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Evaluating the Effect of Pectin Based Coating on Cucumber Storage Quality

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Abstract. Pectin is a natural polysaccharide polymer that has many advantages when used as a coating material. The aim of this study was to assess the effects of pectin based coatings on cucumber quality during storage at 7-10 °C. During the 15 day storage period, shelf life, weight loss, firmness and total soluble solid (TSS) levels were measured. An edible coating was prepared by combining dry pectin (5% w/v), glycerol (50%) as a plasticizer in the pectin solution and melted beeswax (20% dry pectin). Dipping techniques were used to coat cucumbers. Both coated and uncoated cucumbers were stored at 10 °C for chilled storage at 65% relative humidity. The cucumbers were monitored for ripening at time intervals of 1, 3, 7, 9 and 13 days. The results showed that uncoated cucumber showed significant ($P < 0.05$) weight loss (12.7 ± 3.2g) during storage period on 9th days with 27.5% weight change as compared to pectin based coated cucumber (5.7 ± 0.3g) at 13th days of storage period with 12.6% weight change. There were substantial differences in the pH readings of uncoated cucumbers from the 1st to 9th days (0.3 ± 0.1) and (0.6 ± 0.1) in pectin coated cucumbers at 13th days. Moreover, the TSS value of uncoated cucumbers increased by 21% at 9th days and 11.6% in pectin based coated cucumbers. In addition, 13.9% the reduction in hardness was observed in uncoated cucumbers when compared to 7% in pectin-coated cucumbers. Pectin based coatings extend the shelf life, enhance preservation and improve appearance.

Keywords: storage, total soluble solid, shelf life, firmness

Introduction

One of the challenges in the food industry is to maintain the nutritional value, quality and freshness of fruits and vegetables. During post-harvest, vegetables undergo physiological and biochemical changes, such as water loss, texture softening and increased respiration which result in decreased shelf life and lower vegetable quality and consumer appeal (Plesoianu and Nour, 2022). Cucumbers have short postharvest lives and are susceptible to decay. Consumers demand fresh health-promoting cucumber products without reducing their quality. High nutrient and water content causes quality deterioration, resulting in physiological and biochemical changes that cause nutritional, functional and sensory losses (Panahirad *et al*., 2021). The food industry can overcome the challenges of improving quality and increasing shelf life using edible coating materials, including pectin-based coatings (Menezes and Athmaselvi, 2016; Nadin *et al*., 2014). Pectin is a water soluble polysaccharide with a high molecular weight, is primarily composed of ($1 \rightarrow 4$) linked α-d-galacturonic acid-esterified units, providing a structure to primary cell walls in plants and fruits (Freitas *et al*., 2021). A pectin based edible film coating is a thin layer applied to food surfaces to preserve fruits and vegetables and can form an aqueous gel due to its esterification (Antony *et al*., 2012) and film forming properties. (Tumbarski *et al*., 2020). In addition, pectin-based edible coatings act as a barrier, allowing for better moisture, gas exchange and water retention while reducing oxygen diffusion (Tumbarski *et al*., 2020), thereby delaying ripening. Furthermore, these edible coatings can be consumed alongside coated fruits and vegetables, potentially replacing synthetic materials (Rohasmizah and Azizah, 2022).

During storage, cucumber shelf life is influenced by various factors, such as shape, colour, texture, size and microbial populations, which can cause shrinkage and softening (Khojah *et al*., 2021; Perez-Soto *et al*., 2021). The use of pectin edible coating can prolong shelf life by strengthen texture and slow down enzymatic activity (Imeneo *et al*., 2022) Demonstrate that coating carrots with pectin at low temperature storage maintains stable structure integrity, delays browning and delays weight loss for 14 days due to pectin's ability to reduce enzymatic bacterial activity. Pectin can also help preserve

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the antioxidant properties of coated materials (Gavrilovic *et al*., 2019).

Choosing pectin based coatings over conventional coatings is a compelling solution that promotes sustainability, ensures safety and responds to customer demands for natural and environmentally friendly alternatives by exploiting the bio-degradable nature of pectin. Therefore, the aim of this study was to assessed the effects of pectin based coatings on cucumber quality during storage at 7-10 °C. During the 15 day storage period, shelf life, weight loss, firmness and total soluble solid (TSS) levels were measured.

Materials and Methods

Collection and preparation cucumbers. Cucumbers (*Cucumis sativus*- hybrid 501-20) were obtained from a local farm between April and June. The cucumbers were transported to the University of Jerash laboratory. Three independent treatment groups were used. Each treatment group had a sample size of 12. Cucumbers of the same size, firmness and colour were carefully selected. To remove dust, the cucumbers were washed several times with water and dried using a soft towel.

Preparation of pectin base edible coating and application on cucumber. The pectin solution taken to prepare the pectin follows: dry pectin was dissolved in deionized water with gentle stirring at 70 °C at a concentration of 5% (w/v). The solution was vigorously stirred for 30 min to completely dissolve the dried pectin. Glycerol was added to the pectin solution at a concentration of 50% and mixed for 30 min using a magnetic stirrer to homogenize the solution. Melted beeswax, at a concentration of 20% dry pectin which was added to the solution. Subsequently, the mixture was thoroughly mixed.

Using computer generation numbers, cucumbers were randomly divided into four treatment lots. Each treatment received two lots of trays containing six cucumbers. The pectin solution was placed in a deep stainless steel container to ensure that the cucumber was completely dipped. The cucumbers were dipped for 4 min in a prepared pectin solution. For 15-30 min, the coated cucumbers were placed on a drying rack to remove excess pectin solution and ensure a uniform coating. After drying at room temperature (24 °C) for 30 min, dipping and drying procedures were repeated to ensure a thicker coating. When the coated cucumbers had dried and a film had formed, they were placed in sealable polypropylene box and stored at 10 °C with 65% relative humidity which is considered the ideal condition for cucumber storage and transportation (Gutierrez-Pacheco *et al*., 2020). The temperature and RH were controlled during storage using a thermo-hydrometer (Digital Thermometer HTC-2). Uncoated cucumbers were used as control samples and were dipped in distilled water before being stored under the same conditions as the coated cucumbers.

Experimental design. Cucumbers were monitored during storage to determine their shelf life. Weight change, pH, total soluble solids (TSS) and firmness were measured at various time intervals (1, 3, 7, 9 and 13 days).

Weight changes. To determine weight changes, the cucumbers were weighed during the storage period. Weight differences were computed using the following formula:

Weight changes (%) = (initial weight – last weight)/ initial weight×100

The pH measurement. The pH was determined using a digital pH meter (Hanna-HI 98107 pHep). The pH probe was calibrated in a buffer solution before insertion into the cucumber pulp.

Total soluble solid. TSS was determined using the method described by (Daniel *et al*., 2021), in which cucumbers were blended until a homogenized mixture was obtained, drops of the obtained solution were placed in a prism of a refractometer (hand-held optical refractometer HRB32-T) and the reading was taken as a degree of % brix at 20 °C. Throughout the experiment, a hand penetrometer was used to measure the firmness of coated and uncoated samples. Each test was repeated three times and the mean readings were calculated.

Firmness. Penetrometer (fruit hardness tester model GY-3) with head pressure diameter 8mm used to measure the cucumber firmness and the measured value expressed by Kg/cm^2.

Statistical analysis. Statistical package for the social sciences (SPSS, IBM version 23) was used for statistical analysis. Comparisons between treatments were performed using the paired sample *t*-test). One-way analysis of variance (ANOVA) was used to compare the level of significance between treatment groups. In all analyses, a P-value = 0.05 considered as statistically significant.

Results and Discussion

Cucumber has shelf-life range of 10th to 14th days at low temperatures 10 °C) and relative humidity (80 %) (Khojah *et al*., 2021). Cucumber quality is determined by several properties such as appearance, colour, firmness, nutrient content and microbial safety (Olawuyi and Lee, 2019). Maintaining these properties is challenging (Khojah *et al*., 2021). Edible coating is a technique used to preserve many intact and minimally processed fruits and vegetables (Olivas *et al*., 2008). Pectin-edible coatings act as selective permeability against gas exchange, moisture loss and pathogen growth, thereby extending shelf life during storage (Tumbarski *et al*., 2020; Rojas-Grau *et al*., 2009) as measured by the appearance, colour and delay weight loss of the bioactive compounds in vegetables, thereby maintaining the sensory and quality of fresh fruits and vegetables (Perez-Soto *et al*., 2021).

The results are presented in Table 1 and Fig. 1. The uncoated cucumber showed significant weight loss during storage period on 9th day on average (12.7 ± 3.2g) with 27.5% of weight change, when compared to pectin based coated cucumber (5.7 ± 0.3g) on 13th day of storage, with 12.6% of weight loss. Water loss from fruits and vegetables depends on the pressure gradient, storage temperature and respiration rate. Pectin coatings regulate transpiration and gas exchange, prevent excessive water loss through evaporation, reduce dehydration, reduce weight loss, delay ripening and maintain appearance (Hernandez-Guerrero *et al*., 2020).

Table 2. shows that the pH of both coated and uncoated cucumbers gradually decreased during storage. There were no significant differences in the pH parameters between samples group; the pH of the uncoated and coated cucumbers was similar (6.5 ± 0.2). Furthermore, the pH of the uncoated cucumber was (5.8 ± 0.1) on

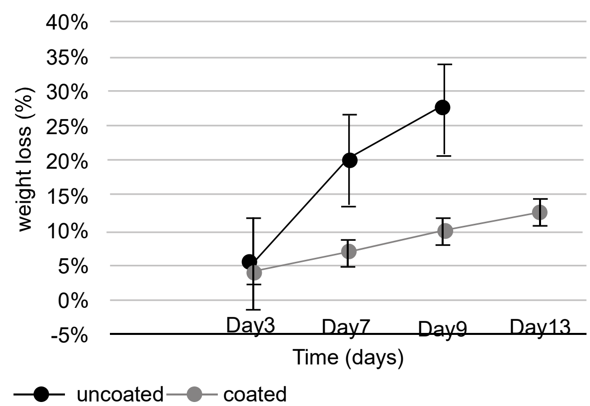

Fig. 1. Weight loss (%) of cucumber in different duration coated with 5% (w/v) pectin and 50% glycerol-20% beeswax.

Table 1. Weight loss (%) of cucumber in different duration coated with 5% (w/v) pectin 50% and glycerol 20% beeswax

Days	Weight loss (g)			
	Uncoated Mean ± SEM	P- value	Coated with pectin mean differences± SEM	P- value
Day 1	46.2 ± 3ᵃ	0.02	44.5 ± 2.6ᵃ	0.001
Day 3	43.8 ± 3		42.7 ± 2.8	
Mean differences ± SEM	2.4 ± 0.7		1.9 ± 0.5	
Day 7	37 ± 2.8		41.5 ± 2.7	
Mean differences ± SEM	6.8 ± 2.9		1.2 ± 0.3	
Day 9	33.5 ± 2.2ᵇ		40.1 ± 2.7	
Mean differences ± SEM	3.4 ± 3		0.9 ± 0.1	
Day 13			38.9 ± 2.7ᵇ	
Mean differences ± SEM			1.7 ± 0.3	
Mean changes	12.7 ± 3.2		5.7 ± 0.3	

Data presented as mean ± SEM; Significant weight changes between the first and last measurement days; Different letters in the same column indicate significant differences (P ≤ 0.05).

Table 2. The effect of pectin coating on the pH changes of coated cucumbers during storage

Days	pH measurements			
	Uncoated cucumbers mean ± SEM P- value	P- value	Coated cucumbers with pectin mean differences± SEM	
1	6.5± 0.2[a]	0.001	6.5 ± 0.2[a]	0.001
3	6.3 ± 0.2		6.4 ± 0.2	
7	6 ± 0.2		6.1 ± 0.2	
Mean differences ± SEM	0.4 ± 0.2		0.4 ± 0.1	
9	5.8 ± 0.1[b]		6 ± 0.2	
Mean differences ± SEM	0.3 ± 0.1		0.1 ± 0.03	
13			5.9 ± 0.2[b]	
Mean differences ± SEM			0.1 ± 0.1	
Mean differences ± SEM	0.7 ± 0.2		0.6 ± 0.1	

Data presented as mean ± SEM; Significant pH changes between the first and last measurement days; Different letters in the same column indicate significant differences (P ≤ 0.05).

day 9th, with significant differences from the 1st day (0.3 ± 0.1). The pH measurement of the coated cucumbers with pectin on the 13th day was (5.9 ± 0.2) and there were significant differences in the pH measurements of the pectin based coated cucumber from the 1st trial day (0.6 ± 0.1). The acidity decreased as fruit ripening due to using of acid as substrate in respiration state (Bibi and Baloch, 2014). Similar finding was found in pectin-based coating avocados reduce moisture and slow respiration rates (Ranjitha *et al*., 2017). Moreover, pectin formed a semi-permeable barrier that reduced water loss while maintaining cucumber tissue structural and cell wall integrity (Khalid *et al*., 2022).

During fruit ripening, starch hydrolysis by amylases increases TSS content and releases glucose, fructose and sucrose (Thokchom and Mandal, 2019). The results are presented in Table 3 and Fig. 2. There were no significant differences in TSS values between the coated and uncoated cucumbers at the start of the study. The TSS value of uncoated cucumber increased by 21%,

Table 3. TSS changes (%) of cucumber in different duration coated with 5% (w/v) pectin, 50% and glycerol 20% beeswax

Days	TSS (% brix)			
	uncoated cucumbers mean ± SEM	P- value	Coated cucumbers with pectin mean differences± SEM	P- value
Day 1	4.3 ± 0.1a	0.001	4.3 ± 0.1a	0.001
Day 3	4.4 ± 0.1		4.3 ± 0.1	
Day 7	4.8 ± 0.1		4.4 ± 0.1	
Mean differences ± SEM	- 0.5 ± 0.2		- 0.1 ± 0.02	
Day 9	5.2 ± 0.1b		4.5 ± 0.1	
Mean differences ± SEM	- 0.4 ± 0.1		- 0.1 ± 0.02	
Day 13			4.8 ± 0.1b	
Mean differences ± SEM			- 0.3 ± 0.1	
Mean differences ± SEM	- 0.9 ± 0.2		- 0.5 ± 0.1	

TSS= Total soluble solid; data presented as mean ± SEM; Significant TSS changes between the first and last measurement days; Different letters in the same column indicate significant differences (P ≤ 0.05).

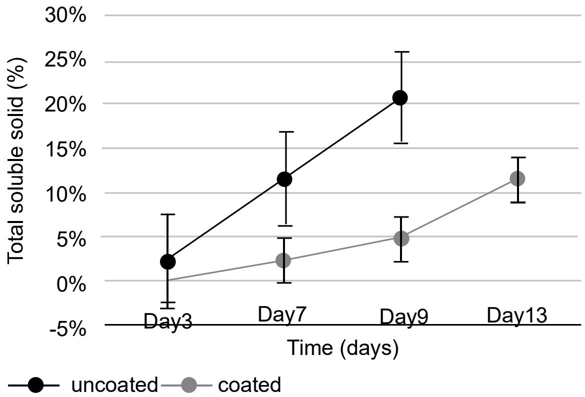

Fig. 2. TSS changes (%) of cucumber in different duration coated with 5% (w/v) pectin 50% and glycerol 20% beeswax.

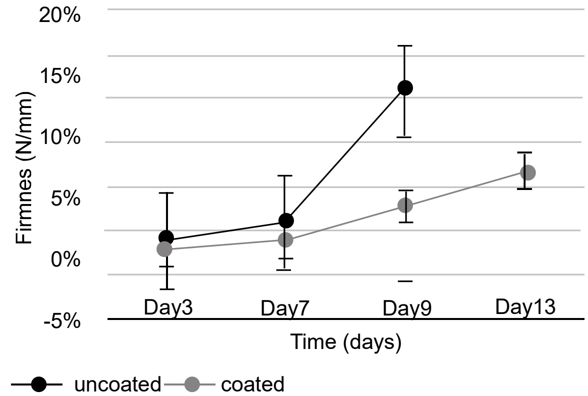

Fig. 3. Firmness change rate of cucumber in different duration coated with 5% (w/v) pectin 50% and glycerol 20% beeswax.

Table 4. Firmness change rate of cucumber in different duration coated with 5% (w/v) pectin 50% and glycerol 20% beeswax

Days	Firmness measurement (Kg/cm^2)			
	Uncoated	P- value	Coated with glycerol and wax	P- value
Day 1	7.2 ± 0.1[a]	0.01	7.1 ± 0.1[a]	0.001
Day 3	7 ± 0.2		7.05 ± 0.1	
Day 7	7 ± 0.1		7 ± 0.1	
Mean differences ± SEM	0.2 ± 0.03		0.1 ± 0.01	
Day 9	6.2 ± 0.3[b]		6.8 ± 0.1	
Mean differences ± SEM	0.8 ± 0.3		0.2 ± 0.04	
Day 13			6.6 ± 0.1[b]	
Mean differences ± SEM			0.2 ± 0.05	
Mean differences ± SEM	1 ± 0.3		0.5 ± 0.1	

Data presented as mean ± SEM; Significant firmness changes between the first and last measurement days; Different letters in the same column indicate significant differences ($P \leq 0.05$).

from (4.3 ± 0.1% brix) to (5.2 ± 0.1% brix) after 9th days, while the value of TSS at the 1st day of trial in pectin based coated cucumber was (4.3 ± 0.1% brix), it increased to (4.8 ± 0.1% brix) after 13th days, representing an 11.6% change.

As shown in Table 4 and Fig. 3. The firmness of the coated and uncoated cucumbers was similar at the start of the experiment but decreased during storage. The reduction was greater in uncoated cucumbers (1 ± 0.3), representing 13.9% reduction changes, than in pectin coated cucumbers (0.5 ± 0.1) and representing 7% reduction changes. The loss of firmness was attributed to the degradation of the cell wall by pectin methylesterase and polygalacturonase enzymes and the loss of insoluble pectin to soluble (Daniel *et al*., 2021; Thokchom and Mandal, 2019). Previous research has found that coating strawberries with pectin and sodium benzoate delayed changes in TSS content and pH (Trevino-Garza *et al*., 2015). The TSS of fresh cucumber pickles increased within the 20th day of storage and then decreased at 7 °C and 90–95 relative humidity, as reported by Haken *et al*. (2006). Furthermore, pectin acts as a barrier against external factors, allowing the pH to be maintained (Menezes and Athmaselvi, 2016).

According to the current study, using pectin along with beeswax and glycerol improves the moisture barrier of coated materials because of its hydrophilic nature, whereas glycerol acts as a plasticizer (Garcia *et al*., 2014). Similar findings were reported by (Radi *et al*., 2017) in orange slices coated with pectin and edible oil and stored at 4 °C for 17 days, resulting in lower weight loss, greater firmness, maintain desired texture and increasing customer satisfaction (Prakash and Manikandan, 2016). Moreover, applying pectin films coated with beeswax and sorbitol would delayed weight loss, acid formation and colour change development in mangoes for more than 2 weeks (Moalemiyan *et al*., 2012). Furthermore, pectin prepared with calcium chloride as a cross-linking agent and edible oil as a lipid source retains the initial firmness of vegetables during storage (Valdes *et al*., 2015) which reduces bacterial enzymatic activity and microbial growth, preserves nutrient content (Gavrilovic *et al*., 2019) and preserves antioxidant properties (Olivas *et al*., 2008).

Conclusion

In conclusion, the findings of this study revealed that pectin coating extends cucumber shelf life by 13 days by delaying weight loss and maintaining pH, firmness and TSS. These findings indicate that pectin based coatings preserve cucumber moisture and structural integrity of the cell wall. Instead of conventional chemical coatings, pectin derived from natural, renewable and low cost materials should be considered as a clean and safe coating material that raises safety and environmental concerns and is more appealing to consumers.

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Conflict of Interest. The authors declare that they have no conflict of interest.

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