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Shelf-Life of Apples Coated with Whey Protein Concentrate-Gellan Gum Edible Coatings

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ABSTRACT: Edible coatings made from whey protein concentrate (WPC) and gellan gum (G) were investigated for their capacity to preserve the quality of *Malus domestica* cv Golab apples. WPC and gellan gum coatings at different concentrations plasticized with glycerol (Gly) were tested. Postharvest storage quality condition testes included weight loss, color and texture changes, titratable acidity and soluble solids content and consumer acceptance. The results indicated that WPC-gellan-coated fruits were rated highest for taste, glossiness, colour and overall acceptability and were lowest for weight loss in this study. Results also showed no significant difference in soluble solids content and titratable acidity between control and the coated apples after 4 weeks at 4°C.

Keywords: *Apple, Edible Coating, Gellan Gum, Shelf-Life, Whey Protein Concentrate.*

Introduction

Edible coatings, which are defined as thin layers of wax or other materials are applied to the surface of food and have been used for over 800 years. Records dated as early as the 12^{th} and 13^{th} centuries showed that wax coatings were applied to citrus fruits in China (Hardenburg, 1967). Coatings of edible materials applied as a thin layer to enhance the quality, extend the shelf-life of fruit and work as a barrier in reducing both respiration and water loss (Olivas *et al*., 2007). Edible coatings can provide an additional protective coating for fresh products and they can also give the same effect as modified atmosphere storage in modifying internal gas composition (Baldwin, 1994).

Recently, several edible coatings for preserving fruits such as oranges, apples and grapefruits were successfully applied (Park, 1998). The mechanism by which coatings preserve fruits and vegetables, were performed by producing a modified atmosphere surrounding the product. This modified atmosphere can serve several purposes, including reducing oxygen availability and increasing the fruit or vegetable's internal carbon dioxide concentration (Smith *et al*., 1987). Modified atmospheres created by coatings are produced by the physical trapping of carbon dioxide gas within the fruit tissues during respiration (Ball, 1997).

Edible films have been proven to be an elective preservation technique that cannot only keep fruit plumpness, fresh appearance and hardness but also improve the luster of fruits surface thereby increasing the commercial value of fruits (Xu & Chen, 2003).

More recently waxes and edible coatings made from proteins, polysaccharides and various combinations of these products have been used on many other fruit and vegetable commodities, as well as for other food applications, including nuts and meat products (Kester & Fennema, 1986). Such

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coatings have been used to reduce moisture loss and surface wounding, as well as to reduce a variety of diseases in apple varieties (Hardenburg, 1967; Kester & Fennema, 1986; Bai *et al*., 2003).

Protein films and coatings possess excellent oxygen barrier properties comparable to synthetic polymer,such as polyvinylidene chloride and ethylene vinyl alcohol films (Trezza & Krochta, 2002). Whey Protein Concentrate (WPC) edible coatings in combination with anti-browning agents effectively extended the shelf-life of minimally processed apple slices by 2 weeks when stored in packed trays at cold storage (Lee *et al*., 2003).Whey protein-based coatings without incorporation of antioxidants were more effective in reducing enzymatic browning of 'Golden Delicious' apples than hydroxypropyl methylcellulose-based coatings (P´erez-Gago *et al*., 2005).

Many gums and their derivatives have been used for coating purposes. Coatings which have been used for apple coating based on hydrocolloids include: Carboxymethyl cellulose (CMC) dust and starch for freshly cut pieces of fruits (Mason, 1969) and chitosan and lauric acid (pennisi, 1992) for apple slices.

The objectives of this investigation were to develop methodologies for forming simple protein and composite protein-gum films based on WPC on apple and to study the shelf life and sensory analysis of coated apples.

Materials and Methods

Materials

WPC (85 percent protein) was supplied by Arla Foods (Videbeak, Denmark). Gellan gum was purchased from Fisher Scientific, Inc. (Fair Lawn, USA). Glycerol and calcium chloride (CC) by Merck (Darmstadt, Germany) were added as a plasticizer to all film-forming solutions.

Fruit selection and preparation

Apples were bought at a local market in Tehran and immediately transported to the laboratory for the experiments. The *Malus pumila* cv Golab was chosen for this experiment because of its short shelf life. Selected apples of uniform size and color were washed in distilled water, dried, and defective ones were eliminated before treatments. Coated and uncoated fruits were kept at 4±1 °C for 28 days.

Experimental design

Initial baseline values of each tested variable were established on day 0 of the test period using 10 apples. The five coated groups and the control group were subsequently tested every seven days. Weight was measured on the 7th, 14th, 21st and 27th days.

Coating formulations

Five coating treatments were applied to *Malus pumila* cv Golab Apples. The control treatment had no coating. The remaining 5 treatments were variations such as: (T1) 4gr Gellan +1 gr Calcium Chloride + 195 gr DW, (T2) 10gr WPC+0.05 gr Gellan + 90 gr distilled water (DW), (T3) 12gr WPC+3 gr Gly+ 0.05 gr Gellan + 88 gr DW, (T4) 11gr WPC +3 gr Gly+ 89 gr DW and (T5) 4 gr Gellan + 3 gr Gly + 193 gr DW. Coating treatments were made by heat denaturing a 10percent (wt/wt) aqueous solution of WPC in a 90 °C water bath for 30 min (McHugh & Krochta, 1994) (Fig.2**)**. The solutions were cooled to room temperature in an ice bath. The appropriate amounts of glycerol plasticizer were added and stirred for 30 min to achieve total dissolution. Deionized water was used for all solutions.

Soluble solids content and titratable acidity

Soluble solids content was quantified every 7 days for 28 days in triplicate order. Soluble solids in the juice were determined using a refractometer. The amount of juice obtained was decreased during the storage as water loss in the apple slices was increased. These higher concentrated juices were conducive to higher values of citric acid and soluble solids. Therefore, the amount of soluble solids obtained was compensated for weight loss as follows:

$V = X\,(100 - \%WLt)\ 100$

Where X is the value for soluble solids obtained from apple juice before weight loss compensation, % WL is the percentage of weight loss at time t, and V is the corresponding true value for soluble solids or citric acid content after weight loss compensation.

Titratable acidity,which was analyzed according the to method described by Lees (1971) was used for the determination of titratable acidity and the results were expressed as the percentage of citric acid.

Weight loss determination

Ten fruits for each specific condition were randomly selected and the fruits were weighed during the study with a laboratory balance (Mettler AE 200-S Greifensee, Switzerland) and the results were expressed as the percentage of weight loss.

Sensory evaluation

Fruit colour was measured by the CIE L*a*b* system using a chroma meter Minolta Model CR-300 (Minolta. Co. Ltd., Japan) at 6 h intervals for 24 h. A white tile (L*: 97.46; a*: -0.02; b*: 1.72) was used as a reference. Firmness was evaluated by a puncture test on the sides of the cubes prepared from quarters using a TA-XT2 texture analyser from Stable Micro Systems with the cross head speed of 100 mm/min and the load cell used was 50 kg. The maximum amount of force needed to puncture the apple sample was recorded. Two samples per apple were tested and analyzed as subsamples equipped with a rounded 2 mm diameter flat-head steel probe. Peel firmness measurements were taken as the first peak force value obtained during the test to penetrate the fruit 7 mm at 1.5 mm/s and pulp firmly as the medium force. Three samples per apple were tested and analyzed as subsamples.

Statistical analyses

Data were analyzed using a factorial analysis in order to determine whether the post harvest coated apples' quality parameters differed from the uncoated control apples. Factorial analysis was also used to determine if any of the parameters tested changed over time. Analysis of variance (ANOVA) calculations was used for the factorial analysis. Days or treatments that differed significantly at the P=0.05 level were subjected to Duncan’s difference test to compare each treatment to the nontreated control.

Results and Discussion

Soluble solids content and titratable acidity

Soluble solids content of coated and un-coated apples stored under cold condition was decreased at the end of the storage period. The loss of soluble solids during the storage period is as natural as sugars which are the primary constituent of the soluble solids content of a product, consumed by respiration and used for the metabolic activities of the fruits (Özden & Bayindirli, 2002).

The major sugar in ‘Golab’ apples was fructose which was 1.68±0.42 gkg^{-1} (fresh weight basis). Coated fruit had lower sugar levels therefore no significant differences were found due to the treatments (Table 1).

Table 1. Average soluble solids and citric acid content of coated and un-coated (control) apples after 28 days cold storage

Sample	S.S (%)	citric acid (g/kg)
Control	11	1.68
T1	9	1.4
T2	11	1.4
T3	10	1.4
T4	9	1.3
T5	11	1.3

Generally all apples exhibited an increase, when their initial titratable acidity contents (expressed as citric acid) were compared to the final ones at the end of storage period, to varying extents, depending on the applied specific treatment.

There were no significant differences in the titratable acidity and soluble solids among the coatings for all of the varieties, possibly because of the relatively brief storage time. This is somewhat unexpected. Apples with inhibited respiration generally maintain organic acid levels during the storage better than fruit with uninhibited respiration rates (Baritelle & Hyde, 2001).

Weight loss of coated apple

Edible coatings produced on T3 and T4 were suited to extending lower fruit weight loss (1.3 percent). The fruits coated with T1, T2 and T5 solutions presented results similar to the uncoated apples. Weight loss was the highest for fruit without any coatings after 14 days and for T2 due to the second week of the storage time. (Fig. 1).

Table 2. Sensory attributes of apples coated with WPC/Gellan gum edible coatings and uncoated (control) apples after 4 week at 4°C

Sensory attribute	Control	T1	T2	T3	T4	T5
Taste	6.16±0.06[a]	4.33±0.23[b]	4.27±0.37[b]	7.50±0.56[c]	7.00±0.06[c]	4.14±0.02[b]
Glossiness	6.33±0.40[a]	4.88±0.12[b]	4.48±0.62[b]	7.14±0.42[c]	6.58±0.26[c]	5.12±0.44[b]
Sweetness	6.06±0.40[a]	5.88±0.12[a]	6.18±0.62[a]	7.14±0.42[b]	5.58±0.26[a]	6.12±0.44[a]
Overall acceptability	5.04±0.08[b]	5.32±0.14[b]	5.450.12[b]	8.02±0.54[c]	6.86±0.30[d]	5.23±0.52[b]

Means with same superscript are not significantly different (P > 0.05)

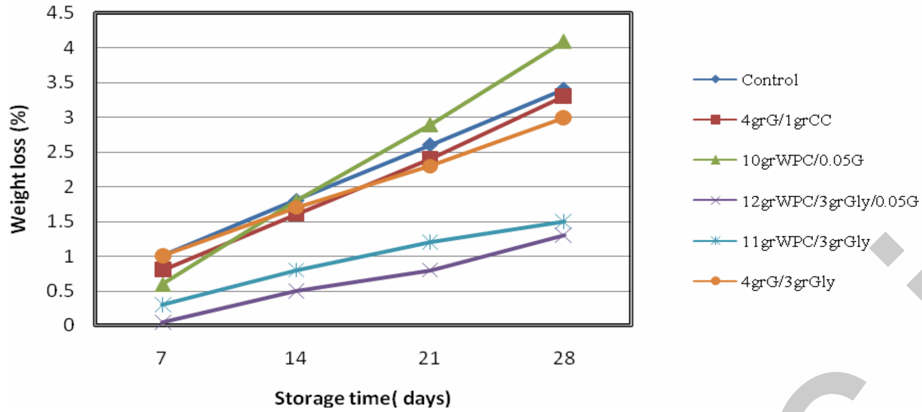

Fig. 1. Weight loss evolution in apple samples during cold storage period. Data shown are the means (6 standard deviation)

Fig. 2. Changes in glossiness, shrinkage and shriveling in coated (A) and un-coated (B: T1, C: T2, D: T3, E: T4 & F: T5) apples after 28 days storage in 4±1 °C and 70± 2 % relative humidity

Post harvest weight changes in fruits and vegetables are usually due to the loss of water through transpiration. This loss of water can lead to wilting and shriveling which both reduce a commodity marketability. Edible films and coatings can also offer a possibility to extend the shelf life of fresh-cut produced by providing a semi-permeable barrier to gases and water vapor, and therefore, they can reduce respiration, enzymatic browning and water loss (Guilbert, 1986; Baldwin & Nisperos-CarriedoBaker, 1995).

No shrinkage was detected for WPC-gellan and gellan (T3 and T4) coated fruits (Fig.2).

Table 3. Color attribute for basic material (BM) at day 0 vs uncoated and coated apples at 28th day

	L*	b*	FMAX
BM	83.6±0.44	42.3±0.34	3.6±0.30
Uncoated	67.2±0.30	44.3±0.47	1.1±0.20
T1	68.7±0.45	47.12±0.50	2.3±0.10
T2	65.6±0.18	45.1±0.57	1.8±0.10
T3	79.8±0.80	58.2±0.40	2.8±0.08
T4	76.26±0.22	56.21±0.37	2.1±0.06
T5	65.82±0.50	48.6±0.24	1.6±0.11

Hatfield and Knee (1988) and Maguire *et al* (2000) reported that even as little as 3.5-5 percent weight loss can lead to shriveling in apples. Only T3 and T4 apples lost lower than 1.5percent of initial weight, which was considered not enough to induce shriveling.

Sensory evaluation

Table 3 shows the sensory evaluations of apples in different coatings and uncoated apples. The result of sensory evaluation conducted on uncoated (control) and coated apples after 28 days of storage.

Concerning colour measurement, the score for T3 and T4 was significantly higher than the score for the fresh sample, while those for the other treatments were significantly similar to uncoated apples (Fig. 3). Although some T2 samples showed significant brownish dots or streaks on the flesh; this is difficult to be detected with the colorimeter, which integrates the entire surface exposed for measurement and probably for diluting the visible incipient browning effect.

After 28 days, the control and sample T1, T2 and T5 had a loose skin and they had been peeled easily from fruit flesh with a knife and even with hands. T3 and T4 Samples had a firm skin. Texture loss is the most noticeable change occurring in fruits and vegetables during prolonged storage and it is related to metabolic changes and water content (Garcı´a & Martino´, 1998)

Taste of T3 and T4 samples was significantly ($P<0.05$) higher than the other treatments and uncoated apples. In T3, apples gave significant difference in the firmness, crunchiness and overall acceptability as compared to other treatments and control.

Conclusion

The present work studied the effects of dipping in the innovative coating solutions on apple in the cold storage. WPC-gellan coatings with added plasticizer effectively maintained color, firmness, glossiness and overall acceptability of apple during the storage. The collected data showed that in the uncoated apple samples, sensory attributes were lower than in the coated samples. No differences were detected in the changes in chemical parameters (weight loss, soluble solids and citric acid) values between both samples during the storage.

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