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Effectiveness of Gum Arabic, Potassium Salts and Their Incorporation in The Control of Postharvest Diseases and Maintaining Quality of 'Washington' Navel Oranges during Long Term Cold Storage

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EDIBLE coating of gum arabic (GA) and food preservatives with antifungal properties included potassium sorbate (PS) and potassium bicarbonate (PB) were evaluated on 'Washington' navel oranges during long term cold storage in 2016 and 2017 seasons. Orange fruits were dipped for three minutes into the following treatments: distilled water and used for untreated fruits (control), 0.2% imazalil (IMZ) and used as a commercial fungicide, 10% GA, 2% PS, 2% PB, 0.2% IMZ incorporated with 10% GA, 2% PS incorporated with 10% GA and 2% PB incorporated with 10% GA. After that, all treatments stored at 5±1˚C and 90±5% relative humidity (RH) for ten weeks followed by one week as a shelf life period at 18-23°C and 55±5% RH. The changes in physical and chemical characteristics of orange fruits were determined every two weeks intervals of cold storage periods followed by one week shelf life. In general, all postharvest treatments effectively reduced fruit weight loss, controlled decay incidence, decreased size of lesion surface diameter, increased marketable fruit percentage, maintained rind firmness and retained fruit visual appearance as compared to untreated oranges and treated with IMZ during storage period. Moreover, these applications significantly decreased loss of fruit juice, ascorbic acid, titratable acidity (TA) as well as significantly slowed the accumulation of total soluble solids (TSS) and TSS/TA ratio. In addition, these applications increased total phenolic content and enhanced total antioxidant capacity of oranges as compared to untreated fruits. In particular, 2% PS or 2% PB incorporated with 10% GA coating applications were the most effective in this aspect in comparison to the other treated and untreated fruits. Thus, these applications showed an easy and inexpensive approach as a suitable alternative to the currently adopted IMZ application for controlling postharvest decay and suppressing the deterioration of physical and chemical characteristics of 'Washington' navel oranges during long term storage at low temperature.

Keywords: Navel oranges, Edible coating, Gum arabic, Potassium sorbate, Potassium bicarbonate, Decay, Antioxidant capacity, Total phenolic, Postharvest quality.

Introduction

Citrus is a very economically important crop in many tropical and sub-tropical countries throughout the world (Murata, 1997). Navel orange is one of the commercially important cultivar in this group. Recently, citrus has become an important fruit crop in the world trade for fresh fruits and its processed products because are consumed fresh and/or juiced. In addition to its economic rewards the fruits are a source of valuable nutrients and bioactive components such as ascorbic acid, folic acid, dietetic fiber, carotenoids, essential oils, pectin and phenolic compounds (Balasundram et al., 2006). In Egypt, citrus is one of the most popular fruits and navel oranges enjoy the most significant importance for local market and export markets (Omran et al., 2002). The total area of citrus in Egypt occupy about 485940 feddans, out of which 418415 feddans are fruiting, yielded about 4272886 tons as annual fruit production, whereas the total area of orange occupy about 329496 feddans, out of which 288724 feddans are fruiting, yielded about 3297593 tons as annual fruit production

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(Anonymous, 2017). However, citrus fruit is susceptible to a number of pathogens such as green mould (*Penicillium digitatum*), blue mould (*Penicillium italicum*), sour rot (*Geotrichum candidum*) and black mould (*Aspergillus niger*) through wound and/or injuries inflicted during harvesting and handling of fruit that affect the considerably deteriorate the fruit quality (Eckert and Eaks, 1989). In addition, citrus fruits that are in contact with waste materials, disease pathogen, fungi, bacteria are not suitable for export (Prusky, 2011). The success of fresh citrus fruit export is mainly dependant on the quality of produce, phytosanitary conditions set by the importing country, world trade organization and the postharvest management to minimize the decay till the consignment reaches to its destination. Synthetic fungicide such as imazalil, thiabendazole and sodium orthophenylphenate incorporated into waxes in the citrus packinghouses is one of the most important steps for controlling postharvest decay in citrus packinghouses. However, the widespread use of these fungicides in commercial packinghouses has led to the proliferation of resistant isolates of fungal pathogens, thus their effectiveness have considerably reduced (Palou et al., 2008). Furthermore, prolonged and extensive use of synthetic chemical fungicides either alone or into conventional waxes may deposit harmful residues on fruit surface with increasing concerns of human health hazards and environmental contamination due to the use of large quantities of chemicals (Palou et al., 2008 and Youssef et al., 2014).

Nowadays, all imported countries have enforced strict import regulations regarding the maximum residue for such chemical treatments of citrus fruits and consumers prefer purchasing the fruits that are not treated with fungicides, free from defects and disease because it is safer for consumption. Therefore, new non-toxic methods for controlling postharvest diseases have shifted towards prioritizing alternatives to synthetic fungicides (Palou et al., 2008). Among the alternative curative methods against citrus postharvest decay with maintain the fruit quality are common antimicrobial food preservatives such as potassium sorbate (Palou et al., 2002, Smilanick et al., 2008, Montesinos-Herrero et al., 2009 and Parra et al., 2014) and potassium bicarbonate (Youssef et al., 2014). These salts are a safer to consumers, workers and environment thus approved as generally regarded as safe (GRAS) compounds and classified as a minimal risk active ingredient and exempt from residue tolerances by the European Food Safety Authority and the United States Food and Drug Administration (Lindsay, 1996). In this context, control of postharvest decay of green and blue mold was achieved by potassium sorbate alone (Palou et al., 2002, Smilanick et al., 2008 and Parra et al., 2014) or in combination with imazalil and thiabendazole even when tested against a resistant isolate of *Penicillium digitatum* and *Penicillium italicum* (Montesinos-Herrero et al., 2009). Moreover, low toxicity salts of potassium sorbate, sodium bicarbonate and potassium phosphite were controlled postharvest diplodia and phomopsis stem end rot of ‘Eureka’ lemons (Cerioni et al., 2013 and Cerioni et al., 2017). Incorporated potassium sorbate, carbonate and bicarbonate at 6% concentration in wax significantly reduced the postharvest decay incidence and decrease the weight loss reduction of citrus fruits (Youssef et al., 2012a). Also, pre or post harvest application of potassium sorbate, potassium carbonate or potassium bicarbonate at 2% reduced postharvest decay of clementines cv. ‘Comune’ and oranges cv. ‘Valencia’ during cold storage at 6°C and 4°C, respectively for two months followed by seven days shelf life at 20±2°C (Youssef et al., 2012b). Moreover, dipping ‘Tarocco’ and ‘Valencia late’ oranges in 3% potassium bicarbonate reduced the percentage of postharvest decay during cold storage and shelf life and could be efficiently using as alternative treatment for conventional synthetic fungicides (Youssef et al., 2014). In addition, applications of potassium sorbate at 2% individually or plus hydrogen peroxide at 2% controlled postharvest diseases of ‘Eureka’ lemons for two weeks at 20°C (Cerioni et al., 2013).

The application of wax coatings is a critical operation in citrus fruit packinghouses, which create a protective barrier that is providing the required shine and gloss on which aesthetic value, protecting weight loss reduction (Wild, 1981). Nevertheless, an increase of stem-end rot and internal core rot caused by *Alternaria citri*, *Diplodia natalensis* and *Fusarium spp.* were observed on citrus fruit treated with different commercial waxes (Wild, 1981 and Waks et al., 1985). Thus, natural products are taking a place as an alternative approach for reducing postharvest deterioration of fruit (Tripathi and Dubey, 2004). Edible coatings are considered an environmentally friendly alternative method able to extend the postharvest life of fresh fruits and vegetables (Dhall, 2013). They form a semi-permeable barrier to gas exchange and water vapor that reduce weight loss because of preventing dehydration of the coated product and decrease metabolic processes such as respiration and ethylene production rates, hence delay fruits senescence. Various compounds have been used as edible coatings and are commonly based on proteins, lipids and polysaccharides. Gum arabic (GA) is a polysaccharide natural secretion from stems and branches of *Acacia* species and is composed of galactose, rhamnose, arabinose and glucoronic acid (Idris et al., 1998). Gum arabic is considered as GRAS compounds. It is widely used extensively in the industrial sector because of its emulsification, film forming and encapsulation properties (Nisperos-Carriedo, 1994). Postharvest coated apples with gum arabic significantly reduced decay incidence, weight loss percentage, softness and colour development as well as maintained internal quality during cold storage as compared to uncoated fruits (El-Anany et al., 2009). Moreover, 10% gum arabic coating alone or combined with lemongrass oil or cinnamon oil controlled anthracnose and maintained quality of banana and papaya fruits (Maqbool et al., 2011). Pre-storage treatment of mangoes with gum arabic at 10% alone or incorporated with calcium chloride at 3% effectively reduced decay incidence, weight loss, colour changes and soluble solid content as well as efficiently maintained high firmness, ascorbic acid, titratable acidity (Khaliq et al., 2015). Additionally, gum arabic coating effectively maintained total antioxidant and total phenolic content in papaya fruits (Addai et al., 2013) and mangoes (Khaliq et al., 2016).

Therefore, the objective of this work was to study the effect of utilization of new edible coating with gum arabic and food additives of potassium sorbate and bicarbonate as a low-toxicity or non-contaminant antifungal methods on postharvest decay and maintaining quality of ‘Washington’ navel oranges during long term storage at 5±1˚C and 90±5% relative humidity (RH).

Materials and Methods

Fruit material, preparation of soaking solutions and treatments

During 2016 and 2017 seasons commercially mature of ‘Washington’ navel oranges (*Citrus sinensis* (L.) Osbeck) were harvested randomly from a private orchard at El-Asher min Ramadan city, El-Sharqia Governorate, Egypt (latitude, 31°74′ N, longitude, 30°29′ E). The trees grafted on ‘Sour Orange’ rootstock, were about 15 years of age, planted at a spacing of 6 × 5 meters apart in sandy soil under drip irrigation system and subjected to standard agriculture practices recommended by ministry of agriculture and land reclamation. Fruit were directly transported in plastic boxes (15 kg capacity) to Department of Horticulture, Faculty of Agriculture, Tanta University, Egypt. At the laboratory, orange fruits sorted to eliminate defects. Samples of fruit of uniform size and appearance were washed by 2% sodium hypochlorite water solution for 2 min to clean the surface of fruits and completely air dried at room temperature. A total of 1008 clean sound oranges were selected and randomly divided into eight treatment with three replicates and each replicate contained seven individual fruit (8 treatments x 6 periods of storage × 3 replicates × 7 fruits).

Gum arabic (GA) powder of food grade was purchased from Sigma Chemical Company, Egypt. GA solution at 10% (w/v) was prepared by dissolving 500 g of gum arabic powder in 5 liter of distilled water. The solution of GA was stirred with low heat at 40˚C for 60 min by using a hot plate with magnetic stirrer (Model: 502P-2 USA), then filtered using muslin cloth to remove impurities and any undissolved materials. After cooling the solution to 20°C, glycerol monostearate at 1% was added as a plasticizer to improve the strength and flexibility of the coating solution. The pH of the solution was adjusted to 5.6 with 1N NaOH using a digital pH meter (Model: AD1000, Romania). Potassium sorbate (PS) or potassium bicarbonate (PB) solution at 2% (w/v) was prepared by dissolving 100 grams of PS or PB in 5 liter of distilled water. Imazalil (IMZ) solution at 0.2% (v/v) was prepared by adding 10 ml of IMZ in 5 liter of distilled water. For the incorporated treatments, after the preparation of 10% GA, either imazalil at 0.2%, potassium sorbate at 2% or potassium bicarbonate solution at 2% was added into GA, stirred for 30 min using magnetic stirrer and the pH of the solutions was adjusted to 5.6 with 1N NaOH using a digital pH meter. Five liter of distilled water without any additives was used to untreated fruits (control). Tween 80 was added to each the solution at a concentration of 0.05% (v/v) to improve wettability and adherence to ‘Washington’ navel oranges surface. Treatments for the experiment were as follow: distilled water and used for untreated fruits (control), IMZ at 0.2% and used as a commercial fungicide, GA at 10%, PS at 2%, PB at 2%, GA at 10% incorporated with IMZ at 0.2%, GA at 10% incorporated with PS at 2% and GA at 10% incorporated with PB at 2%. These treatments were performed by soaking 'Washington' navel oranges in these solutions for three minutes. After soaking treatment, orange fruits were allowed to dry for one hour at room temperature by electric fan. All orange fruits in each treatment were packed in cardboard boxes with dimensions of 45×35×10 cm covered with polyethylene plastic films with a thickness of 0.04 mm, five holes of 7 mm in diameter were made in the plastic film. Each treatment consisted of 126 fruits and each replicate contained of seven orange fruits for each storage period. All experimental boxes were stored at 5±1˚C and 90±5% RH for ten weeks. Samples of oranges were taken at zero and every two weeks intervals of cold storage period at 5˚C followed by seven days at ambient conditions (18-23°C and 55±5% RH) as a shelf life period to examine the effect of postharvest treatments and storage periods on decay incidence and measure the changes in physical and chemical attributes. Whereas, total phenolic content and total antioxidant capacity of orange fruits were determined at zero, two, six and ten weeks of cold storage period at 5˚C followed by seven days shelf life at room temperature.

Measurement of fruit weight loss, decay and marketable percentage

Fruit weight loss percentage: it was calculated by the following formula: [(fruit weight before storage - fruit weight after each period of storage) / fruit weight before storage] × 100.

Fruit decay percentage: it was recorded by the number of decayed fruits due to fungus and any micro-organisms infection and calculated as a percentage of the initial number of stored fruits using the following equation: (number of decayed fruits after each storage period / initial number of stored fruits) × 100.

Fruit decay severity: it was determined as the diameter of the lesion surface (mm) of orange fruits.

Marketable fruit percentage was calculated by the following formula: (weight of sound fruits after special storage period / initial weight of fruits) × 100.

Measurement of fruit visual appearance and firmness

Fruit visual appearance was measured by a rating system and fruit was scored as very good = 9, good = 7, acceptable = 5, unacceptable = 3 and poor = 1

Fruit firmness was measured in three orange fruits per replication at two equatorial sites to determine the penetration force by using a hand-held fruit firmness tester (FT-327, Italy) equipped with an 8 mm cylindrical stainless steel plunger tip (Watkins and Harman, 1981). Two readings were taken of each fruit after removing outer layer of peel. The firmness value was expressed in terms of kilogram force (kgf) and data was calculated as Newton (N) by the following formula (1 N = 0.1 kgf).

Measurement of fruit juice, ascorbic acid (AsA), total soluble solids (TSS), titratable acidity (TA) contents and TSS/TA ratio in pulp

After each of storage period, nine orange fruits from each treatment (three replicates) were extracted by using a rotary extractor and then juice percentage (w/w) was calculated.

Fruit AsA analysis was determined according to AOAC (2005). Samples of fruit juice were used, oxalic acid solution was added to each sample and titrated with 2,6-dichlorophenol-indophenol dye solution and expressed as a milligram of AsA and was calculated as mg/100 ml juice.

Fruit TSS content was measured using a hand refractometer, 0-32 scale (ATAGO N-1_E, Japan) and expressed in °Brix after making the temperature correction at 20°C according to AOAC (2005).

Fruit TA was assayed based on the method of adopting the procedure described by AOAC (2005). Aliquot of fruit juice was taken and titrated against 0.1 N NaOH in the presence of phenolphthalein as an indicator to the end point and expressed as a percentage of citric acid.

Fruit TSS/TA ratio was calculated from the values recorded for fruit juice TSS and TA percentages determined.

Determination of total phenolic content (TPC)

The TPC in the peel of oranges was spectrophotometrically determined by the Folin-Ciocalteu method (Slinkard and Singleton, 1977). Fruit samples were taken from six oranges (three replicates) at zero, two, six and ten weeks of cold storage period at 5°C followed by seven days shelf life. The absorbance against distilled water as a blank was determined at 765 nm by using a spectrophotometer (Thermo fisher 300 UV/VIS, USA). TPC was calculated from a standard curve obtained from different concentrations of gallic acid and expressed as mg of gallic acid equivalents/gram fresh weight (g fw) for the peel extract.

Total antioxidant capacity (TAC) assay

The TAC in the peel of orange fruits was determined according to the method of Prieto et al. (1999). Fruit samples were taken from six oranges at zero, two, six and ten weeks of cold storage period at 5°C followed by seven days shelf life. An aliquot of 0.5 ml of the sample ethanolic solution (three replicates) was mixed with 3 ml of the reagent solution (0.6 M sulfuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate). For the blank, 0.5 ml ethanol was mixed with 3 ml of the reagent solution. The tubes of the samples and blank capped and were incubated in a water bath at 95°C for 90 minutes. After the samples had cooled to room temperature, the absorbance of the sample was measured at 695 nm against a blank by using a spectrophotometer (Thermo fisher 300 UV/VIS, USA). α-Tocopherol was used for calibration curve and TAC was expressed as mg of α-tocopherol equivalents per 100 gram of fresh weight (g fw) for the peel extract.

Experimental design and statistical data analysis

This experiment was arranged in a completely randomized design having three replicates and consisting of two factors, postharvest treatments and storage period. This experiment was analysis as factorial. Data calculated as percentage were transformed to arcsine of square root before statistical analysis and non-transformed means are shown. The effects of postharvest treatments and cold storage period on different attributes were analyzed statistically by analysis of variance (ANOVA) using the MSTAT-C statistical package (M-STAT, 1993). Comparisons between means were done by Duncan's multiple range test (DMRT) at probability ≤ 0.05.

Results and Discussion

Effect of some postharvest dip treatments on physical characteristics of 'Washington' navel oranges during storage

Fruit weight loss, decay incidence, lesion diameter, marketable percentage and visual appearance score

Results in Tables 1, 2, 3, 4 and 5 reveal that weight loss, decay percentage and size of lesion surface diameter on 'Washington' navel oranges gradually and significantly increased with prolonging of cold storage period at 5°C followed by one week shelf life at 18-23°C in both seasons. On the other hand, navel oranges fruits showed gradual and significant reduction in marketable percentage and visual appearance score with the advancement of storage period during the two seasons. Our results indicate that, the significant maximum weight loss percentage (14.45 & 14.13 %), decay incidence (15.91 & 14.68 %) and size of lesion surface diameter (41.21 & 40.46 mm), moreover, the significant minimum marketable fruits percentage (69.65 & 71.19 %) and visual appearance score (5.42 & 5.25) of oranges were observed at the end of storage period in the first and second seasons, respectively.

In addition, on the average, statistical data also demonstrate that, all postharvest treatments were significantly effective in reducing weight loss, decay percentage and size of lesion surface diameter with significant high in marketable fruit percentage and visual appearance of 'Washington' navel oranges as compared to control or treated fruits with imazalil in both seasons. Potassium sorbate or potassium bicarbonate incorporated into gum arabic was superior to either treatment alone or gum arabic incorporated with imazalil in this respect. Treatment of navel oranges with 10% gum arabic incorporated with 2% potassium sorbate and stored at 5°C followed by shelf life at 18-23°C recorded the significant lowest values of weight loss (4.43 & 4.60 %), decay incidence (1.70 & 1.63 %) and lesion surface diameter (2.94 & 2.72 mm), furthermore recorded the significant highest values of marketable fruits (93.87 & 93.77 %) and visual appearance score (8.67 & 8.67) in the first and the second seasons, respectively followed by treated fruits with 10% gum arabic incorporated with 2% potassium bicarbonate. Conversely, control fruits exhibited the significant highest values of weight loss (12.28 & 12.29 %), decay incidence (12.58 & 11.49 %) and lesion surface diameter (46.28 & 45.67 mm) with the significant lowest values of marketable fruits (75.14 & 76.23 %) and visual appearance score (5.78 & 5.78) in 2016 and 2017 seasons, respectively followed by treated oranges with 0.2% imazalil.

The interaction effect between postharvest treatments and storage periods showed significant differences at $p \leq 0.05$ for these characteristics in both seasons. Data declare that, postharvest treatment of oranges with 2% potassium sorbate incorporated with 10% gum arabic significantly delayed the decay incidence for six weeks at 5°C followed by one week shelf life at 18-23°C as compared to individual treatments and untreated fruits (control) in the two seasons. Our results indicate that, after the end of cold storage period followed by shelf life, postharvest treatment of orange fruits with 2% potassium sorbate incorporated with 10% gum arabic recorded the significant lowest values of weight loss percentage (8.81 & 8.96 %), decay percentage (7.07 & 8.10 %) and lesion surface diameter (11.33 & 10.33 mm), moreover recorded the significant highest values of marketable percentage (84.12 & 84.21 %) and visual appearance score (8.00 & 8.00) in the first and second seasons, respectively. On the opposite, untreated fruits (control) showed the significant highest values of fruit weight loss percentage (21.85 & 21.24 %), decay percentage (29.16 & 26.08 %) and lesion surface diameter (108.67 & 110.00 mm) with recorded the significant lowest values of marketable fruits percentage (48.99 & 52.68 %) and visual appearance score (2.33 & 2.33) in 2016 and 2017 seasons, respectively.

The major cause in loss of visual quality for many citrus fruits is water loss whereby leading to economic losses for the industry and to undesirable effects such as shrinking, desiccated appearance, aging acceleration and loss firmness leading to the various rind disorders (Youssef et al., 2012a and Parra et al., 2014). Thus, the increasing in water loss and decay incidence with prolonging cold storage followed by shelf life due to an increase in water evaporation and aging of 'Washington' navel oranges.

Edible coatings have barrier properties that reduce the surface permeability of fruits to oxygen and carbon dioxide leading to modification of internal gas composition which in turn reduction of oxidative metabolism and increases the shelf life of fruits (Dhall, 2013). Thus, the application of gum arabic can reduce the exchange of gases between orange fruits and the environment by the accumulation of carbon dioxide in fruits and a low availability of oxygen for respiration and subsequently the inhibition of respiratory enzymes. Moreover, gum arabic coating it has ability to plug openings present in the peel. Furthermore, coating has the ability to prevent the growth of fungi in wide horticultural produces (Tripathi and Dubey, 2004).

In this study, gum arabic coating can form a film on the orange surface and this film acts as a fence to protect the fruits from pathogen infection, which reduced decay incidence during the storage and shelf life. In addition, sorbic acid seems to inhibit several enzymes such as fumarase, espartase and succinic dehydrogenase that involved in microorganism growth (York and Vaughn, 1964). Moreover, the antimicrobial activities for potassium sorbate and potassium bicarbonate are primarily due to the undissociated form of the acid, which is naturally more abundant at low pH (Davidson, 1997). The inhibitory ability of potassium sorbate and potassium bicarbonate depends on the presence of residues of these compounds within the wound infection courts occupied by the fungus and on interactions between this residue and constituents of the rind that preformed antifungal compounds (Palou et al., 2002).

TABLE 1. Effect of some postharvest dip treatments on weight loss percentage of 'Washington' navel oranges after cold storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks) 0		2		4		6		8		10		Means	
Season 2016														
Distilled water (control)	3.10	s-v	6.29	m-p	10.06	hij	14.34	def	18.05	b	21.85	a	12.28	A
0.2% imazalil (IMZ)	2.53	t-w	5.01	o-r	7.46	klm	10.77	hi	13.75	def	16.30	c	9.30	B
10% gum arabic (GA)	1.94	vw	3.90	q-u	6.06	m-p	9.05	ijk	12.65	fg	14.25	def	7.98	CD
2% potassium sorbate (PS)	2.02	vw	4.20	q-t	6.34	m-p	9.56	hij	12.84	fg	14.75	cde	8.29	CD
2% potassium bicarbonate (PB)	2.16	uvw	4.68	p-s	6.71	mno	9.88	hij	13.01	efg	14.85	cd	8.55	C
10% GA incorporated with 0.2% IMZ	1.84	vw	3.87	q-u	6.05	m-p	8.92	jk	11.30	gh	13.90	def	7.65	D
10% GA incorporated with 2% PS	0.72	w	1.43	vw	3.21	r-v	5.30	n-q	7.14	lmn	8.81	jkl	4.43	F
10% GA incorporated with 2% PB	1.18	w	2.10	uvw	4.09	q-t	6.94	mn	9.27	ij	10.85	hi	5.74	E
Means	1.94	F	3.94	E	6.25	D	9.35	C	12.25	B	14.45	A		
Season 2017														
Distilled water (control)	2.96	uvw	5.64	pq	10.23	j	14.95	d	18.71	b	21.24	a	12.29	A
0.2% imazalil (IMZ)	2.43	vwx	4.57	qrs	7.39	mn	10.66	ij	13.95	def	16.55	c	9.26	B
10% gum arabic (GA)	2.12	v-y	4.02	stu	5.99	op	8.71	kl	11.87	hi	13.90	def	7.77	D
2% potassium sorbate (PS)	2.22	v-y	4.31	rst	6.11	op	9.76	jk	12.51	gh	14.01	de	8.15	CD
2% potassium bicarbonate (PB)	2.28	vwx	4.48	q-t	6.20	nop	9.77	jk	12.72	fgh	14.26	de	8.29	C
10% GA incorporated with 0.2% IMZ	2.06	v-y	2.45	vwx	5.63	pq	8.16	lm	10.81	ij	13.23	efg	7.06	E
10% GA incorporated with 2% PS	0.93	y	1.83	wxy	3.26	tuv	5.54	pqr	7.08	mno	8.96	kl	4.60	G
10% GA incorporated with 2% PB	1.12	xy	2.21	v-y	4.17	stu	6.96	mno	8.67	kl	10.93	ij	5.68	F
Means	2.02	F	3.69	E	6.12	D	9.32	C	12.04	B	14.13	A		

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

TABLE 2. Effect of some postharvest dip treatments on decay incidence (%) of 'Washington' navel oranges after cod storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks) 0	2	4	6	8	10	Means
Season 2016							
Distilled water (control)	0.00 j	2.78 ij	6.45 f-i	14.53 cd	22.54 b	29.16 a	12.58 A
0.2% imazalil (IMZ)	0.00 j	0.00 j	3.76 hij	8.72 e-h	16.23 c	23.25 b	8.66 B
10% gum arabic (GA)	0.00 j	0.00 j	0.00 j	3.61 hij	10.35 def	14.44 cd	4.73 C
2% potassium sorbate (PS)	0.00 j	0.00 j	0.00 j	3.76 hij	11.09 def	14.51 cd	4.89 C
2% potassium bicarbonate (PB)	0.00 j	0.00 j	3.27 ij	4.84 g-j	11.01 def	17.44 c	6.09 C
10% GA incorporated with 0.2% IMZ	0.00 j	0.00 j	0.00 j	3.93 g-j	8.97 efg	12.44 cde	4.22 CD
10% GA incorporated with 2% PS	0.00 j	0.00 j	0.00 j	0.00 j	3.13 ij	7.07 f-i	1.70 E
10% GA incorporated with 2% PB	0.00 j	0.00 j	0.00 j	2.68 ij	4.95 g-j	8.93 efg	2.76 DE
Means	0.00 E	0.35 DE	1.69 D	5.26 C	11.03 B	15.91 A	
Season 2017							
Distilled water (control)	0.00 k	2.84 jk	6.40 g-j	12.99 cd	20.60 b	26.08 a	11.49 A
0.2% imazalil (IMZ)	0.00 k	0.00 k	4.89 ij	9.71 d-h	14.43 cd	21.04 b	8.35 B
10% gum arabic (GA)	0.00 k	0.00 k	0.00 k	4.67 ijk	10.71 d-g	13.77 cd	4.86 CD
2% potassium sorbate (PS)	0.00 k	0.00 k	0.00 k	4.89 ij	11.57 c-f	14.37 cd	5.14 CD
2% potassium bicarbonate (PB)	0.00 k	0.00 k	0.00 k	5.41 hij	12.35 cde	16.07 c	5.64 C
10% GA incorporated with 0.2% IMZ	0.00 k	0.00 k	0.00 k	3.28 ijk	8.04 e-i	11.18 def	3.75 D
10% GA incorporated with 2% PS	0.00 k	0.00 k	0.00 k	0.00 k	2.95 jk	6.83 f-j	1.63 E
10% GA incorporated with 2% PB	0.00 k	0.00 k	0.00 k	0.00 k	4.16 ijk	8.10 e-i	2.04 E
Means	0.00 D	0.36 D	1.41 D	5.12 C	10.60 B	14.68 A	

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

TABLE 3. Effect of some postharvest dip treatments on lesion surface diameter (mm) of 'Washington' navel oranges after cold storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks) 0	2	4	6	8	10	Means
Season 2016							
Distilled water (control)	0.00 j	16.00 f-i	25.00 d	45.67 c	82.33 b	108.67 a	46.28 A
0.2% imazalil (IMZ)	0.00 j	0.00 j	11.67 hij	21.67 f-i	55.00 c	79.67 b	28.00 B
10% gum arabic (GA)	0.00 j	0.00 j	5.67 ij	9.00 hij	18.33 g-j	27.33 efg	10.06 CD
2% potassium sorbate (PS)	0.00 j	0.00 j	4.00 ij	9.00 hij	18.33 g-j	32.67 de	10.67 C
2% potassium bicarbonate (PB)	0.00 j	0.00 j	6.00 ij	10.00 hij	19.67 f-j	28.00 def	10.61 C
10% GA incorporated with 0.2% IMZ	0.00 j	0.00 j	0.00 j	11.00 hij	14.33 f-j	24.67 fgh	8.33 CD
10% GA incorporated with 2% PS	0.00 j	0.00 j	0.00 j	0.00 j	6.33 ij	11.33 hij	2.94 D
10% GA incorporated with 2% PB	0.00 j	0.00 j	0.00 j	7.00 ij	10.67 hij	17.33 fgh	5.83 CD
Means	0.00 E	2.00 E	6.54 D	14.17 C	28.13 B	41.21 A	
Season 2017							
Distilled water (control)	0.00 j	12.00 hij	17.33 gh	47.67 d	87.00 b	110.00 a	45.67 A
0.2% imazalil (IMZ)	0.00 j	0.00 j	10.33 hij	23.67 gh	43.67 e	74.33 c	25.33 B
10% gum arabic (GA)	0.00 j	0.00 j	6.33 ij	7.67 ij	17.33 hij	28.00 fg	9.89 C
2% potassium sorbate (PS)	0.00 j	0.00 j	4.67 ij	7.00 ij	17.67 hij	29.33 fg	9.78 C
2% potassium bicarbonate (PB)	0.00 j	0.00 j	5.00 ij	10.33 hij	19.00 hij	31.67 ef	11.00 C
10% GA incorporated with 0.2% IMZ	0.00 j	0.00 j	0.00 j	7.00 ij	15.00 g-j	24.33 gh	7.72 CD
10% GA incorporated with 2% PS	0.00 j	0.00 j	0.00 j	0.00 j	6.00 ij	10.33 hij	2.72 D
10% GA incorporated with 2% PB	0.00 j	0.00 j	0.00 j	0.00 j	10.00 hij	15.67 ghi	4.28 CD
Means	0.00 D	1.50 D	5.46 D	12.92 C	26.96 B	40.46 A	

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

TABLE 4. Effect of some postharvest dip treatments on marketable percentage of 'Washington' navel oranges after cold storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks)						Means
	0	2	4	6	8	10	
Season 2016							
Distilled water (control)	96.90 ab	90.93 c-h	83.50 klm	71.12 qr	59.41 s	48.99 t	75.14 F
0.2% imazalil (IMZ)	97.47 ab	94.99 a-e	88.78 g-j	80.51 lmn	70.01 qr	60.45 s	82.04 E
10% gum arabic (GA)	98.06 ab	96.10 abc	93.94 a-f	87.34 h-k	77.01 no	71.30 pqr	87.29 C
2% potassium sorbate (PS)	97.98 ab	95.80 abc	93.66 b-g	86.68 h-k	76.07 nop	70.75 qr	86.82 CD
2% potassium bicarbonate (PB)	97.84 ab	95.32 a-d	90.03 e-i	85.28 i-l	75.98 nop	67.70 r	85.36 D
10% GA incorporated with 0.2% IMZ	98.16 ab	96.13 abc	93.95 a-f	87.15 h-k	79.73 mn	73.66 opq	88.13 C
10% GA incorporated with 2% PS	99.28 a	98.57 ab	96.79 ab	94.70 a-f	89.74 f-i	84.12 j-m	93.87 A
10% GA incorporated with 2% PB	98.82 ab	97.90 ab	95.91 abc	90.37 d-i	85.78 h-k	80.22 mn	91.50 B
Means	98.06 A	95.72 B	92.07 C	85.40 D	76.72 E	69.65 F	
Season 2017							
Distilled water (control)	97.04 abc	91.52 d-g	83.38 jkl	72.06 pq	60.69 r	52.68 s	76.23 E
0.2% imazalil (IMZ)	97.57 abc	95.43 a-d	87.72 g-j	79.63 lmn	71.63 pq	62.41 r	82.40 D
10% gum arabic (GA)	97.88 abc	95.98 a-d	94.01 a-e	86.62 hij	77.42 mno	72.33 pq	87.37 C
2% potassium sorbate (PS)	97.78 abc	95.69 a-d	93.89 b-e	85.35 h-k	75.93 nop	71.63 pq	86.71 C
2% potassium bicarbonate (PB)	97.72 abc	95.52 a-d	93.80 b-e	84.82 ijk	74.93 op	69.67 q	86.07 C
10% GA incorporated with 0.2% IMZ	97.94 abc	97.55 abc	94.37 a-e	88.56 f-i	81.15 klm	75.59 nop	89.19 B
10% GA incorporated with 2% PS	99.07 a	98.17 abc	96.74 abc	94.46 a-e	89.97 e-h	84.21 i-l	93.77 A
10% GA incorporated with 2% PB	98.88 ab	97.79 abc	95.83 a-d	93.04 c-f	87.16 g-j	80.97 klm	92.28 A
Means	97.99 A	95.95 B	92.47 C	85.57 D	77.36 E	71.19 F	

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

The application of 'Washington' navel oranges with gum arabic coating especially incorporated with potassium sorbate or potassium bicarbonate causing a decrease in evapotranspiration and helped to delay fruits senescence because of slowing the metabolism and respiration rate. Moreover, the particularly low decay incidence for gum arabic coating incorporated with potassium sorbate or potassium bicarbonate treatment can be explained by the ability of this combination to inhibit molds by preformed antifungal compounds (Palou et al., 2008 and Montesinos-Herrero et al., 2009). A film of gum arabic on the orange surface can protect the fruits from pathogen infection. Moreover, potassium sorbate and bicarbonate provokes the collapse of hyphal cell walls and ultimately cell death (USEPA, 1998). In addition, potassium sorbate and potassium bicarbonate salts may have entered the wounds during infliction leading to an interaction between salt residues and constituents of oranges rind, thus creating unfavorable environmental conditions for the pathogen and possibly increasing tissue resistance (Youssef et al., 2012b and Youssef et al., 2014). Therefore, the reduction of decay incidence and lesion surface diameter of oranges by postharvest applications particularly potassium sorbate or potassium bicarbonate incorporated with gum arabic coating is probably due to the reduction of cell turgor pressure that caused collapse and shrinkage of hyphae and spores.

Furthermore, gum arabic coating enhanced retention of potassium sorbate or potassium bicarbonate on the oranges surface, which led to the higher antifungal effectiveness as compared to dipping oranges in aqueous solution alone. However, potassium sorbate and bicarbonate degraded by oxidation when used in aqueous solutions on food because of rapid reaction with food components (Scotter and Castle, 2004). Moreover, hydroxypropyl methylcellulose lipid edible composite coatings containing potassium sorbate, sodium benzoate and their mixtures were effective in reducing the development of green and blue moulds on 'Valencia' oranges (Valencia-Chamorro et al., 2009). Therefore, when potassium sorbate or potassium bicarbonate added to gum arabic as an alternative to conventional chemical fungicide (imazalil) apparently did not alter the cosmetic properties of 'Washington' navel oranges, reduced weigh loss percentage, controlled decay incidence and decreased size of lesion surface diameter with an increase in the percent of marketable oranges and visual appearance score.

TABLE 5. Effect of some postharvest dip treatments on visual appearance score of 'Washington' navel oranges after cold storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks)													
	0		2		4		6		8		10		Means	
Season 2016														
Distilled water (control)	8.67	ab	8.00	a-d	6.33	c-g	5.33	e-h	4.00	hi	2.33	i	5.78	E
0.2% imazalil (IMZ)	9.00	a	8.67	ab	7.00	a-f	6.00	d-g	4.67	gh	4.00	hi	6.56	D
10% gum arabic (GA)	9.00	a	9.00	a	9.00	a	7.33	a-e	6.67	b-g	5.67	e-h	7.78	BC
2% potassium sorbate (PS)	9.00	a	9.00	a	8.33	abc	7.00	a-f	6.00	d-g	5.33	e-h	7.44	C
2% potassium bicarbonate (PB)	9.00	a	9.00	a	8.33	abc	7.00	a-f	5.67	e-h	5.00	fgh	7.33	C
10% GA incorporated with 0.2% IMZ	9.00	a	9.00	a	8.33	abc	8.00	a-d	6.67	b-g	5.67	e-h	7.78	BC
10% GA incorporated with 2% PS	9.00	a	9.00	a	9.00	a	8.67	ab	8.33	abc	8.00	a-d	8.67	A
10% GA incorporated with 2% PB	9.00	a	9.00	a	9.00	a	8.33	abc	8.00	a-d	7.33	a-e	8.44	AB
Means	8.96	a	8.83	a	8.17	b	7.21	c	6.25	d	5.42	e		
Season 2017														
Distilled water (control)	8.67	ab	8.33	abc	7.00	a-e	5.00	e-h	3.33	hi	2.33	i	5.78	E
0.2% imazalil (IMZ)	9.00	a	9.00	a	7.67	a-d	6.33	c-f	4.67	fgh	4.00	ghi	6.78	D
10% gum arabic (GA)	9.00	a	9.00	a	9.00	a	7.00	a-e	6.33	c-f	5.33	e-h	7.61	BC
2% potassium sorbate (PS)	9.00	a	8.67	ab	8.33	abc	7.00	a-e	6.00	d-g	5.00	e-h	7.33	CD
2% potassium bicarbonate (PB)	9.00	a	8.67	ab	8.33	abc	6.67	b-f	6.00	d-g	5.00	e-h	7.28	CD
10% GA incorporated with 0.2% IMZ	9.00	a	9.00	a	8.33	abc	7.67	a-d	6.67	b-f	5.33	e-h	7.67	BC
10% GA incorporated with 2% PS	9.00	a	9.00	a	9.00	a	8.67	ab	8.33	abc	8.00	a-d	8.67	A
10% GA incorporated with 2% PB	9.00	a	9.00	a	9.00	a	8.33	abc	7.67	a-d	7.00	a-e	8.33	AB
Means	8.96	A	8.83	A	8.33	A	7.08	B	6.13	C	5.25	D		

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

The results are in agreement with the findings of previous research, which reported that weight loss and decay incidence were reduced with gum arabic coating in 'Choke Anan' mangoes (Khaliq et al., 2015), banana and papaya fruits (Maqbool et al., 2011) and 'Anna' apples (El-Anany et al., 2009). Moreover, the obtained results were similar to those mentioned by Palou et al. (2002), Smilanick et al. (2008), Montesinos-Herrero et al. (2009), Youssef et al. (2012a, b), Cerioni et al. (2013), Parra et al. (2014), Youssef et al. (2014) and Cerioni et al. (2017). They noted that citrus fruits treated with potassium sorbate or potassium bicarbonate significantly reduced weight loss percentage, postharvest decay incidence and lesion surface diameter without altering the visual appearance of fruits. Similarly, Palou et al. (2009) observed the same results when stone fruits treated with potassium bicarbonate solution.

Fruit firmness

Results in Table 6 show that, a gradual and significant decrease in 'Washington' navel oranges firmness was observed with prolonging of cold storage period at 5°C followed by one week shelf life at 18-23°C in the two seasons. Hence, the results indicate that, the significant minimum firmness of orange fruits was recorded at the end of cold storage period and the values reaches of 18.03 & 18.60 N in the first and second seasons, respectively.

On the average, displayed results also prove that, all postharvest applications of 'Washington' navel oranges significantly reduced the deterioration of fruit firmness as compared to water control or treated oranges with imazalil after cold storage at 5°C followed by one week shelf life at 18-23°C in the two seasons. In this context, the co-application of gum arabic and either potassium sorbate or potassium bicarbonate was superior to either treatment alone or gum arabic incorporated with imazalil. Treatment of navel oranges with 2% potassium sorbate incorporated with 10% gum arabic recorded the significant highest values of fruit firmness (34.72 & 34.12 N) in 2016 and 2017 seasons, respectively followed by treated navel oranges with 2% potassium bicarbonate incorporated with 10% gum arabic. On contrary, untreated fruits showed the significant lowest values of fruit firmness (18.48 & 19.73 N) in the first and second seasons, respectively followed by treated oranges with 0.2% imazalil.

Referring to the interaction effect, there was a significant interaction between postharvest treatments and storage periods at $p \leq 0.05$ for firmness in both seasons. The results indicate that, after the end of cold storage period followed by shelf life, postharvest treatment of orange fruits with 2% potassium sorbate incorporated with 10% gum arabic had the significant highest firmness (24.52 & 25.83 N) in the first and second seasons, respectively. On contrary, untreated fruits (control) had the significant lowest firmness (9.16 & 9.48 N) in 2016 and 2017 seasons, respectively.

TABLE 6. Effect of some postharvest dip treatments on firmness (N) of 'Washington' navel oranges after cold storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks)						
	0	2	4	6	8	10	Means
	Season 2016						
Distilled water (control)	36.30 fgh	26.82 l-o	15.37 tu	12.43 uv	10.79 v	9.16 v	18.48 G
0.2% imazalil (IMZ)	38.91 a-f	32.70 ij	26.16 mno	19.95 qrs	16.68 st	15.37 tu	24.96 F
10% gum arabic (GA)	41.53 ab	36.95 d-h	31.39 jk	24.20 nop	18.97 rst	18.64 rst	28.61 D
2% potassium sorbate (PS)	39.90 a-f	36.63 e-h	30.74 jk	23.22 opq	17.33 st	17.66 st	27.58 DE
2% potassium bicarbonate (PB)	40.22 a-e	36.63 e-h	30.08 jkl	21.91 pqr	17.01 st	16.68 st	27.09 E
10% GA incorporated with 0.2% IMZ	40.88 abc	37.28 c-h	34.99 ghi	27.14 lmn	23.54 n-q	20.27 qrs	30.68 C
10% GA incorporated with 2% PS	42.51 a	40.55 a-d	38.59 b-g	33.68 hij	28.45 klm	24.52 nop	34.72 A
10% GA incorporated with 2% PB	41.53 ab	38.59 b-g	36.62 e-h	32.05 ij	24.53 nop	21.91 pqr	32.54 B
Means	40.22 A	35.77 B	30.49 C	24.32 D	19.66 E	18.03 F	
	Season 2017						
Distilled water (control)	36.62 e	26.16 lm	17.99 rst	15.37 stu	12.75 u	9.48 v	19.73 F
0.2% imazalil (IMZ)	38.91 b-e	33.68 f	26.49 lm	24.20 mn	18.31 qrs	15.04 tu	26.10 E
10% gum arabic (GA)	41.53 ab	37.28 e	31.07 fgh	27.80 i-l	22.23 nop	19.62 o-r	29.92 C
2% potassium sorbate (PS)	41.20 ab	36.95 e	30.74 f-i	27.14 klm	21.26 n-q	17.98 rst	29.21 CD
2% potassium bicarbonate (PB)	40.55 a-d	36.63 e	30.41 g-j	25.83 lm	19.29 pqr	17.66 rst	28.40 D
10% GA incorporated with 0.2% IMZ	40.87 abc	37.61 de	32.37 fg	28.12 h-l	28.12 h-l	20.60 o-r	31.28 B
10% GA incorporated with 2% PS	43.49 a	39.24 b-e	33.68 f	32.04 fg	30.41 g-j	25.83 lm	34.12 A
10% GA incorporated with 2% PB	41.85 ab	37.93 cde	32.70 fg	30.08 g-k	27.47 jkl	22.56 no	32.10 B
Means	40.63 A	35.69 B	29.43 C	26.32 D	22.48 E	18.60 F	

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

Fruit softening is one the most important quality deterioration parameters during postharvest storage. Fruit softening attributed to biochemical processes involving the hydrolysis of pectin in the cell wall by hydrolytic enzymes such as pectinesterase, pectin methylesterase and polygalacturonase (Payasi et al., 2009). Our results in the current study indicated that, firmness retention in coated oranges by gum arabic incorporated with potassium sorbate or potassium bicarbonate is related to a reduction in enzymatic activities involved in softening process. Also, related to their ability to control weight loss caused by a modification of the internal atmosphere of the fruit as documented by Khaliq et al. (2015). In addition, dramatic drop in the firmness after cold storage followed by shelf life of 'Washington' navel oranges could be attributed to the increase in weight loss rate and conversion of insoluble protopectin into water soluble pectin.

These results are in agreement with those obtained by Maqbool et al. (2011) in banana and papaya fruits and Khaliq et al. (2015) in 'Choke Anan' mangoes they reported that, treated fruits with edible coatings of gum arabic significantly higher firmness than uncoated fruits during cold storage and shelf life.

Effect of some postharvest dip treatments on chemical characteristics of 'Washington' navel oranges during storage

Fruit juice percentage, ascorbic acid (AsA), total soluble solids (TSS), titratable acidity (TA) and TSS/TA ratio

Changes in juice, AsA, TSS, TA contents and TSS/TA ratio of 'Washington' navel oranges after cold storage period at 5°C followed by one week shelf life at 18-23°C are shown in Tables 7, 8, 9, 10 and 11. Results illustrate that, significant declining trend in juice, ascorbic acid and TA contents were noticed with prolonging of cold storage period in the first and second seasons. While, significant rising trend in TSS and TSS/TA ratio were observed with the advancement of storage period in the both seasons. Also, results reveal that, the significant lowest of fruits juice percentage (31.18 & 30.49 %), AsA content (38.51 & 37.81 mg/100 ml juice) and TA percentage (0.52 & 0.54 %), furthermore the significant highest of TSS (12.24 & 12.23 °Brix) and TSS/TA ratio (24.60 & 24.31) in the first and second seasons, respectively were noticed after the end of storage period.

In addition, on the average also results reveal that, all postharvest dip treatments of orange fruits significantly increased juice percentage, AsA content and TA as compared to water control or treated fruits with imazalil in both seasons. Moreover, non-significant differences of juice percentage and AsA content were observed when treated oranges with gum arabic, potassium sorbate or potassium bicarbonate individually in the two seasons. In addition, treatment of navel oranges with gum arabic alone or incorporated with potassium sorbate or potassium bicarbonate significantly slowed the rate of increase of TSS content than control or individual treatment of potassium sorbate and potassium bicarbonate in both seasons. Furthermore, all postharvest treatments especially co-applications were significantly effective in reducing TSS/TA ratio of navel oranges as compared to the water control or treated oranges with imazalil during the two seasons. Data also clearly indicate that, postharvest treatment of 'Washington' navel oranges with 2% potassium sorbate incorporated with 10% gum arabic showed the significant highest of juice percentage (42.33 & 44.24 %), AsA content (59.85 & 58.31 mg/100 ml juice) and TA percentage (0.85 & 0.92 %), whereas, recorded the significant lowest of TSS (9.97 & 10.11 °Brix) and TSS/TA ratio (12.31 & 11.44) in the first and second seasons, respectively followed by treated oranges with 2% potassium bicarbonate and incorporated with 10% gum arabic. Conversely, untreated fruits had the significant lowest juice percentage (33.36 & 33.75 %), AsA content (45.87 & 44.03 mg/100 ml juice) and TA percentage (0.61 & 0.68 %), moreover had the significant highest TSS (10.76 & 11.02 °Brix) and TSS/TA ratio (19.57 & 18.25) in 2016 and 2017 seasons, respectively followed by treated oranges with 0.2% imazalil.

Data also declare that, there was a significant interaction among postharvest treatments and storage periods at $p \leq 0.05$ for these characteristics in the two seasons. Our results indicate that, after the end of cold storage period followed by shelf life, postharvest treatment of orange fruits with 2% potassium sorbate incorporated with 10% gum arabic had the significant highest of juice percentage (37.24 & 36.29 %), AsA content (47.74 & 47.05 mg/100 ml juice) and TA percentage (0.68 & 0.79 %), whereas recorded the significant lowest of TSS (11.67 & 11.60 °Brix) and TSS/TA ratio (17.70 & 15.61) in the first and second seasons, respectively. On contrary, untreated fruits (control) recorded the significant lowest of juice percentage (23.17 & 22.23 %), AsA content (27.16 & 26.10 mg/100 ml juice) and TA percentage (0.41 & 0.41 %), while recorded the significant highest of TSS (12.53 & 12.47 °Brix) and TSS/TA ratio (30.97 & 30.82) in 2016 and 2017 seasons, respectively.

Maintaining juice percentage in treated 'Washington' navel oranges with gum arabic incorporated with potassium sorbate or potassium bicarbonate coating is probably due to the reduction of water loss from the fruits as compared to other treated fruits. Moreover, a progressive decline in juice content after cold storage period followed by shelf life attributed to an increase in water loss from oranges.

Ascorbic acid was considered as antioxidant and play important role in reducing the oxidative damage of fruits caused by reactive oxygen species. The reduction of AsA loss in coated 'Washington' navel oranges with gum arabic incorporated with potassium bicarbonate or potassium bicarbonate was proposed to be due to the low oxygen permeability around fruit surface and restraining the physiological activities by delaying ageing of oranges. Lowered oxygen level resulted in a slow down of the respiration rate and reduced the activity of the ascorbic acid oxidase enzymes (Blokhina et al., 2003). Thus, our results in this study indicated that, potassium sorbate or potassium bicarbonate incorporated into gum arabic preventing the oxidation of AsA of oranges as compared to water control or treated fruits with imazalil as mentioned by Liu et al. (2014) and Khaliq et al. (2015). In addition, the loss of ascorbic acid content of 'Washington' navel oranges during storage period followed by shelf life might be due to rapid conversion of L-ascorbic acid into dehydroascorbic acid in the presence of oxidizing enzymes like ascorbic acid oxidase and ascorbate peroxidase (Mapson, 1970).

TSS and TA are two main components that greatly influence flavor properties of citrus fruits. Edible coatings created an excellent semi-permeable film around the fruit and modifying the internal atmosphere by reducing oxygen and elevating carbon dioxide resulting in decreased respiration rate (Dhall, 2013). In the present study, coated 'Washington' navel oranges with gum arabic incorporated with potassium sorbate or potassium bicarbonate showed delay the rate of increase of TSS and TSS/TA ratio with high level of TA, which means that this treatment might be maintained the organic acid by reduction of respiration rate, metabolic activity and inhibited oxidation of organic acid. Thus, protected the degradation of organic acids and clearly delayed the decrease in TA as documented by Khaliq et al. (2015) in this respect. While the highest TSS values in other treatments of oranges maybe attributed to the loss of water and increasing metabolic activity of fruits. In water control or treated orange fruits with imazalil, the high reduction in TA might be resulted from increased respiration rate that caused degeneration of organic acids (El-Anany et al., 2009). Citric acid is the major organic acid in citrus fruits. The reduction in TA after cold storage followed by shelf life might be attributed to the use of organic acids as substrates for respiratory metabolism in fruits and conversion of acids into salts and sugars by the enzymes (Valero and Serrano, 2010).

TABLE 7. Effect of some postharvest dip treatments on juice percentage of 'Washington' navel oranges after cold storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks)													
	0		2		4		6		8		10		Means	
	Season 2016													
Distilled water (control)	43.50	b-f	38.87	i-o	35.25	p-s	32.22	st	27.16	v	23.17	w	33.36	E
0.2% imazalil (IMZ)	42.25	d-h	41.98	d-i	37.52	l-p	35.14	p-s	32.58	st	28.56	uv	36.34	D
10% gum arabic (GA)	44.73	a-d	43.30	c-f	39.34	h-n	38.02	k-p	36.23	n-r	32.23	st	38.98	C
2% potassium sorbate (PS)	44.09	b-e	43.67	b-e	38.72	j-o	37.45	l-p	35.69	o-r	31.03	tu	38.44	C
2% potassium bicarbonate (PB)	43.87	b-e	42.79	c-g	38.35	j-p	36.91	m-r	35.90	o-r	29.06	uv	37.81	C
10% GA incorporated with 0.2% IMZ	46.71	ab	44.27	b-e	40.95	e-k	39.91	g-m	37.74	k-p	33.99	rst	40.60	B
10% GA incorporated with 2% PS	47.46	a	46.08	abc	44.24	b-e	41.30	e-j	37.67	l-p	37.24	l-q	42.33	A
10% GA incorporated with 2% PB	45.08	a-d	44.09	b-e	42.31	d-h	40.28	f-l	37.90	k-p	34.18	qrs	40.64	B
Means	44.71	A	43.13	B	39.59	C	37.65	D	35.11	E	31.18	F		
	Season 2017													
Distilled water (control)	47.19	b-e	40.79	i-l	34.35	p	30.46	rst	27.48	uv	22.23	w	33.75	F
0.2% imazalil (IMZ)	47.57	a-d	42.11	h-k	38.02	l-o	33.01	p-s	31.18	q-t	26.98	v	36.48	E
10% gum arabic (GA)	48.85	a-d	44.47	e-h	39.73	kl	35.01	op	35.16	nop	30.57	rst	38.97	D
2% potassium sorbate (PS)	47.88	a-d	43.87	f-i	39.24	klm	34.80	p	34.21	pq	29.51	tuv	38.25	D
2% potassium bicarbonate (PB)	47.22	b-e	42.87	g-j	38.52	lm	34.18	pq	34.22	pq	30.12	stu	37.86	D
10% GA incorporated with 0.2% IMZ	49.25	abc	46.12	c-f	42.97	g-j	38.59	lm	36.22	m-p	33.27	pqr	41.07	C
10% GA incorporated with 2% PS	50.66	a	49.85	ab	45.78	d-g	42.92	g-j	39.94	jkl	36.29	m-p	44.24	A
10% GA incorporated with 2% PB	49.77	ab	48.13	a-d	44.17	e-h	40.60	jkl	38.19	lmn	34.92	p	42.63	B
Means	48.55	A	44.78	B	40.35	C	36.20	D	34.58	E	30.49	F		

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

TABLE 8. Effect of some postharvest dip treatments on ascorbic acid content (mg/100 ml juice) of 'Washington' navel oranges after cold storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks)													
	0		2		4		6		8		10		Means	
	Season 2016													
Distilled water (control)	65.72	c-f	59.05	hi	48.76	lm	40.15	qr	34.40	u	27.16	v	45.87	F
0.2% imazalil (IMZ)	67.66	bcd	62.93	fg	54.88	jk	47.56	mn	40.24	qr	34.96	tu	51.37	E
10% gum arabic (GA)	68.66	abc	64.37	d-g	58.91	hi	51.63	l	43.49	opq	38.62	rs	54.28	CD
2% potassium sorbate (PS)	68.41	bc	64.08	efg	58.91	hi	50.41	lm	42.68	opq	37.80	rst	53.71	CD
2% potassium bicarbonate (PB)	68.16	bc	63.50	fg	58.05	hij	50.00	lm	42.27	opq	35.77	stu	52.96	D
10% GA incorporated with 0.2% IMZ	69.52	ab	65.24	c-f	57.71	hij	52.27	kl	44.28	op	41.16	pqr	55.03	C
10% GA incorporated with 2% PS	71.91	a	68.09	bc	63.19	fg	57.58	ij	50.61	lm	47.74	mn	59.85	A
10% GA incorporated with 2% PB	70.48	ab	67.14	b-e	61.19	gh	55.30	jk	49.03	lm	44.85	no	58.00	B
Means	68.81	A	64.30	B	57.70	C	50.61	D	43.38	E	38.51	F		
	Season 2017													
Distilled water (control)	64.76	d-g	56.19	jkl	47.47	pq	38.70	tu	30.98	w	26.10	x	44.03	E
0.2% imazalil (IMZ)	67.91	a-d	62.36	fgh	54.89	k-n	47.15	pq	38.61	tu	33.74	vw	50.78	D
10% gum arabic (GA)	68.90	ab	64.94	c-f	59.19	hij	52.03	mno	43.49	rs	38.21	tu	54.46	C
2% potassium sorbate (PS)	68.90	ab	63.79	efg	58.91	hij	51.63	no	42.68	rs	36.99	tuv	53.82	C
2% potassium bicarbonate (PB)	68.41	abc	63.79	efg	58.33	ijk	50.41	op	42.27	rs	36.18	uv	53.23	C
10% GA incorporated with 0.2% IMZ	69.05	ab	63.34	efg	58.08	ijk	52.49	mno	44.31	qr	40.33	st	54.60	C
10% GA incorporated with 2% PS	70.95	a	66.19	b-e	61.11	ghi	55.55	j-m	49.02	op	47.05	pq	58.31	A
10% GA incorporated with 2% PB	69.52	ab	64.76	d-g	59.09	hij	54.40	lmn	47.45	pq	43.89	qrs	56.52	B
Means	68.55	A	63.17	B	57.14	C	50.30	D	42.35	E	37.81	F		

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

TABLE 9. Effect of some postharvest dip treatments on total soluble solids content (°Brix) of 'Washington' navel oranges after cold storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks) 0		2		4		6		8		10		Means	
Season 2016														
Distilled water (control)	9.00	s-v	9.67	opq	10.40	klm	11.13	gh	11.80	cde	12.53	a	10.76	A
0.2% imazalil (IMZ)	8.93	t-w	9.53	qr	10.33	klm	11.07	ghi	11.73	cde	12.33	ab	10.66	A
10% gum arabic (GA)	8.87	t-w	9.33	q-t	10.13	l-o	10.73	h-k	11.40	efg	11.93	bcd	10.40	B
2% potassium sorbate (PS)	8.93	t-w	9.47	qrs	10.40	klm	11.13	gh	11.73	cde	12.60	a	10.71	A
2% potassium bicarbonate (PB)	9.00	s-v	9.47	qrs	10.53	j-m	11.20	fgh	11.80	cde	12.67	a	10.78	A
10% GA incorporated with 0.2% IMZ	8.80	uvw	9.27	q-u	10.07	m-p	10.60	i-l	11.33	efg	12.20	abc	10.38	B
10% GA incorporated with 2% PS	8.47	w	9.00	s-v	9.60	pqr	10.13	l-o	10.93	g-j	11.67	def	9.97	C
10% GA incorporated with 2% PB	8.53	vw	9.13	r-u	9.73	n-q	10.20	lmn	11.13	gh	12.00	bcd	10.12	C
Means	8.82	F	9.36	E	10.15	D	10.77	C	11.48	B	12.24	A		
Season 2017														
Distilled water (control)	9.60	r-u	9.80	qrs	10.80	lmn	11.40	ij	12.07	b-f	12.47	abc	11.02	A
0.2% imazalil (IMZ)	9.53	r-v	9.73	rs	10.67	mno	11.33	ijk	11.93	d-h	12.40	a-d	10.93	A
10% gum arabic (GA)	9.47	r-w	9.60	r-u	10.33	nop	10.80	lmn	11.67	e-i	12.00	c-g	10.64	B
2% potassium sorbate (PS)	9.60	r-u	9.87	p-s	10.73	l-o	11.47	hij	12.07	b-f	12.53	ab	11.04	A
2% potassium bicarbonate (PB)	9.67	rst	9.93	pqr	10.87	klm	11.53	g-j	12.13	a-e	12.60	a	11.12	A
10% GA incorporated with 0.2% IMZ	9.33	s-w	9.47	r-w	10.00	pqr	10.73	l-o	11.60	f-i	12.27	a-d	10.57	B
10% GA incorporated with 2% PS	9.00	w	9.07	vw	9.67	rst	10.27	opq	11.07	j-m	11.60	f-i	10.11	C
10% GA incorporated with 2% PB	9.13	uvw	9.20	t-w	9.87	p-s	10.33	nop	11.20	i-l	11.93	d-h	10.28	C
Means	9.42	F	9.58	E	10.37	D	10.98	C	11.72	B	12.23	A		

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

TABLE 10. Effect of some postharvest dip treatments on titratable acidity percentage of 'Washington' navel oranges after cold storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks) 0		2		4		6		8		10		Means	
Season 2016														
Distilled water (control)	0.88	def	0.73	ijk	0.64	mn	0.56	op	0.45	st	0.41	t	0.61	G
0.2% imazalil (IMZ)	0.89	de	0.75	ij	0.65	mn	0.60	no	0.49	qrs	0.44	st	0.64	F
10% gum arabic (GA)	0.93	cd	0.86	efg	0.75	ij	0.64	mn	0.56	op	0.54	pq	0.71	D
2% potassium sorbate (PS)	0.93	cd	0.83	fgh	0.72	jkl	0.64	mn	0.53	pqr	0.47	rs	0.69	E
2% potassium bicarbonate (PB)	0.93	cd	0.79	hi	0.68	klm	0.64	mn	0.53	pqr	0.47	rs	0.67	E
10% GA incorporated with 0.2% IMZ	0.95	bc	0.88	def	0.81	gh	0.68	lm	0.60	no	0.56	op	0.75	C
10% GA incorporated with 2% PS	1.03	a	0.95	bc	0.89	de	0.83	fgh	0.75	ij	0.68	lm	0.85	A
10% GA incorporated with 2% PB	0.99	ab	0.88	def	0.81	gh	0.75	ij	0.68	lm	0.60	no	0.79	B
Means	0.94	A	0.83	B	0.74	C	0.67	D	0.57	E	0.52	F		
Season 2017														
Distilled water (control)	0.96	cde	0.83	hi	0.73	k	0.61	mn	0.53	o	0.41	r	0.68	F
0.2% imazalil (IMZ)	0.97	cd	0.86	gh	0.72	k	0.60	mn	0.53	op	0.44	qr	0.69	F
10% gum arabic (GA)	1.01	bc	0.90	fg	0.82	hi	0.68	kl	0.56	no	0.54	o	0.75	D
2% potassium sorbate (PS)	1.01	bc	0.86	gh	0.79	ij	0.64	lm	0.56	no	0.47	pq	0.72	E
2% potassium bicarbonate (PB)	0.97	cd	0.86	gh	0.79	ij	0.64	lm	0.56	no	0.47	pq	0.72	E
10% GA incorporated with 0.2% IMZ	1.05	ab	0.92	d-g	0.87	gh	0.73	jk	0.64	lm	0.53	op	0.79	C
10% GA incorporated with 2% PS	1.09	a	0.96	cde	0.94	def	0.90	fg	0.83	hi	0.79	ij	0.92	A
10% GA incorporated with 2% PB	1.07	a	0.94	def	0.90	efg	0.83	hi	0.73	k	0.64	lm	0.85	B
Means	1.02	A	0.89	B	0.82	C	0.70	D	0.62	E	0.54	F		

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

TABLE 11. Effect of some postharvest dip treatments on total soluble solids/titratable acidity ratio of 'Washington' navel oranges after cold storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks) 0		2		4		6		8		10		Means	
Season 2016														
Distilled water (control)	10.33	r-v	13.25	l-r	16.32	h-l	20.33	efg	26.19	bc	30.97	a	19.57	A
0.2% imazalil (IMZ)	10.17	r-v	12.77	m-s	16.04	h-l	18.57	f-i	24.27	cd	28.38	ab	18.37	B
10% gum arabic (GA)	9.61	s-v	11.14	p-v	13.57	k-q	16.89	hij	20.24	efg	22.26	de	15.62	C
2% potassium sorbate (PS)	9.68	s-v	12.19	n-u	14.74	j-o	18.70	f-i	22.49	de	27.00	bc	17.47	B
2% potassium bicarbonate (PB)	9.66	s-v	12.16	n-u	15.76	i-m	17.82	g-j	22.70	de	27.13	b	17.54	B
10% GA incorporated with 0.2% IMZ	9.26	uv	10.52	q-v	12.58	n-t	15.68	i-m	19.00	fgh	22.29	de	14.89	C
10% GA incorporated with 2% PS	8.33	v	9.47	tuv	10.87	p-v	12.31	n-u	15.16	j-n	17.70	g-j	12.31	E
10% GA incorporated with 2% PB	8.68	v	10.47	q-v	12.00	o-u	13.67	k-p	16.47	h-k	21.03	ef	13.72	D
Means	9.46	F	11.50	E	13.98	D	16.75	C	20.82	B	24.60	A		
Season 2017														
Distilled water (control)	10.04	o-s	11.83	l-q	15.02	jk	18.92	efg	22.84	c	30.82	a	18.25	A
0.2% imazalil (IMZ)	9.85	p-s	11.43	m-s	15.06	jk	19.19	efg	22.96	c	28.55	ab	17.84	AB
10% gum arabic (GA)	9.40	qrs	10.65	n-s	13.09	k-o	16.36	g-j	20.72	c-f	22.35	cd	15.43	C
2% potassium sorbate (PS)	9.53	p-s	11.61	l-r	14.83	jk	18.48	fgh	21.43	cde	26.83	b	17.12	B
2% potassium bicarbonate (PB)	10.19	o-s	11.68	l-r	13.92	j-m	18.47	fgh	21.55	cde	26.93	b	17.12	B
10% GA incorporated with 0.2% IMZ	8.97	qrs	10.34	n-s	11.83	l-q	14.63	jkl	18.27	f-i	23.59	c	14.61	C
10% GA incorporated with 2% PS	8.29	s	9.47	qrs	10.31	n-s	11.58	l-r	13.39	j-n	15.61	h-k	11.44	E
10% GA incorporated with 2% PB	8.57	rs	9.80	p-s	11.12	m-s	12.66	k-p	15.50	ijk	19.79	def	12.91	D
Means	9.36	F	10.85	E	13.15	D	16.29	C	19.58	B	24.31	A		

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

Our results are in line with the findings of Khaliq et al. (2015) who reported that the application of 'Choke Anan' mangoes with 10% GA alone or combined with 3% calcium chloride significantly maintained high TA and AsA as compared to control during cold storage at 6°C for 28 days and additional five days shelf life at 25°C. Similarly, treated banana and papaya fruits with 10% gum arabic alone or combined with 0.05% lemongrass oil or 0.4% cinnamon oil significantly delayed the rate of increase of TSS content and maintained the highest TA compared to essential oils alone and control after cold storage for 28 days and five days shelf life at room temperature (Maqbool et al., 2011). Moreover, coated mangoes with bentonite loaded with potassium sorbate significantly maintained high AsA content, preserved TA and delayed the accumulation of TSS as compared to uncoated fruits (Liu et al., 2014).

Total phenolic content (TPC) and total antioxidant capacity (TAC)

Results in Tables 12 and 13 demonstrate that, gradual and significant increase in TPC and TAC of 'Washington' navel oranges were observed during six weeks of cold storage period at 5°C plus one week shelf life at 18-23°C followed by a significant decrease at end of the experiment in the two seasons. These results indicate that, the significant highest peak of TPC (3.36 & 3.65 mg gallic acid/g fw) and TAC (230.15 & 219.11 mg α-tocopherol/100 g fw) in 2016 and 2017 seasons, respectively were recorded at six weeks of storage period. After that, TPC and TAC were significantly declined after end of cold storage period followed by one week shelf life and the values reached of 2.55 & 2.75 mg gallic acid/g fw and 170.65 & 180.87 mg α-tocopherol/100 g fw, respectively in the first and second seasons, respectively.

On the average, results also show that, all postharvest applications of 'Washington' navel oranges significantly increased TPC and TAC as compared to water control or treated oranges with imazalil after cold storage at 5°C followed by one week shelf life at 18-23°C in the two seasons. Moreover, combined treatments of gum arabic and potassium sorbate or potassium bicarbonate were superior to individual treatment and gum arabic incorporated with imazalil. Postharvest treatment of navel oranges with 2% potassium sorbate incorporated with 10% gum arabic recorded the significant highest of TPC (3.89 & 4.21 mg gallic acid/g fw) and TAC (260.62 & 252.45 mg α-tocopherol/100 g fw) in 2016 and 2017 seasons, respectively followed by treated navel oranges with 2% potassium bicarbonate incorporated with 10% gum arabic. On the other hand, untreated fruits (control) showed the significant lowest of TPC (2.04 & 2.21 mg gallic acid/g fw) and TAC

(136.96 & 135.35 mg α-tocopherol/100 g fw) in the first and second seasons, respectively followed by treated oranges with 0.2% imazalil.

Referring to the interaction effect, there was a significant interaction between postharvest treatments and storage periods at $p \leq 0.05$ for TPC and TAC in both seasons. Data declare that, the significant highest peak of TPC of individual treatments were recorded after two weeks of cold storage period followed by shelf life, while this peak of combined treatments was recorded after six weeks of cold storage period followed by shelf life in both seasons. Moreover, the highest peak of TAC of individual and incorporated treatments was observed after six weeks of cold storage period followed by shelf life in the two seasons. On contrary, untreated fruits and treated with 0.2% imazalil showed gradual and significant decrease of TPC and TAC during cold storage period followed by shelf life in both seasons. Our results indicate that, after the end of cold storage period followed by shelf life, postharvest treatment of orange fruits with 2% potassium sorbate incorporated with 10% gum arabic had the significant highest values of TPC (3.63 & 3.92 mg gallic acid/g fw) and TAC (243.63 & 258.22 mg α-tocopherol/100 g fw) in the first and second seasons, respectively. On the opposite, untreated fruits (control) had the significant lowest values of TPC (1.38 & 1.49 mg gallic acid/g fw) and TAC (96.85 & 102.64 mg α-tocopherol/100 g fw) in 2016 and 2017 seasons, respectively.

Phenolic possesses antioxidant properties and serve as protective mechanisms in fruits. TPC has a defense mechanism against the invasion of plant pathogens and playing an important role in plant resistance (Beckman, 2000). Moreover, the presence of antioxidants and phenols could be substantially reduced the reactive oxygen species (ROS) and prevented lipid peroxidation of plant tissue by trapping the lipid alkoxyl radical (Blokhina et al., 2003).

The effect of postharvest treatments especially applications of gum arabic incorporated with potassium sorbate or potassium bicarbonate coating in maintaining TPC and enhancing TAC could be ascribed to ability to scavenging the excess ROS and consequently reducing the oxidative damage of the fruit (Khaliq et al., 2016 and Vargas-Torres et al., 2017). Therefore, these treatments delayed the senescence process of orange fruits as compared to control. Previously, a positive correlation among TPC and TAC has also been reported in mangoes (Khaliq et al., 2016). Therefore, in our study, the maximum amount of TPC in treated oranges especially 10% gum arabic incorporated with 2% potassium sorbate or 2% potassium bicarbonate means that those fruit maintained higher TAC than uncoated fruits or treated with 0.2% imazalil, which means that treated fruit enhanced the resistance of plant tissues to pathogens and reducing their physiological deterioration.

TABLE 12. Effect of some postharvest dip treatments on total phenolic content (mg gallic acid/g fw) of 'Washington' navel oranges after cold storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks)								Means	
	0		2		6		10			
Season 2016										
Distilled water (control)	2.54	u	2.27	x	1.99	y	1.38	z	2.04	H
0.2% imazalil (IMZ)	2.83	r	2.60	t	2.33	w	2.27	x	2.51	G
10% gum arabic (GA)	3.01	p	3.36	l	3.32	m	2.49	v	3.05	E
2% potassium sorbate (PS)	3.12	o	3.42	k	3.54	j	2.70	s	3.19	D
2% potassium bicarbonate (PB)	2.93	q	3.31	m	3.22	n	2.35	w	2.95	F
10% GA incorporated with 0.2% IMZ	3.43	k	3.67	g	4.02	c	2.49	v	3.40	C
10% GA incorporated with 2% PS	3.73	f	3.90	d	4.31	a	3.63	h	3.89	A
10% GA incorporated with 2% PB	3.59	i	3.85	e	4.11	b	3.12	o	3.67	B
Means	3.15	C	3.30	B	3.36	A	2.55	D		
Season 2017										
Distilled water (control)	2.74	t	2.45	w	2.16	x	1.49	y	2.21	H
0.2% imazalil (IMZ)	3.05	q	2.80	s	2.53	v	2.45	w	2.71	G
10% gum arabic (GA)	3.25	o	3.62	k	3.61	k	2.69	u	3.29	E
2% potassium sorbate (PS)	3.37	n	3.68	j	3.85	i	2.91	r	3.45	D
2% potassium bicarbonate (PB)	3.16	p	3.56	l	3.50	m	2.53	v	3.19	F
10% GA incorporated with 0.2% IMZ	3.70	j	3.96	g	4.38	c	2.69	u	3.68	C
10% GA incorporated with 2% PS	4.02	f	4.21	d	4.69	a	3.92	h	4.21	A
10% GA incorporated with 2% PB	3.87	i	4.16	e	4.48	b	3.37	n	3.97	B
Means	3.39	C	3.55	B	3.65	A	2.75	D		

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

TABLE 13. Effect of some postharvest dip treatments on total antioxidant capacity (mg α-tocopherol/100 g fw) of 'Washington' navel oranges after cold storage at 5±1°C followed by one week shelf life at 18-23°C

Postharvest treatments	Storage period (weeks) 0		2		6		10		Means	
Season 2016										
Distilled water (control)	177.83	s	150.17	v	123.00	x	96.85	z	136.96	H
0.2% imazalil (IMZ)	180.59	r	170.67	t	148.24	w	114.52	y	153.50	G
10% gum arabic (GA)	200.46	o	235.55	j	239.14	i	170.43	t	211.40	E
2% potassium sorbate (PS)	221.53	m	251.64	f	265.48	d	176.86	s	228.88	D
2% potassium bicarbonate (PB)	194.10	p	219.67	n	222.86	l	162.48	u	199.77	F
10% GA incorporated with 0.2% IMZ	234.38	k	240.02	hi	266.93	c	181.67	q	230.75	C
10% GA incorporated with 2% PS	240.38	h	267.08	c	291.40	a	243.63	g	260.62	A
10% GA incorporated with 2% PB	233.34	k	253.69	e	284.14	b	218.79	n	247.49	B
Means	210.32	C	223.56	B	230.15	A	170.65	D		
Season 2017										
Distilled water (control)	171.96	t	143.98	v	122.84	x	102.64	z	135.35	H
0.2% imazalil (IMZ)	174.63	s	163.63	u	140.63	w	121.37	y	150.07	G
10% gum arabic (GA)	193.85	o	225.84	k	226.87	j	180.63	r	206.80	E
2% potassium sorbate (PS)	214.22	l	241.26	g	251.86	e	187.45	q	223.70	D
2% potassium bicarbonate (PB)	187.69	q	210.61	n	211.42	m	172.20	t	195.48	F
10% GA incorporated with 0.2% IMZ	226.64	j	230.12	i	253.23	d	192.54	p	225.63	C
10% GA incorporated with 2% PS	232.44	h	242.71	f	276.45	a	258.22	c	252.45	A
10% GA incorporated with 2% PB	225.64	k	230.55	i	269.57	b	231.89	h	239.41	B
Means	203.38	C	211.09	B	219.11	A	180.87	D		

Means followed by the same letters within postharvest treatments, storage periods and their interactions in each season are not significantly different at level $P \leq 0.05$ according to DMRT.

A low amount of TPC and TAC in untreated fruits or treated with 0.2% imazalil might be due to the higher rate of respiration, senescence and breakdown of cell structure during storage as mentioned by Addai et al. (2013). Thus, untreated fruits or treated with 0.2% imazalil failed to acquire the protection and deteriorated oranges quickly. These results of the present study are comparable with the previous findings of Addai et al. (2013) in papaya fruits. They reported that gum arabic coating effectively maintained TPC and TAC during storage in comparison to untreated fruits. In the same way, coated 'Choke Anan' mangoes with 10% gum arabic alone or in combination with 3% calcium chloride effectively inhibited the loss of TPC and antioxidant activity (Khaliq et al., 2016). In addition, dipped jackfruit in potassium sorbate for five minutes alone or combined with 1000 nL/L of 1-methylcyclopropene and different edible coatings significantly increased TPC and TAC as compared to control during cold storage at 4°C (Vargas-Torres et al., 2017).

Conclusion

In conclusion, this research offers potential new methods to the 'Washington' navel oranges for implementation of nonpolluting postharvest diseases management especially devoted to high added value of organic markets or export markets. The present study showed that, edible coating of 10% gum arabic (GA), 2% potassium sorbate (PS), 2% potassium bicarbonate (PB) and GA incorporated with PS or PB significantly reduced the deterioration of physical and chemical characteristics of 'Washington' navel oranges during long term storage at low temperature as compared to untreated fruits or treated fruits with IMZ. In particular, 2% PS or 2% PB incorporated with 10% GA coating was the most effective in this respect. Thus, this study recommends with use of PS or PB at 2% incorporated with GA at 10% postharvest application of 'Washington' navel oranges instead of the currently adopted IMZ to reduce the risk of fungicide usage for controlling postharvest decay and keeping fruit quality for 10 weeks at 5°C followed by one week shelf life at 18-23°C.

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فعالية الصمغ العربي وأملاح البوتاسيوم واندماجهما في السيطرة علي أمراض ما بعد الحصاد والمحافظة علي جودة ثمار البرتقالِ بسره صنف ‘واشنطن’ أثناء التخزين المبرد علي المدى البعيد

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تم تقييم الصمغ العربي كطلاء صالح للأكل والمواد الغذائية الحافظة التي لها خواص معادية للفطريات متضمنة سوربات البوتاسيوم وبيكربونات البوتاسيوم علي ثمار البرتقال بسره صنف ‘واشنطن’ أثناء التخزين المبرد علي المدى البعيد في موسمي ٢٠١٦ و ٢٠١٧. نقعت ثمار البرتقال لمدة ثلاثة دقائق في المعاملات التالية: الماء المقطر واستخدم للثمار غير المعاملة (الكنترول)، ٠,٢٪ ايمازيليل واستخدم كمبيد تجاري، ١٠٪ صمغ عربي، ٢٪ سوربات بوتاسيوم ، ٢٪ بيكربونات بوتاسيوم ، ١٠٪ صمغ عربي متحد مع ٠,٢٪ ايمازيليل، ١٠٪ صمغ عربي متحد مع ٢٪ سوربات بوتاسيوم و١٠٪ صمغ عربي متحد مع ٢٪ بيكربونات بوتاسيوم. بعد ذلك، جميع المعاملات تم تخزينها على درجة ٥ ± ١ درجة مئوية و٩٠±٥٪ رطوبة نسبية لمدة عشرة أسابيع متبعة بأسبوع لتقييم العمر التسويقي علي ١٨-٢٣ درجة مئوية و ٥٥-٦٥٪ رطوبة نسبية. تم تقدير التغيرات في الخواص الطبيعية والكيميائية للثمار كل أسبوعين أثناء التخزين المبرد متبعة بأسبوع فترة عمر تسويقي. عموماً، كل معاملات ما قبل التخزين خفضت بشكل فعال الفقد في وزن الثمار وسيطرت علي حدوث التلف وقللت من قطر التلف السطحي وأدت إلي زيادة النسبة المئوية للثمار القابلة للتسويق وحافظت علي صلابة القشرة وأبقت علي المظهر الخارجي للثمار مقارنة بثمار البرتقال غير المعاملة والمعاملة بالايمازيليل أثناء التخزين. إضافة إلى ذلك، هذه المعاملات التطبيقية قللت من الفقد في العصير وحامض الأسكوربيك والحموضة المقدرة بالإضافة إلي أنها أبطأت بشكل معنوي تراكم المواد الصلبة الذائبة الكلية ونسبة المواد الصلبة الذائبة الكلية إلى الحموضة المقدرة. علاوة على ذلك، فإن هذه المعاملات أدت إلي زيادة محتوي الثمار من المواد الفينولية الكلية وتحسين قدرة مضادات الأكسدة الكلية بالمقارنة بالثمار غير المعاملة (الكنترول). بشكل خاص، ٢٪ سوربات بوتاسيوم أو ٢٪ بيكربونات بوتاسيوم متحد مع ١٠٪ صمغ عربي كانت الأكثر فعالية في هذا التأثير بالمقارنة مع الثمار الأخرى المعاملة وغير المعاملة (الكنترول). لذلك، أظهرت هذه المعاملات التطبيقية طريقة سهلة ورخيصة كبديل مناسب للايمازيليل المستخدم حالياً للسيطرة علي التلف بعد الحصاد ومنع تدهور الخواص الطبيعية والكيميائية لثمار البرتقال بسره صنف ‘واشنطن’ أثناء التخزين علي المدى البعيد في درجة الحرارة المنخفضة.