was programmed to collect real time data of CO_2 concentration at 1 min interval over a 4h period. From the regression slope of CO_2 concentration, respiration rate was obtained and evaluated as ml CO_2 $kg^{-1}.h^{-1}$. The experiments were conducted twice and the results were averaged.

2.6 Texture

Textural properties were evaluated using a Lloyd Universal Testing Machine (Model LRX-2500N, Lloyd Instruments Ltd., Fareham, Hans, UK). The instrument was equipped with a 50 N load cell. Using a 5 mm diameter round tipped puncture probe, samples were subjected to a puncture test at a constant speed of 50 mm/min. Force-deformation curves were recorded and firmness was obtained as the slope of the linear section of the curve (N/mm)

2.7 Color

Surface color analysis of the cucumber fruits was evaluated using a hand-held tristimulus colorimeter meter (Minolta Chroma Meter, Minolta Corp., Ramsey, NJ). L* value (lightness or brightness), a* value (redness or greenness), and b* value (yellowness or blueness) of the cucumber samples were recorded. Measurements were taken on four samples and the average of L*, a*, and b* values were recorded.

2.8 Total Soluble Solids (TSS)

Total soluble solids content of the fruit was measured using a hand refractometer (Atago, Japan) and following the procedure used by Maftoonazad & Ramaswamy (2008).

2.9 Chlorophyll Content

For this purpose, ~1 g of fruit sample was cut individually from each of the four fruits and separately cut into small pieces. Ten ml of dimethyl sulfoxide (DMSO) and 80 percent acetone mixture (1:1 ratio) was poured into test tubes containing the comminuted fruit pieces and incubated overnight. The colored solution was then decanted into measuring cylinder and the volume was made up to 25 ml with DMSO-aceton mixture. Using a spectrophotometer (Visible Spectrophotometer, Novaspec II, Biochrom Ltd., Cambridge, England) the OD values were recorded at 645 and 663nm. The chlorophyll a, chlorophyll b, and the total chlorophyll content were obtained using the following formula and expressed as mg g^{-1} fresh weight.

$$\text{Chlorophyll a} = \left[12.7\ (A_{663}) - 2.69\ (A_{645})\right] \text{X} \ \frac{V}{1000 \text{ x } W \text{ x } a}\left(\text{mg g}^{-1}\text{fruit weight}\right)$$

$$\text{Chlorophyll b} = \left[22.9\ (A_{645}) - 4.68\ (A_{663})\right] \text{X} \ \frac{V}{1000 \text{ x } W \text{ x } a}\left(\text{mg g}^{-1}\text{fruit weight}\right)$$

$$\text{Total Chlorophyll} = \text{Chlorophyll a} + \text{Chlorophyll b}$$

Where A = absorbance at specific wavelengths (645 and 663 nm)

B = final volume of the chlorophyll content (ml)

W = fresh weight of the sample (g)

a = path length of light (1 cm)

2.10 Statistical Analysis

The results were analyzed using the Statistical Analysis System (SAS, version 8.02, SAS Institute Inc., Cary, NC, USA). General linear model (PROC GLM) and Mixed (PROC Mixed) were used to determine the effect of treatment on dependent variables at each sampling time during storage. Significant differences were determined by Scheffe's multiple comparison procedure at $P \leq 0.05$.

3. Results and Discussion

3.1 Preliminary Results

Different emulsions (Table 1) were evaluated initially for coating cucumbers as done in previous studies (Maftoonazad et al., 2007). These results indicated that when the concentration of pectin increased beyond 3%, wilting and decay development increased on the surface of the cucumbers. From the general coating test results based on the visual quality evaluation and incidence of decay (Table 1), the best composition was chosen as A1 and used in the rest of this study.

3.2 Weight Loss

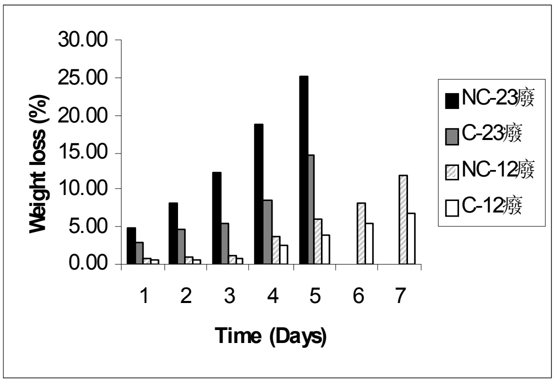
Figure 1(a) shows the weight loss of stored cucumber as a function of storage time and temperature for coated and non-coated samples. Both at the ambient and refrigerated storage, the percentage of weight loss increased with the storage time for both coated and non-coated cucumber. The weight loss of control samples were higher than in coated samples and the weight loss at ambient temperature was higher than at refrigerated condition ($P \leq 0.05$). In control fruits, the weight loss reached 12% and 25% at 10°C and 23°C, respectively, after 13 and 7 days, while in the coated samples these were 6.8% and 15%, respectively. Desiccation was the major cause for the termination of the shelf-life of cucumber and based on visual observation, the maximum acceptable moisture level of moisture loss was considered 8-9% for the cultivar of our study. Pectin-based composite coating could thus extend the shelf-life of cucumber at 23°C from 2 days to 5 days (a 2.5 fold increase) and at 12°C from 10 days to more than 13 days. The experiments were terminated at the end of 13 days due to lack of samples and the product was still acceptable. Kaynas & Ozelkok (1999) found that application of Semperfresh coating reduced the water loss of cucumber from 25% to 19%.

3.3 Respiration Rate

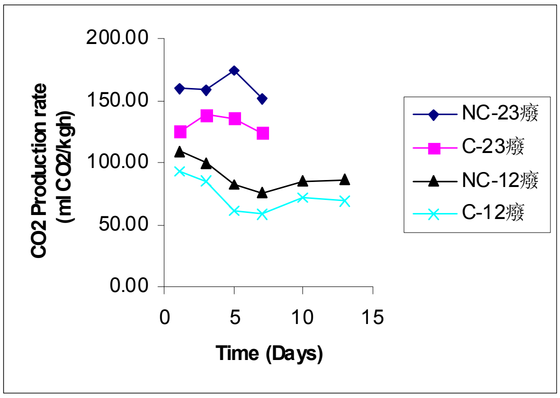
Figure 1(b) shows the respiration rate of stored cucumber as a function of storage time and temperature. Statistical analysis showed that were significant differences ($P \leq 0.05$) in the respiration rates between control and coated samples at all temperatures. As expected, respiration rate for cucumbers was lower at lower temperatures, and lower for coated as compared with uncoated controls. Reduction of the respiration rate as a result of coating with edible films or CA storage has also previously been reported for other cultivars of cucumber (El Ghaouth et al., 1991; Wang & Qi, 1997; Wills et al., 1998; Maftoonazad & Ramaswamy, 2008).

3.4 Texture

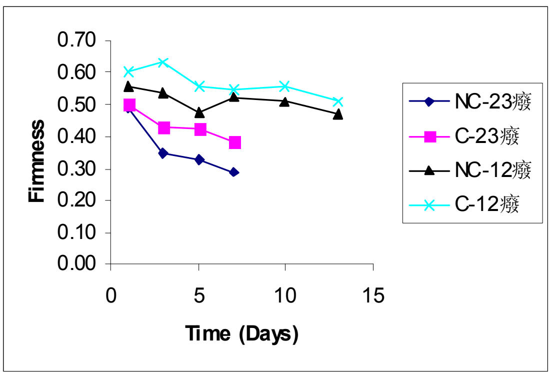
Firmness of cucumbers decreased during storage time both at ambient and cold temperatures (Figure 1c). Again, statistical analysis showed a significant difference between control and coated fruits at 12 and 23°C. The post-harvest change in texture primarily results from enzymatic degradation of the components responsible for structural rigidity of the fruit, primarily the insoluble pectin and proto-pectin. In the current study, the coating of cucumber with a pectin-based composite coating can be expected to modify the internal gas compositions of fruits, especially reducing the oxygen concentrations and elevating carbon dioxide concentration which might explain the slower textural changes in the coated fruits.



(a)



(b)



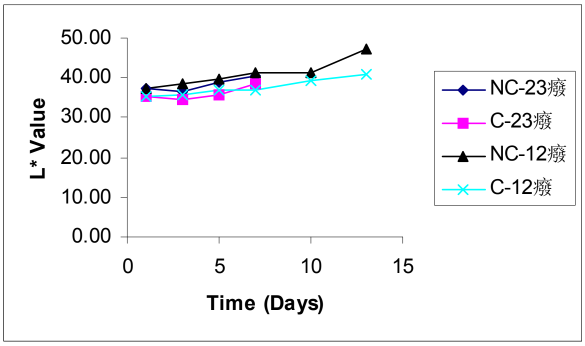
(c)

Figure 1. Changes in weight loss (a), respiration rate (b) and firmness (c) of coated and uncoated cucumbers during storage at different temperatures

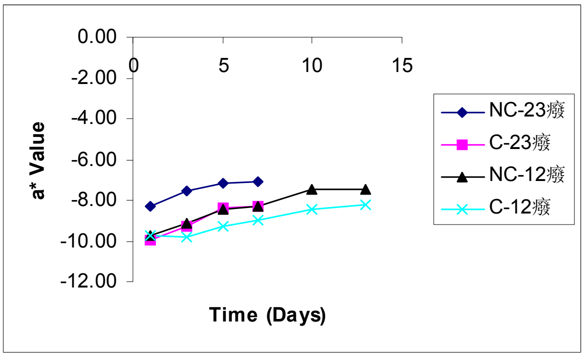
3.5 Color

The results of different color changes in cucumber skin as influenced by storage time and temperature are shown in Figure 2. These were associated with an increase in L*, a*, and b* values. The rate of increase in L values (lightness or brightness) was small and dependent on the storage time and temperature. Statistical analysis showed significant effect for coating on L* value at each temperature.

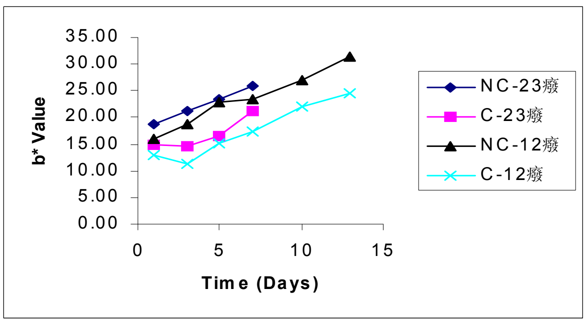
The a* values of coated and control fruits kept at different conditions are shown in Figure 2b. Clearly, the changes in greenness happened at a much slower rate in coated samples and did not reach the day 7 control values even after the end of 13 day storage. The a* value was more negative (greener) in coated samples and statistical analysis showed significant differences between coated and control samples. The differences in a* values between ambient and low temperature storage were statistically significant ($P < 0.05$). Figure 2c shows the increase in b* value again with significant differences between coated and non-coated samples at 23 and 12°C. The increase of b* values of at both temperatures indicated more yellowness in sample color with the passage of time.



(a)



(b)



(c)

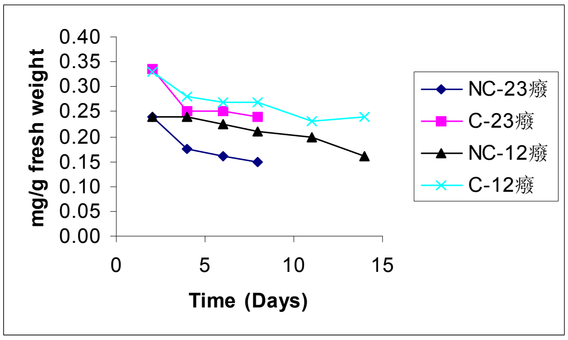
Figure 2. Changes in skin color parameters (L, a and b values) of coated and uncoated cucumbers during storage at different temperatures

In general, vegetables remain living, respiring tissues after harvest. After separation from mother plant, metabolic pathways, responsible for color development related to ripening or senescence can continue to operate. In freshly harvested green vegetables, yellow carotenoids coexist with green chlorophylls. During senescence chlorophyll is rapidly degraded, exposing the lighter yellow pigments. If stored for a long time, most green vegetables will undergo unmasking of chlorophyll. At temperatures above 12°C (and especially in the presence of ethylene) cucumbers loose their dark green color within a few days and begin to turn yellow (Kanellis et al., 1986). In the current study, pectin-based composite coating was effective in preserving green color and delaying yellowness in cucumbers especially at lower temperatures. Retardation of color changes in coated fruits may be due to high CO_2 and/or low O_2 levels in the internal atmosphere of the fruits. These results are in agreement with

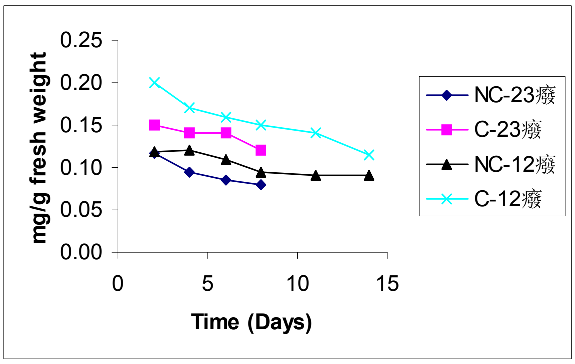
Bastrash et al. (1993) wherein low O_2 and high CO_2 environment inhibit yellowing of cut broccoli at low temperatures.

3.6 Chlorophyll

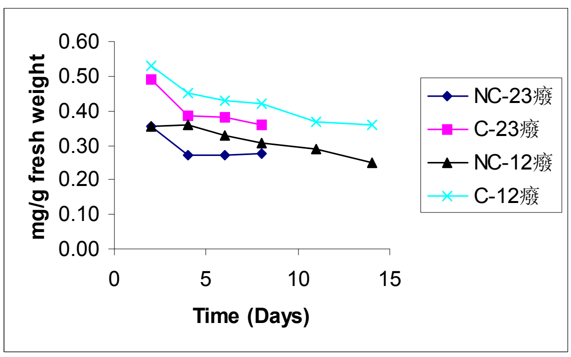
Figure 3 (a-c) and 6 show changes in chlorophyll content of cucumbers during the 13 day storage. The chlorophyll degradation began immediately with storage and the degradation was found to occur at slower rates in coated fruits as compared with control samples ($P \leq 0.05$). The chlorophyll a loss in coated cucumbers were 29% and 27% at 23 and 12°C, respectively, while they were 38% and 33% for control fruits. The changes in chlorophyll "b" content and total chlorophyll content were similar to chlorophyll "a" content except that chlorophyll "b" had always smaller value than chlorophyll "a" for the same treatment and at the same conditions. A beneficial effect of coating with edible film has also been reported for other cultivars of cucumbers (Kaynas & Ozelkok, 1999).



(a) Chlorophyll a



(b) Chlorophyll b



(c) Total chlorophyll

Figure 3. Changes in chlorophyll content of coated and uncoated cucumbers stored at different temperatures

3.7 Total Soluble Solids (TSS)

Figure 4 illustrates changes in the total soluble solids as influenced by storage conditions. Changes were found to be significant with respect to coating, storage time and storage temperature. In general, TSS was lower in the coated fruits compared to the control fruits and was also lower at lower storage temperature. The increase in TSS indicates the conversion of starch to sugars in the fruit tissues. The TSS of coated fruits was lower than in control, suggesting synthesis sugars at a slower rate. The general trend in TSS observed in our study was also observed by Haken Ozer et al. (2006) who reported an increase in TSS in control from 0 to 10 days, then a decrease up to day 30. For fruits kept at different CA conditions TSS increased from day 0 to day 20 and then decreased up to day 30.

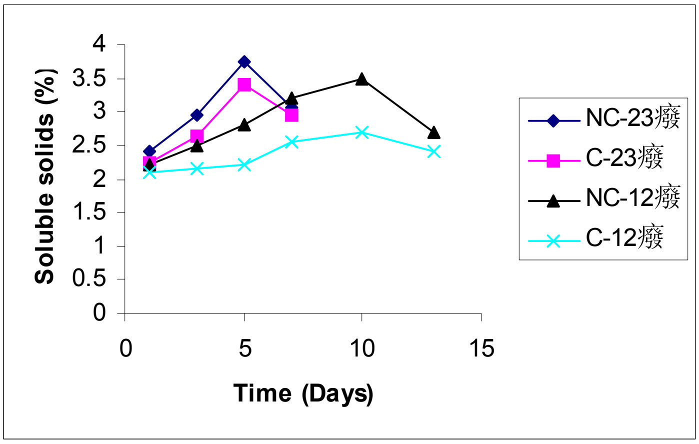


Figure 4. Changes in total soluble solids of coated and uncoated cucumbers at different temperatures

3.8 Shelf Life

The pectin based coating delayed deterioration and increased the shelf life of cucumber which was detected by observing external appearance, shriveling, the loss of color, decay, and weight loss data (Table 2). The loss of color, wilting, weight, and decay were greater in non-coated than in coated cucumbers kept at both 12°C and 23°C. While the maximum acceptable storage period for control samples was only 2 days at 23°C, the coated samples maintained their acceptability for 5 days at the same condition, there by giving a 2.5 fold increase. For fruits held at 12°C, the control samples were acceptable for 10 days while the coated samples were acceptable for 2 weeks. Any increase in shelf life for such a short life cultivar of cucumber would be a welcome sign for the cucumber industry. It is possible to increase the shelf life of cucumbers longer by application of the coating at the right time and control of variations due to storing of fruits at different conditions.

4. Conclusions

The coating of cucumbers with an emulsion using high methoxyl pectin as hydrophilic polymer, beeswax as hydrophobic phase, sorbitol as plasticizer, and a monoglyceride as emulsifying agent was effective for reducing moisture loss and prolong the storage life. The coating helped to better retain the different quality parameters by reducing changes in firmness, color, chlorophyll, and other quality parameters. All changes were also reduced at lower storage temperatures. The ambient storage shelf-life of cucumbers was extended from 2 to 5 days and the refrigerated shelf life was extended to two weeks.

Table 2. Effect of pectin-based coating on quality, decay, and weight loss of cucumber stored at 12 and 23°C

Days	Visual quality[1]	Decay[2]	Weight loss (%)
Control at 23°C			
0	+ + + + +	-	0
1	+ + +	-	4.7
2	+ +	-	8.3
3	+	+	12.3
5	+	+ +	18.8
7	+	+ +	25.1
10			
13			
Coated at 23°C			
0	+ + + + +	-	0
1	+ + + +	-	3,0
2	+ + + +	-	4.7
3	+ + +	-	5.5
5	+ +	-	8.5
7	+	+	14.6
10			
13			
Control at 12°C			
0	+ + + + +	-	0
1	+ + + + +	-	0.6
2	+ + + + +	-	0.9
3	+ + + +	-	1.2
5	+ + + +	+	3.7
7	+ + +	+ +	5.9
10	+ +	+ +	8.2
13	+	+ + +	11.9
Coated at 12°C			
0	+ + + + +	-	0
1	+ + + + +	-	0.4
2	+ + + + +	-	0.6
3	+ + + + +	-	0.7
5	+ + + +	-	2.6
7	+ + + +	-	3.9
10	+ + + +	-	5.5
13	+ + +	+	6.8

[1]Visual quality rating: + + + + + = excellent, + + + + = good, + + + = moderate, + + = acceptable, + = non-acceptable

[2] Decay: - = none, + = slight, + + = moderate, + + + = severe

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