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Effects of Edible Coatings on the Shelf-Life and Quality of Anna Apple (*Malus domestica Borkh*) During Cold Storage

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Abstract: Edible coating has been used for preserving the quality and safety of fresh fruit and vegetables. The objective of this research was to evaluate the effect of soybean gum, jojoba wax, glycerol and Arabic gum as edible coatings instead of paraffin oil on the shelf-life and quality of Anna apple during cold storage at (0°C, 90-95% RH). The results indicated that coated apples showed a significant delay in the change of weight loss, firmness, titrateable acidity, total soluble solids, decay and color compared to uncoated ones. Sensory evaluation results showed that coatings maintained the visual quality of the Anna apple during the storage time. The results suggested using soybean gum, jojoba wax, glycerol and Arabic gum as edible coatings instead of paraffin oil.

Key words: Coating, jojoba, gum, anna, apple, sensory, quality and storage

INTRODUCTION

The extension of fruit shelf life is an important goal to be attained. Many storage techniques have been developed to extend the marketing distances and holding periods for commodities after harvest. Different preservation methodologies have been studied. One method of extending post harvest shelf life is the use of the edible coatings (Baldwin *et al*., 1995). Edible coatings provide a semipermeable barrier against oxygen, carbon dioxide (CO_2) moisture and solute movement; thereby reducing respiration, water loss and oxidation reaction rates (Baldwin *et al*., 1999; Park, 1999). Proteins, lipids and polysaccharides are the main constituents of edible films and coatings. Among the studied proteins are wheat gluten, corn zein, soy protein rice protein, egg albumin and milk proteins (Sobral *et al*., 2001; Lee *et al*., 2003; Bai *et al*., 2003; Perez-Gago *et al*., 2005; Falcão-Rodrigues *et al*., 2007). Polysaccharide-based coatings i.e. Alginate, pectins, cellulose and derivatives, starch and sucrose polyestershave been used to extend the shelf-life of fruits and vegetables (Ni´speros-Carriedo, 1994; Nussinovitch, 1997, 2000; Mancini and McHugh, 2000; Yang and Paulson, 2000; Rhim, 2004; Rojas-Grau *et al*., 2007). Lipids also include waxes, acylglycerols and fatty acids have been used for extending the shelf-life of fruits and vegetables (Perez-Gago *et al*., 2006; Falcão-Rodrigues *et al*., 2007). In this respect, mineral hydrocarbon MHC-based coatings are used on specific types of fruits and vegetables to prevent the loss of moisture, protect the commodities from bruising and add various degrees of sheen. MHC-based coatings may consist of one compound, such as mineral oil, or may consist of a mixture of MHC compounds, such as mineral oil, paraffin wax and petrolatum, blended to modify the melting point of the coating. Furthermore, a coating may be 100% MHC or the MHC product (s) may be part of a water-based emulsion, especially if a mold inhibitor or insecticide is added. When mineral oil is used, it is typically a low viscosity oil <15 cST at 40°C (Heimbach *et al*., 2002). In this regard, several authors noted that certain types of MHC oils and waxes have been shown to cause adverse effects in laboratory test animals (Baldwin *et al*., 1992; Low *et al*., 1992; Firriolo *et al*., 1995; Smith *et al*., 1996; Scotter *et al*., 2003; Farag *et al*., 2007). There is some evidence that mineral oil exposure may be associated with human disease. Subcutaneous injection of mineral oil induces scalloping lipogranulomas a chronic local inflammatory reaction (Di Benedetto *et al*., 2002) and aspiration causes a severe chronic pneumonitis termed lipoid pneumonia (Spickard and Hirschmann, 1994).

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The objectives of this research were to evaluate the potential of soybean gum, jojoba wax, glycerol and Arabic gum to extend the shelf-life and quality of apple during cold storage and to compare the effect of these alternative materials to that of paraffin oil.

MATERIALS AND METHODS

Apple samples: Undamaged mature Anna apple (Malus domesticus Borkh) fruits of uniform size, shape, weight and color, free of physical damage as well as fungal infection were harvested in June 2007 at Nubaria city, Egypt and transported to the laboratory of Fruit Handling Dept. Horticulture Research Institute, Agricultural Research Center, Giza, Egypt.

Edible coatings: Soybean gum was obtained from Cairo for oil and soap company (Giza, Egypt). Paraffin oil and Glycerol (99.0%) were of reagent grade (Gomhoria Co., Amireya-Cairo, Egypt). Jojoba (Simmondsia chinensis) oil (Alkanz Co., Zagazig, Egypt) and Arabic gum (Giza, Egypt) were of commercial grade. Arabic gum solution (15% w v^{-1}) was prepared by dissolving Arabic gum in distilled water and heated at 40°C, while stirring until the solution became clear.

Coating process: Apple fruits were washed in running tap water and cleaned with muslin cloth. The fruits were divided randomly into 6 groups (100 apples/group):

- Controlgroup (untreated)
- Fruits were coated with thin layer of Jojoba wax
- Fruits were coated with thin layer of paraffin oil
- Fruits were coated with thin layer of Soybean gum
- Fruits were coated with thin layer of Glycerol
- Fruits were coated with thin layer of Arabic gum

The treated and untreated fruits were packed in foam plates and wrapped with polyethylene (thin 10/miceron) each plate contain 4 of fruits. The plates were stored at (0°C, 90-95% RH).

Physicochemical analysis: The physico-chemical tests were conducted atthe beginning of the experiment and after 15, 30, 45 and 60 days of storage.

Weight loss was measured by weighting 4 of foam plates with apple fruits (the same plates during all the storage times) and the losses were recorded for each replicate. Weight loss percentages were calculated as percentage from the initial weight. Apple fruit firmness was measured with a hand-held penetrometer (mod. FT 327, McCormick, Facchini, Alfonsine, Italy) equipped with a 7.9 mm diameter cylindrical probe, results were expressed as kg cm^{-2}. Decay percentage of apple fruits was calculated as the number of decayed fruit divided by initial number of all fruits time 100. External fruit color was determined according (McGuire, 1992; Voss, 1992) using a Hunter LAB DP-9000 colorimeter (Hunter Associates Laboratory, Reston, Va, USA).

From 3 apple fruits juice was extracted with an electrical juicer and used for the determination of Total Soluble Solids content (TSS, Brix%) with a refractometer (Carl Zeiss, Germany) and of Titratable Acids (TA). TA was measured by titration with 0.1 N NaOH and expressed in percent of malic acid/100 mL of juice AOAC (2000). Sensory properties were evaluated at room temperature under fluorescent light by 10 experienced panelists of Horticulture Research Institute (Fruit Handling Dept.). Apple fruits were served in randomly coded containers. Each panelist was asked about taste, odor and appearance and over all acceptability. According to Bai *et al.* (2003), the sensory characteristics were evaluated using the following 9 grading categories:

9	=	Excellent
7	=	Very good
5	=	Good, limit of marketability
3	=	Fair, limit of usability
1	=	Poor, inedible

Statistical analysis: The data of the present research (except sensory evaluation data) were subjected to analysis by 2 ways ANOVA (Completely randomized design factorial arrangement). Statistical analysis for the sensory data was performed by one way ANOVA (Complete randomized design one factor). P-values of 0.05 or less were considered significant.

RESULTS AND DISCUSSION

Weight loss percentage: Table 1 shows the changes of Weight Loss Percentages (WLPs) of coated and uncoated apple (control) during cold storage. Generally, the WLP

Table 1: Effect of coating with jojoba wax, paraffin oil, soybean gum, glycerol and Arabic gum on weight loss percentages during cold storage at (0°C, 90-95% RH)

Treatments/ storage period (day)	Control	Jojoba Wax	Paraffin oil	Soybean oil gum	Glycerol	Arabic gum
0	0.00^{m}	0.00^{m}	0.00^{m}	0.00^{m}	0.00^{m}	0.00^{m}
15	1.99^{j}	0.99^{l}	1.46^{k}	1.15^{kl}	1.28^{kl}	1.52^{k}
30	2.73^{defg}	2.03^{j}	2.38^{ghij}	2.15^{ij}	2.26^{hij}	2.47^{fghi}
45	3.77^{c}	2.19^{ij}	2.62^{efgh}	2.54^{fghi}	2.79^{def}	2.77^{defg}
60	5.82^{a}	3.11^{d}	3.94^{c}	3.00^{de}	3.88^{c}	4.66^{b}

LSD at 0.05 = 0.3541; Values followed by different letter are significantly different at ($p<0.05$)

increased gradually ($p \leq 0.05$) during storage period. The primary mechanism of moisture loss from fresh fruits and vegetables is by vapor-phase diffusion driven by a gradient of water vapor pressure at different locations (Yaman and Bayoindirli, 2002). On the other hand, respiration causes a weight reduction because a carbon atom is lost from the fruit in each cycle (Labuza, 1984; Pan and Bhowmilk, 1992). However, coating process caused a significant ($p \leq 0.05$) decrease in WLPs compared with control sample. Control samples had significantly ($p \leq 0.05$) higher WLP (5.82%) at the end of the storage period, while apple samples coated with soybean oil gum and jojoba wax had significantly ($p \leq 0.05$) the lowest WL p-values (3.00 and 3.11%, respectively). This reduction in weight loss was probably due to the effects of these coatings as a semi permeable barrier against oxygen, carbon dioxide, moisture and solute movement, thereby reducing respiration, water loss and oxidation reaction rates (Baldwin *et al*., 1999; Park, 1999). The obtained results are in a good agreement with the findings by Garc´ia *et al*. (1998a, b) for strawberries coated with starch-based coatings and those of Joyce *et al*. (1995), who reported that waxing extended the storage life of avocado both through a reduction in water loss and a modification of the internal atmosphere. Similar data were reported by Bai *et al*. (2003) studying Gala apple, coated with 10% zein (natural corn protein). Sumnu and Bayindirli (1995) noted that Semperfresh (10 g L^{-1}) Jonfresh and Fomesa apple wax coatings were efficient in reducing the rate weight loss of Amasya apples. Chitosan and polyethylene wax (PE) coatings also provide good protection for Hami melon (Cong *et al*., 2007).

Firmness: Flesh firmness is one of the most important parameters as regards consumer acceptance and eating quality of apples (Wills *et al*., 1980).As shown in Table 2, firmness significantly ($p \leq 0.05$) decreased with storage period in both treated and untreated fruits. At the end of storage, control samples clearly had the lowest ($p \leq 0.05$) firmness (3.95 kg cm^{-2}) while apples coated with jojoba wax, paraffin oil, soy gum and glycerol retained the highest ($p \leq 0.05$) firmness (4.94, 4.96, 4.95, 4.94 kg cm^{-2}). Fruits coated with Arabic gum were significantly less firm than the other treated samples (4.69 kg cm^{-2}). Nevertheless, this edible coating still largely reduces firmness losses if compared to untreated fruits.

The retention of firmness can be explained by retarded degradation of insoluble protopectins to the more soluble pectic acid and pectin. During fruit ripening, depolymerization or shortening of chain length of pectin substances occurs with an increase in pectinesterase and polygalactronase activities (Yaman and Bayoindirli, 2002).

Table 2: Effect of coating with jojoba wax, paraffin oil, soybean gum, glycerol and Arabic gum on firmness (kg cm^{-2}) during cold storage at (0°C, 90-95% RH)

Treatments/ storage period (day)	Control	Jojoba Wax	Paraffin oil	Soybean oil gum	Glycerol	Arabic gum
0	5.46^{a}	5.46^{a}	5.46^{a}	5.46^{a}	5.46^{a}	5.46^{a}
15	5.00^{h}	5.33^{b}	5.31^{bc}	5.34^{b}	5.26^{bcde}	5.28^{bcd}
30	4.74^{i}	5.26^{bcde}	5.22^{cdef}	5.22^{cdef}	5.19^{def}	5.18^{def}
45	4.50^{j}	5.16^{ef}	5.14^{f}	5.12^{fg}	5.12^{fg}	5.03^{gh}
60	3.95^{k}	4.94^{h}	4.96^{h}	4.95^{h}	4.94^{h}	4.69^{i}

LSD at 0.05 =0.0946; Values followed by different letter are significantly different at ($p<0.05$)

Table 3: Effect of coating with jojoba wax, paraffin oil, soybean gum, glycerol and Arabic gum on Titratable acidity during cold storage at (0°C, 90-95% RH)

Treatments/ storage period (day)	Control	Jojoba Wax	Paraffin oil	Soybean oil gum	Glycerol	Arabic gum
0	0.45^{a}	0.45^{a}	0.45^{a}	0.45^{a}	0.45^{a}	0.45^{a}
15	0.38^{fghi}	0.41^{bc}	0.40^{cde}	0.42^{b}	0.41^{bcd}	0.41^{bc}
30	0.37^{hijk}	0.40^{cde}	0.39^{efg}	0.40^{def}	0.39^{efgh}	0.38^{ghi}
45	0.35^{m}	0.38^{ghi}	0.37^{ijkl}	0.37^{ijkl}	0.36^{klm}	0.36^{klm}
60	0.30^{n}	0.37^{ijkl}	0.35^{lm}	0.36^{klm}	0.35^{lm}	0.35^{lm}

LSD at 0.05 = 0.01461; Values followed by different letter are significantly different at ($p<0.05$)

Low oxygen and high carbon dioxide concentrations reduce the activities of these enzymes and allows retention of the firmness during storage (Salunkhe *et al*., 1991). Hence, our results nicely reflect the findings by Yaman and Bayoindirli (2002) for cherries coated with Semperfresh™. Furthermore, Patricia *et al*. (2005) reported that refrigerated strawberry coated with wheat gluten-based films had a better firmness retention than control fruit. Sumnu and Bayindirli (1995) also noted that Semperfresh™, Jonfresh and Fomesa apple wax were efficient in reducing the firmness change of Amasya apples during storage process. The same effects were observed by Pre-Aymard *et al*. (2005) for Anna apple treated with 1-MCP.

Titratable acidity: Table 3 shows the changes of titratable acidity of coated and uncoated apple (control) during storage period. The results showed that titratable acidity values were gradually and significantly ($p \leq 0.05$) decreased with increasing storage period. Control samples without coating treatments had the lowest ($p \leq 0.05$) level of titratable acidity was 0.30% the end of storage period. Titratable acidity of apple coated with jojoba wax, jojoba wax, paraffin oil, soybean oil gum, glycerol and Arabic gum at the end of storage period were approximately 1.23, 1.16, 1.20, 1.16 and 1.16 times higher than titratable acidity of control sample without coating. Since, organic acids such as malic or citric acid are primary substrates for respiration, a reduction in acidity and, hence, an increase in pH are expected in highly respiring fruits. Coatings reduce respiration rates and may, therefore, delay the utilization of organic acids (Yaman and Bayoindirli, 2002). A retention of titratable acidity was indeed reported for various fruits all treated with Semperfresh (Dhalla and Hanson, 1988; Bayindirli *et al*., 1995; Summu and Bayindirli, 1995; Yaman and Bayoindirli, 2002). Also, Patricia *et al*. (2005) indicated that coating with PVC pack were effective in the retention of titratable acidity of strawberry fruit during the storage time. The same observation was noted by Pre-Aymard *et al*. (2005), who reported that coating with 1-MCP prevented acidity loss of Anna apple stored at 20°C for 12 days.

Total Soluble Solids (TSS): The results presented in Table 4 show the changes of TS. values of coated and uncoated apple (control) during storage period. Data showed that control samples without coating treatments had significantly ($p \le 0.05$) the highest level of TSS value was 14.60% at the end of storage period. TSS values of apple coated with jojoba wax, paraffin oil, soybean oil gum, glycerol and Arabic gum at the end of storage period were approximately 1.06, 1.05, 1.06, 1.08 and 1.08 times lower than TSS value of control sample without coating. Similar effects were reported by Kittur *et al*. (2001) for banana and mango coated with polysaccharide-based coatings and by Patricia *et al*. (2005) for strawberry coated with wheat gluten-based films.

Decay percentage: Data summarized in Table 5 shows the changes of decay percentage values of coated and uncoated apple (control) during storage period. No decay signs were observed until 2 weeks after the beginning of storage period. Coating significantly ($p \le 0.05$) reduced decay compared to control sample without coating treatment during the storage period. Decay percentage of control sample at the end of storage period were approximately 2.41, 2.44, 3.21, 2.35 and 1.61 times higher than decay percentage of apple coated with jojoba wax, paraffin oil, soybean oil gum, glycerol and Arabic gum, respectively. This decreasing in decay percentages of treated samples was probably due to the effects of these coatings on delaying senescence, which makes the commodity more vulnerable to pathogenic infection as a result of loss of cellular or tissue integrity (Patricia *et al*., 2005). These results are in a good agreement with the findings by Bai *et al*. (2003) for Gala apple, coated with 10% zein. They found that coating with zein maintained apple quality similar to a commercial shellac formulation and extended apple shelf life compared with non-coated controls. Also, Patricia *et al*. (2005) indicated that wheat gluten coatings and films extended the shelf life of strawberries and retarded the senescence process.

Table 4: Effect of coating with jojoba wax, paraffin oil, soybean gum, glycerol and Arabic gum on Total Soluble Solids (TSS) during cold storage at (0°C, 90-95% RH)

Treatments/ storage period (day)	Control	Jojoba Wax	Paraffin oil	Soybean oil gum	Glycerol	Arabic gum
0	12.50^{m}	12.50^{m}	12.50^{m}	12.50^{m}	12.50^{m}	12.50^{m}
15	12.96^{jkl}	12.82^{kl}	12.87^{kl}	12.87^{kl}	12.73^{lm}	12.83^{kl}
30	13.32^{fghi}	13.00^{jkl}	13.18^{hij}	13.19^{ghij}	13.00^{jkl}	12.97^{jkl}
45	13.95^{b}	13.25^{fghij}	13.46^{efgh}	13.64^{cde}	13.17^{hij}	13.07^{ijk}
60	14.60^{a}	13.75^{bcd}	13.80^{bc}	13.67^{cde}	13.49^{def}	13.47^{efg}

LSD at 0.05= □; Values followed by different letter are significantly different at ($p<0.05$)

Table 5: Effect of coating with jojoba wax, paraffin oil, soybean gum, glycerol and Arabic gum on decay (%) during cold storage at (0°C, 90-95% RH)

Treatments/ storage period (day)	Control	Jojoba Wax	Paraffin oil	Soybean oil gum	Glycerol	Arabic gum
0	0.00^{j}	0.00^{j}	0.00^{j}	0.00^{j}	0.00^{j}	0.00^{j}
15	0.00^{j}	0.00^{j}	0.00^{j}	0.00^{j}	0.00^{j}	0.00^{j}
30	9.71^{c}	3.63^{ghi}	3.96^{ghi}	2.95^{i}	3.40^{hi}	6.31^{d}
45	12.33^{b}	5.01^{ef}	4.75^{ef}	4.28^{efgh}	4.48^{efg}	6.69^{d}
60	17.17^{a}	7.11^{d}	7.01^{d}	5.34^{e}	7.30^{d}	10.63^{c}

LSD at 0.05 = 0.9662; Values followed by different letter are significantly different at ($p<0.05$)

Table 6: Effect of coating with jojoba wax, paraffin oil, soybean gum, glycerol and Arabic gum on color L (lightness) during cold storage at (0°C, 90-95% RH)

Treatments/ storage period (day)	Control	Jojoba Wax	Paraffin oil	Soybean oil gum	Glycerol	Arabic gum
0	37.38^{a}	42.73^{a}	42.77^{a}	39.00^{a}	40.08^{a}	39.39^{a}
15	34.65^{a}	40.60^{a}	40.83^{a}	36.19^{a}	38.14^{a}	36.32^{a}
30	34.34^{a}	39.53^{a}	39.76^{a}	35.67^{a}	37.58^{a}	35.29^{a}
45	33.05^{a}	38.41^{a}	38.68^{a}	34.48^{a}	37.07^{a}	34.25^{a}
60	29.71^{a}	38.27^{a}	28.28^{a}	34.27^{a}	36.00^{a}	34.17^{a}

LSD at 0.05 = Not significant; Values followed by different letter are significantly different at ($p<0.05$)

Table 7: Effect of coating with jojoba wax, paraffin oil, soybean gum, glycerol and Arabic gum on color (a^* value) during cold storage at (0°C, 90-95% RH)

Treatments/ storage period (day)	Control	Jojoba Wax	Paraffin oil	Soybean oil gum	Glycerol	Arabic gum
0	21.20^{n}	21.20^{n}	21.20^{n}	21.20^{n}	21.20^{n}	21.20^{n}
15	25.17^{ghi}	22.79^{m}	23.59^{jklm}	22.86^{m}	22.77^{m}	23.11^{lm}
30	28.26^{c}	23.63^{jklm}	24.72^{hilk}	23.79^{jklm}	23.42^{klm}	24.45^{ijkl}
45	30.93^{b}	25.50^{ghi}	26.14^{efg}	26.02^{fgh}	24.87^{ghij}	25.91^{fgh}
60	32.59^{a}	27.36^{cde}	28.45^{c}	27.15^{cdef}	26.92^{def}	27.75^{cd}

LSD at 0.05 =1.183 Values followed by different letter are significantly different at ($p<0.05$)

Colour: Colour evaluation of coated and uncoated apple (control) during storage period is shown in Table 6. Lightness gradually decreased during storage in both coated and uncoated samples (Table 6 and 7). No significant ($p>0.05$) differences were observed between the differently treated apples. Table 7 shows the changes of a* value of coated and uncoated apple (control) during storage period. The a* values of coated and control samples gradually increased ($p \le 0.05$) during storage. At the end of storage period the a* value of control sample

Table 8: Sensory evaluation of apple samples coated with jojoba wax, paraffin oil, soybean gum, glycerol and Arabic gum at the end of cold storage (0°C, 90-95% RH)

Treatments	Taste	Odor	Visual appearance	Texture	Over all acceptability
Control	7.86^{a}	7.14^{a}	6.60^{d}	6.07^{c}	6.91^{c}
Jojoba wax	7.17^{b}	7.05^{a}	7.79^{a}	7.61^{a}	7.40^{ab}
Paraffin oil	7.34^{b}	7.07^{a}	7.89^{a}	7.50^{a}	7.44^{a}
Soybean gum	7.09^{b}	6.99^{a}	6.80^{c}	7.57^{a}	6.86^{c}
Glycerol	7.11^{b}	7.12^{a}	7.45^{b}	6.83^{b}	7.12^{abc}
Arabic gum	7.27^{b}	7.03^{a}	6.70^{cd}	6.85^{b}	6.96^{bc}
LSD at 0.05	0.5050	NS	0.1488	0.1378	0.4394

Values followed by different letter are significantly different at ($p<0.05$); NS: Not Significant

was approximately 1.19, 1.14, 1.20, 1.21and 1.17 times higher than that of apple coated with jojoba wax, paraffin oil, soybean oil gum, glycerol and Arabic gum, respectively. Our results are in a good agreement with the findings by Summu and Bayindirli (1995) for Amasya apple.

Sensory evaluation: Sensory evaluation results are given in Table 8. Sensory results indicated no significances ($p\leq 0.05$) difference between coated and uncoated apple for odor scores (Table 8). Control samples had the highest ($p\leq 0.05$) score for taste, 7.86, at the end of the storage period. No significant differences were observed between the samples coated with jojoba wax, paraffin oil, soy gum, glycerol or Arabic gum. Control sample had the lowest ($p\leq 0.05$) scores for visual appearance, texture and over all acceptability while samples coated with paraffin oil and jojoba wax had significantly ($p\leq 0.05$) the highest scores. The results of sensory evaluation suggest that jojoba wax, soy gum, glycerol and Arabic gum can be successfully used as edible coatings instead of paraffin oil.

CONCLUSION

The results of the current investigation indicated that apple fruits coated with jojoba wax, soy gum, glycerol and Arabic gum showed a significant delay in the change of weight loss, firmness, titratable acidity, total soluble solids, decay and colour during cold storage compared to uncoated ones. Sensory evaluation results showed also that coatings maintained the visual quality of the Anna apple during the storage time.

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