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Pre-Harvest Applications of Potassium Silicate, Chitosan and Calcium Chloride to Improve Mango cv. 'Zibda' Fruit Quality and Storability

M.A.A. Mohamed*, A.F. Abd El-Khalek and H.G. Elmehrat*****

Fruit Handling Department, Horticulture Research Institute, Agricultural Research Centre,Horticulture Department, Faculty of Agriculture, Tanta University, and***Organic Agriculture, Central Lab., Agricultural Research Centre, Cairo, Egypt.*

THE EFFECT of pre-harvest coating with potassium silicate, chitosan and calcium chloride on mango cv. 'Zibda' fruit storability was study during two successive seasons, 2014 and 2015. Mango fruits were coated with chitosan at 1%, potassium silicate at 2000 and 3000 ppm, calcium chloride at 2 and 4% or the combination among the first treatment and four other treatments in addition water only used as control treatment. These treatments were sprayed before two weeks of anticipated commercial harvest. After two weeks from these applications, fruits were harvested and directly transported to the laboratory were washed and dried then packaged in carton boxes and stored at 13°C and 85-90% relative humidity (RH) for five weeks. Fruit samples were taken at harvest and at one week intervals during cold storage to evaluate fruit quality and storability. This experiment revealed that, pre-harvest coating of 'Zibda' mango fruits with all treatments significantly reduced the deterioration of physical and chemical characteristics. Moreover, this study confirmed that, the combination treatments effectively increased fruit storability and shelf life in comparison to individual treatments and untreated fruits (control). This study illustrated that, pre-harvest applications of 1% chitosan in combination with potassium silicate at 2000 or 3000 ppm and calcium chloride at 2 or 4% as coating treatments at two weeks before harvesting are the promising strategy for keeping postharvest quality and increasing storability of mangoes cv. 'Zibda' up to five weeks at 13ºC and 85-90 % RH.

Keywords: Pre-harvest, Chitosan, Potassium silicate, Calcium chloride, Zibda mango, Fruit quality.

Introduction

Mango (*Mangifera indica* L.) is an economically and popular important tropical fruit in the world and also in Egypt. The total planted area of mango orchards in Egypt reached of 183341 feddans with annually total production of 786528 tons (Statistics of Ministry of Agriculture and land reclamation, 2014). Mango fruit quality consists of many attributes that are considered the key components that contribute to a high quality fresh mango and in the consumer acceptability. They include texture, sweetness, acidity, flavor, volatiles, aroma, nutritional value, chemical components, appearance of flesh colour and shelf life (Mitra & Baldwin, 1997). Mango is a climacteric fruit, it has poor storage life and the fruit ripening rapidly after harvesting, which greatly affects a loss in commercial value and ripe fruits it becomes much more susceptible to pathogen infections, due to the reduction in peel impedance and the raising of pulp softening, availability of water and sugars (Wongkhot et al., 2012).

Natural products are taking a place as an alternative approach for retardant ripening and decreasing postharvest deterioration of fruit (Tripathi & Dubey, 2004). Applications of natural, safe and environmentally friendly coatings reduced postharvest decay and maintained fruit quality as well as increase shelf life and collapse

Corresponding author: maamohamed61@yahoo.com
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of fresh produce. Edible coatings act as a barrier decrease gas exchange between fruit and the surrounding atmosphere, cause in modified internal atmosphere (high CO_2 and low O_2) as well as decreased water loss (Baldwin et al., 1999 and Jiang & Li, 2001). Edible coatings are used as postharvest management to maintain fruit quality (Zhu et al., 2008, Abbasi et al., 2009 and Elsabee & Abdou, 2013).

Chitosan (poly-β-(1,4) N-acetyl-D-glucoseamine) is a natural biopolymer compound derived by deacetylation of chitin, a major component of the shells of crustacean such as crab, shrimp, and crawfish (Sanford, 2002). Chitosan is an ecologically sound alternative for controlling important pathogenic microorganisms and has received much interest for applications in agriculture, biomedicine, biotechnology, and for the food industry because of its non-toxicity, biocompatibility, biodegradability and bioactivity (Wu et al., 2005 and Muzzarelli et al., 2012). Physiologically, chitosan is able to form a film on a surface of fruit and vegetable and thus reduce respiration rate by adjusting the permeability of carbon dioxide and oxygen, which results in reduced fruit metabolism and extends shelf life (Aider, 2010 and Elsabee & Abdou, 2013). In addition, chitosan coating, which can form a protective barrier on the surface of fruit and this could result in inhibits the growth of decay and induces defense response in fruit tissues (Shibuya & Minami, 2001 and Zeng et al., 2010). Chitosan coating is able to preservative and improvement fruit quality, extend storage life, delayed ripening process, maintained acidity and ascorbic acid contents, enhanced antioxidant capacity, delayed browning, controlled the decay, retarded water loss and reduced the drop in sensory quality of mango fruits (Kittur et al., 2001; Wang et al., 2007; Zhu et al., 2008 and Abbasi et al., 2009), longan and papaya fruits (Jiang & Li, 2001; Ali et al., 2004; Ali et al., 2011 and Shi et al., 2013). Moreover, chitosan edible coating delay textural changes and reduce ripening process in mango (Wang et al., 2007 and Zhu et al., 2008).

Silicon has been reported as a beneficial nutrient, protecting plants against various diseases (Datnoff et al., 2007). Silicon confers resistance to certain diseases are associated with the physical block created by the deposition of this element under the cuticle and on the epidermal cell wall or with the enhancement of defense mechanisms such as production of phenolic compounds. Hence increased lignification and promoted cell wall strengthening to control many diseases in plant (Datnoff et al., 2007 and Lopes et al., 2014). Silicon dioxide is considered most promising to improve the food preservation of chitosan coatings on jujube fruits (Yu et al., 2012). Postharvest application with Potassium silicate (KSi) of 'Hass' avocado fruits reduced firmness, weight loss and increasing fruit quality (Anderson et al., 2005 and Tesfay et al., 2011). Furthermore, KSi applications reduced the severity of green mold and extending shelf life of orange fruits (Moscoso-Ramírez & Palou, 2014).

Calcium is an substantial constituent of cultivate tissues and has a vital role in maintaining and modulating various cell functions by increasing membrane stability, cell wall strength and maintaining the cell to cell contact resulted in reducing degradation of middle lamella (Martin-Diana et al., 2007 and Dodd et al., 2010). This is due to a decrease in the activity of 1-aminocyclopropane-1-carboxylic acid oxidase (Guan et al., 1991). In this concern, calcium chloride has been extensively used in fruits and vegetables for preservative and firming agent. It has been observed that calcium is correlating with fruit firmness, stress tolerance, ripening and aging (Martin-Diana et al., 2007). Calcium chloride treatment delayed ripening, maintaining fruit firmness, delayed skin colour, reduced weight loss, respiration rate, reduced decay incidence and increased marketability with better appearance of mango fruits during storage (Chitarra et al., 2001 and Singh et al., 2007). Moreover, dipping mango 'Totapuri' and 'Banggapalli' fruits, guava 'L-49' 'Maamoura' and 'Sardar' fruits and 'Cuarenta Dias' banana fruits in calcium chloride solutions as a postharvest treatment at 0.5-4% for 2-5 minutes achieved a remarkable reduction in fruit decay percentage, fruit rotting and increased fruit storability (Fatma-Shaaban, 2006; El-Badawy, 2007 and Salazar & Serrano, 2013). Pre and postharvest sprays of calcium compounds significantly retained more ascorbic acid in mature green mango and guava fruits and during storage as compared to control fruits (Fatma-Shaaban, 2006 and El-Badawy, 2007).

Therefore, the objective of this study was conducted to examine the effect pre-harvest applications of chitosan, potassium silicate and calcium chloride in maintaining quality and extending the storage life of mango cv. 'Zibda' fruits.

Materials and Methods

This investigation was carried out during two successive seasons (2014 and 2015) on fifteen years old, vigorous, fruitful on mango trees cv. 'Zibda' (*Mangifera indica.* L*)*. This study was conducted in a private orchard located in El-Behera Governorate, 180 Kilometers from Cairo, Egypt. Thirty healthy trees were selected, three for each treatment, approximately vigorously uniform in their size and free from diseases. These trees were subjected to all ideal standard horticultural practices according to the Ministry of agriculture and land reclamation. Fruits were sprayed at two weeks before anticipated commercial harvest in the third week of July. Fruits were sprayed with the following treatments:

1- Water only as a control.
2- Chitosan at 1%.
3- Potassium silicate (KSi) at 2000 ppm.
4- KSi at 3000 ppm.
5- Calcium chloride ($CaCl_2$) at 2%.
6- $CaCl_2$ at 4%.
7- Chitosan at 1% plus KSi at 2000 ppm.
8- Chitosan at 1% plus KSi at 3000 ppm.
9- Chitosan at 1% plus $CaCl_2$ at 2%.
10- Chitosan at 1% plus $CaCl_2$ at 4%.

Preparation of coating solutions

Chitosan solution was prepared as mentioned by Jiang & Li (2001). Chitosan (MW: 50–190 kDa, degree of deacetylation ≥75%) chitosan low molecular weight was purchased from Sigma Chemical Co. purified chitosan was dispersed in an aqueous solution of glacial acetic acid 0.5% (v/v) under continuous stirring to form a homogeneous mixture.

Potassium silicate (KSi) solution (25% SiO_2, K_2O 10%, pH≤9), KSi was dissolved in water to a final concentration of 2000 and 3000 ppm of SiO_2.

Tween-80 at 0.05% (v/v) was added in each previous treatment to improve wetting of the coating and adherence to mangoes surface and the pH of the solutions were adjusted to 5.6 with 1 N NaOH. Fruits free from visual symptoms of any disease or blemishes were picked two weeks later and immediately transported to the laboratory of horticulture research institute at Giza governorate. once arrival to laboratory, mango fruits were air dried by electric fan for one hour, then packaged in carton boxes (50×35×15 cm). Each treatment included ten boxes and each each box containing nine fruits (90 fruits per treatment). All carton boxes were stored at 13 ±1°C and 85-90 % relative humidity (RH) for five weeks. Fruit samples were taken at harvest time and at one week intervals of cold storage period plus three days shelf life at ambient temperature (22–28°C and 60–75% RH) to evaluate fruit quality and storability as affected by pre-harvest spraying treatments.

Measurements of fruit physical and chemical characteristic

Weight loss percentage was calculated by the following equation [(initial fruit weight - fruit weight at examination date) / (initial fruit weight)] × 100.

Decayed fruit percentage was determined as follow [(number of decayed fruits at examination date) / (initial number of fruits)] ×100.

Marketable fruit percentage was calculated by the following formula [(sound fruits at examination date) / (initial fruit weight)] ×100.

Fruit colour was measured using a Minolta CR-400 Chroma Meter (Minolta Co. ltd. Osaka, Japan). The measurements of skin and flesh colour were expressed in chromaticity values of hue angle (h°). Three readings were taken at different locations of each mango fruit during each data observation (McGuire, 1992 and Voss, 1992).

Fruit firmness of the flesh was recorded by using lfra texture analyzer Instrument. The force required to penetrate 1 cm inside the fruit using a needle probe diameter of 5 mm was measured. The machine was set with peak mode and speed of 0.3 mm/sec. Readings were recorded on three points in the equatorial region of the whole fruit and the results were expressed as the resistance force to the penetrating tester in units of pressure g/cm² (Watkins & Harman, 1981).

Fruit juice was extracted by crushing the pulp of each fruit and fruit juice strained through a muslin cloth and used for measuring internal fruit quality as follow:

Fruit content of total soluble solids (TSS) was determined by 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 (2000).

Fruit content of titratable acidity (TA) was determined as per the procedure of AOAC (2000). 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 was calculated as grams of citric acid/100 ml of the juice.

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

Fruit content of ascorbic acid was determined according to method of adopting the procedure described by AOAC (2000) and was calculated as mg/100 ml juice.

Statistical analysis

This experiment was arranged in a randomized complete block design having three replications (Steel et al., 1997) and consisting of two factors (pre-harvest treatments and storage periods). 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 pre-harvest treatments and cold storage periods 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 tests (DMRT) at probability ≤ 0.05.

Results and Discussion

Fruit physical characteristics

Weight loss, decay and marketable fruit percentages

Data presented in Tables 1, 2 and 3 cleared that, weight loss percentage and decay percentage of mango fruits gradually and significantly increased with prolonging of storage period during the two seasons in this investigation. On contrast, marketable fruits percentage gradually and significantly decreased with prolonging of storage period during the two seasons under this work.

Data also indicated that, all coating treatments were significantly reduced weight loss and decay incidence of fruits as well as increased marketable fruits percentage during cold storage as compared to untreated fruits during the two seasons in this study. Moreover, the combination pre-harvest treatments were the most effective in this aspect.

Data also cleared that, there was a significant interaction among treatments and storage periods for weight loss, decay and marketable percentages of mango fruits in both seasons in this research.

The loss of fresh fruits and vegetables weight is mainly due to the loss of water caused by transpiration and respiration processes (Wang et al., 2007; Zhu et al., 2008 and Elsabee & Abdou, 2013). The increase of mango fruit weight loss during storage may be due to the increase of the respiratory metabolism of the fruits and exacerbate the loss of water absorbed by the chitosan coating on the fruit surface (Zhu et al., 2008 and Abbasi et al., 2009). Chitosan coating forms a layer of semi-transparent to smooth the pericarp surface (González-Aguilar et al., 2009) and can be used as a protective barrier to reduce respiration and transpiration rates through fruit surfaces (Wang et al., 2007; Zhu et al., 2008 and Elsabee & Abdou, 2013).

Chitosan coating treatment of mango fruits was clearly effective in conferring a physical barrier to moisture loss, therefore a decreasing of weight loss in coated fruit with chitosan was observed in this study. Moreover, KSi treatment covers fruit stomata with a silicon layer, it reduces fruit respiration and concomitantly resulted in decreased weight loss (Tesfay et al., 2011). Thus, KSi treatment positively associated with delaying fruit weight loss by maintaining fruit moisture. Furthermore, silicon deposition is related to membrane integrity (Tesfay et al., 2011).

Mango fruits susceptibility to postharvest diseases during storage as a result of the physiological changes and senescence process (Prusky & Keen, 1993). The reduction of mangoes decay incidence during storage because of pre-harvest applications of chitosan, KSi and $CaCl_2$ coatings especially in combination treatments may be due to the low respiration rate and the delay of senescence, which could enhance resistance to infection and lesion development as has been previously suggested by Zeng et al. (2010) and Wang et al. (2014). Chitosan inhibits the growth of decay and induces defense response in host tissues (Shibuya & Minami, 2001 and Zeng et al., 2010). Chitosan treatment showed positive effects in maintaining membrane integrity and increasing the activities of antioxidant enzymes and phenolic compounds (Jiang & Li, 2001; Zeng et al., 2010; Hong et al., 2012 and Kumari et al., 2015). Moreover, The NH_3^+ group of chitosan may also restrain the propagation of harmful germs and promoting protection from further fungal, thus effectively controlled fruit decay (Devlieghere et al., 2004).

Moreover, silicon confers resistance to certain diseases are associated with the physical barrier created by the sedimentation of this element under the cuticle and on the epidermal cell wall or with the enhancement of defense mechanisms such as production of phenolic compounds, hence

TABLE 1 . Effect of pre-harvest coating treatments on weight loss percentage of 'Zibda' mango fruits during storage at 13°C plus 3 days shelf life at 22-28°C

Pre-harvest coating treatments	Storage period (days)						
	0	7	14	21	28	35	Means
	Season 2014						
Water only (control)	4.47 t-x	6.83 n-s	9.00 i-m	13.00 cd	16.23 b	20.50 a	11.67 A
2000 ppm potassium silicate (KSi)	2.73 w-z	4.67 t-w	6.67 o-s	9.00 i-m	10.67 f-i	12.73 cde	7.74 B
3000 KSi	2.47 yz	4.67 t-w	6.33 p-t	7.67 l-q	9.67 g-k	12.73 cde	7.26 B
2% calcium chloride ($CaCl_2$)	2.97 w-z	4.33 u-y	6.67 o-s	9.33 h-l	10.00 g-j	12.20 c-f	7.58 B
4% $CaCl_2$	2.80 w-z	4.00 v-y	6.33 p-t	9.33 h-l	9.67 g-k	12.87 cde	7.50 B
1% chitosan (Chit)	2.70 xyz	3.67 v-y	6.67 o-s	8.67 j-n	10.00 g-j	13.33 c	7.51 B
1% Chit + 2000 KSi	1.54 z	4.00 v-y	5.00 s-v	7.00 n-r	8.00 k-p	12.10 c-f	6.27 C
1% Chit + 3000 KSi	1.25 z	3.67 v-y	5.33 r-v	7.00 n-r	8.33 j-o	11.07 e-h	6.11 C
1% Chit + 2% $CaCl_2$	1.65 z	4.00 v-y	6.00 q-u	7.67 l-q	8.33 j-o	11.20 d-h	6.48 C
1% Chit + 4% $CaCl_2$	1.35 z	3.67 v-y	5.33 r-v	7.33 m-q	8.33 j-o	11.40 d-g	6.24 C
Means	2.39 F	4.35 E	6.33 D	8.60 C	9.92 B	13.01 A	
	Season 2015						
Water only (control)	2.37 m-p	3.63 mno	8.48 hi	10.46 fg	16.25 b	21.96 a	10.52 A
2000 ppm potassium silicate (KSi)	1.26 p	2.15 m-p	5.77 jkl	7.03 ij	11.74 d-g	13.84 c	6.97 B
3000 KSi	1.23 p	2.32 m-p	5.87 jk	7.08 ij	11.49 d-g	12.57 cde	6.76 B
2% calcium chloride ($CaCl_2$)	1.75 op	2.55 m-p	5.73 jkl	6.84 ij	12.01 c-f	13.10 cd	6.99 B
4% $CaCl_2$	1.72 op	2.45 m-p	6.00 j	7.22 ij	11.19 d-g	12.25 c-f	6.81 B
1% chitosan (Chit)	2.01 nop	2.73 m-p	6.15 j	7.32 ij	10.91 efg	11.95 c-f	6.85 B
1% Chit + 2000 KSi	0.97 p	2.51 m-p	4.02 klm	5.86 jk	9.82 gh	12.29 c-f	5.91 C
1% Chit + 3000 KSi	0.78 p	2.30 m-p	4.08 klm	5.73 jkl	10.48 fg	11.74 d-g	5.85 C
1% Chit + 2% $CaCl_2$	1.05 p	2.54 m-p	3.90 lmn	6.20 j	10.47 fg	12.04 c-f	6.03 C
1% Chit + 4% $CaCl_2$	0.92 p	2.50 m-p	3.93 lmn	6.06 j	10.37 fg	12.02 c-f	5.97 C
Means	1.41 F	2.57 E	5.39 D	6.98 C	11.47 B	13.38 A	

Means followed by the same letters within pre-harvest coating 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 pre-harvest coating treatments on decay percentage of 'Zibda' mango fruits during storage at 13°C plus 3 days shelf life at 22-28°C

Pre-harvest coating treatments	Storage period (days)						
	0	7	14	21	28	35	Means
	Season 2014						
Water only (control)	0.00 l	0.00 l	9.53 i	19.39 cd	35.19 b	44.52 a	18.10 A
2000 ppm potassium silicate (KSi)	0.00 l	0.00 l	0.00 l	2.92 k	8.19 ij	12.49 h	3.94 B
3000 KSi	0.00 l	0.00 l	0.00 l	0.00 l	6.47 j	13.56 gh	3.34 BCD
2% calcium chloride ($CaCl_2$)	0.00 l	0.00 l	0.00 l	0.00 l	0.00 l	21.43 c	3.57 BC
4% $CaCl_2$	0.00 l	0.00 l	0.00 l	0.00 l	2.65 k	18.51 de	3.53 BC
1% chitosan (Chit)	0.00 l	0.00 l	0.00 l	0.00 l	3.25 k	16.69 ef	3.32 BCD
1% Chit + 2000 KSi	0.00 l	0.00 l	0.00 l	0.00 l	0.00 l	14.63 fgh	2.44 D
1% Chit + 3000 KSi	0.00 l	0.00 l	0.00 l	0.00 l	0.00 l	13.63 gh	2.27 D
1% Chit + 2% $CaCl_2$	0.00 l	0.00 l	0.00 l	0.00 l	0.00 l	15.76 fg	2.63 CD
1% Chit + 4% $CaCl_2$	0.00 l	0.00 l	0.00 l	0.00 l	0.00 l	13.93 gh	2.32 D
Means	0.00 E	0.00 E	0.95 D	2.23 C	5.58 B	18.51 A	
	Season 2015						
Water only (control)	0.00 j	0.00 j	9.83 fgh	20.66 c	30.43 b	45.05 a	17.66 A
2000 ppm potassium silicate (KSi)	0.00 j	0.00 j	0.00 j	0.00 j	8.27 f-i	17.00 cde	4.21 BC
3000 KSi	0.00 j	0.00 j	0.00 j	0.00 j	3.72 ij	17.09 cde	3.47 BC
2% calcium chloride ($CaCl_2$)	0.00 j	0.00 j	0.00 j	0.00 j	8.37 f-i	17.45 cde	4.30 B
4% $CaCl_2$	0.00 j	0.00 j	0.00 j	0.00 j	4.42 hij	18.10 cd	3.75 BC
1% chitosan (Chit)	0.00 j	0.00 j	0.00 j	0.00 j	6.51 ghi	17.22 cde	3.95 BC
1% Chit + 2000 KSi	0.00 j	0.00 j	0.00 j	0.00 j	0.00 j	13.35 def	2.22 BC
1% Chit + 3000 KSi	0.00 j	0.00 j	0.00 j	0.00 j	0.00 j	11.14 fg	1.86 C
1% Chit + 2% $CaCl_2$	0.00 j	0.00 j	0.00 j	0.00 j	0.00 j	12.11 efg	2.02 BC
1% Chit + 4% $CaCl_2$	0.00 j	0.00 j	0.00 j	0.00 j	0.00 j	11.34 fg	1.89 C
Means	0.00 D	0.00 D	0.98 CD	2.07 C	6.17 B	17.98 A	

Means followed by the same letters within pre-harvest coating 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 pre-harvest coating treatments on marketable percentage of 'Zibda' mango fruits during storage at 13°C plus 3 days shelf life at 22-28°C

Pre-harvest coating treatments	Storage period (days)						
	0	7	14	21	28	35	Means
Season 2014							
Water only (control)	95.53 a-i	93.17 g-m	81.47 r	67.61 tu	48.58 v	34.98 w	70.22 C
2000 ppm potassium silicate (KSi)	97.27 a-e	95.33 a-j	93.33 f-m	88.08 nop	81.14 r	74.77 s	88.32 B
3000 KSi	97.53 a-d	95.33 a-j	93.67 e-m	92.33 h-m	83.86 qr	73.71 s	89.41 B
2% calcium chloride ($CaCl_2$)	97.03 a-f	95.67 a-i	93.33 f-m	90.67 l-o	90.00 m-p	66.37 u	88.84 B
4% $CaCl_2$	97.20 a-e	96.00 a-h	93.67 e-m	90.67 l-o	87.68 op	68.62 tu	88.97 B
1% chitosan (Chit)	97.30 a-e	96.33 a-g	93.33 f-m	91.33 k-n	86.75 pq	69.97 t	89.17 B
1% Chit + 2000 KSi	98.46 ab	96.00 a-h	95.00 b-k	93.00 g-m	92.00 i-m	73.27 s	91.29 A
1% Chit + 3000 KSi	98.75 a	96.33 a-g	94.67 c-k	93.00 g-m	91.67 j-m	75.31 s	91.62 A
1% Chit + 2% $CaCl_2$	98.35 abc	96.00 a-h	94.00 d-l	92.33 h-m	91.67 j-m	73.04 s	90.90 A
1% Chit + 4% $CaCl_2$	98.65 ab	96.33 a-g	94.67 c-k	92.67 g-m	91.67 j-m	74.67 s	91.44 A
Means	97.61 A	95.65 B	92.71 C	89.17 D	84.50 E	68.47 F	
Season 2015							
Water only (control)	97.63 a	96.37 ab	81.69 fgh	68.89 k	53.33 l	32.99 m	71.82 D
2000 ppm potassium silicate (KSi)	98.74 a	97.85 a	94.23 a-d	92.97 a-d	79.98 f-i	69.16 k	88.82 C
3000 KSi	98.77 a	97.68 a	94.13 a-d	92.92 a-d	84.79 ef	70.34 jk	89.77 BC
2% calcium chloride ($CaCl_2$)	98.25 a	97.45 a	94.27 a-d	93.16 a-d	79.62 f-i	69.45 k	88.70 C
4% $CaCl_2$	98.29 a	97.55 a	94.00 a-d	92.78 a-d	84.39 ef	69.65 k	89.44 C
1% chitosan (Chit)	97.99 a	97.27 a	93.85 a-d	92.68 a-d	82.59 fg	70.83 jk	89.20 C
1% Chit + 2000 KSi	99.03 a	97.49 a	95.98 a-d	94.14 a-d	90.18 b-e	74.37 ijk	91.87 AB
1% Chit + 3000 KSi	99.22 a	97.70 a	95.92 a-d	94.27 a-d	89.52 de	77.12 ghi	92.29 A
1% Chit + 2% $CaCl_2$	98.95 a	97.46 a	96.10 abc	93.80 a-d	89.53 de	75.85 hij	91.95 AB
1% Chit + 4% $CaCl_2$	99.08 a	97.50 a	96.07 abc	93.94 a-d	89.63 cde	76.64 ghi	92.15 A
Means	98.60 A	97.43 A	93.63 B	90.95 C	82.36 D	68.64 E	

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

promoted cell wall strength to control many diseases in plant (Datnoff et al., 2007 and Lopes et al., 2014). Also, calcium is an important constituent of plant tissues and has a vital role in keeping and modulating various cell functions by increasing membrane stability, cell wall strength and maintaining the cell to cell contact by reducing degradation of middle lamella and enhanced tissue develops resistance to harmful enzymes produced by fungi by stabilizing or strengthening cell wall (Dodd et al., 2010).

These results are in agreement with Chitarra et al. (2001), Kittur et al. (2001), Singh et al. (2007), Wang et al. (2007), Zhu et al. (2008) and Abbasi et al. (2009) on mango fruits. Also, these results were confirmed by Chien et al. (2007), Moscoso-Ramírez & Palou (2014) on citrus fruits. They reported that, chitosan, KSi and $CaCl_2$ coating pre-harvest treatments reduced fruit weight loss and decay percentage and decreased the reduction of marketable fruits percentage during storage. Furthermore, they illustrated that, fruits weight loss and decay incidence gradually and significantly increased with prolonging of storage period.

Fruit firmness

Data presented in Table 4 clearly indicated that, mango fruit firmness gradually and significantly decreased with the progress of storage period. Moreover, data indicated that, all pre-harvest coating treatments significantly delayed the softening incidence of stored 'Zibda' mango fruit as compared to untreated fruits (control) in both seasons under this investigation. Data also shown that, coated fruits with the combinations treatments were superior to those coated with either chitosan, KSi or $CaCl_2$ alone in this study.

Data also mentioned that, there was a significant interaction among treatments and storage periods for mango fruit firmness in the two seasons in this research.

Losses in firmness with the progress of storage period due to ripening of mango fruits as a result of an increase in activities of cell wall hydrolysis enzymes such as pectinesterase, polygalacturonase pectin methylesterase and pectatelyases during ripening and cold storage (Ali et al., 2004). In the cell wall, hydrolyzing enzymes are enhanced by CO_2 production in climacteric fruits (Abbasi et al., 2009; Zhu et al., 2008; De S. Medeiros et al., 2012; Hong et al., 2012; Yu et al., 2012; Elsabee & Abdou, 2013 and Shi et al., 2013). The calcium ions in fruit is associated with firmness and is attributed to increase tissue strengthen the cell wall and mainly the middle lamella by holding the cells altogether thus, reduced ripening and senescence processes (Vicente et al., 2007). Moreover, chitosan, silicon and calcium edible coating alter gas diffusion and thus the exchange of CO_2 and O_2 exchange between fruit tissue and the outside atmosphere, maintaining fruit moisture and reducing the normal metabolic activity consequently, delay textural changes and reduce ripening process in mango (Wang et al., 2007 and Zhu et al., 2008). The obtained results are in harmony with those of Singh et al. (2007) and Hojo et al. (2009) they found that, calcium is known to delay senescence resulted in firmer fruits and thus firmness of mango fruits was increased by treatment of calcium as compared to the control. Pre-harvest application with chitosan, KSi and $CaCl_2$ coating treatments especially in combination treatments helped delayed ripening process, retain firmness and extended the storage life of mango cv. 'Zibda' fruits by reducing weight loss, as has been shown previously by Chitarra et al. (2001), Kittur et al. (2001), Singh et al. (2007), Wang et al. (2007), Zhu et al. (2008), Abbasi et al. (2009) and Hojo et al. (2009) on mango fruits.

TABLE 4. Effect of pre-harvest coating treatments on firmness (g/cm^2) of 'Zibda' mango fruits during storage at 13°C plus 3 days shelf life at 22-28°C

Pre-harvest coating treatments	Storage period (days)						
	0	7	14	21	28	35	Means
Season 2014							
Water only (control)	213.7 abc	203.0 bcd	174.3 e	92.3 i-l	47.0 p	33.7 p	127.3 D
2000 ppm potassium silicate (KSi)	208.7 a-d	198.3 cd	148.3 f	111.3 gh	111.0 gh	74.7 mno	142.1 ABC
3000 KSi	208.0 a-d	195.3 d	160.7 ef	111.0 gh	114.3 g	68.7 no	143.0 ABC
2% calcium chloride ($CaCl_2$)	215.7 abc	202.0 bcd	164.0 e	104.7 ghi	85.7 k-n	66.0 o	139.7 C
4% $CaCl_2$	212.7 a-d	206.0 a-d	164.3 e	111.7 gh	78.0 l-o	71.0 mno	140.6 BC
1% chitosan (Chit)	221.3 a	212.3 a-d	171.7 e	102.7 g-j	85.0 k-n	69.7 no	143.8 ABC
1% Chit + 2000 KSi	216.7 ab	212.0 a-d	173.7 e	106.7 ghi	96.7 h-k	77.7 l-o	147.2 AB
1% Chit + 3000 KSi	218.0 ab	213.0 abc	173.7 e	105.0 ghi	106.0 ghi	73.3 mno	148.2 A
1% Chit + 2% $CaCl_2$	217.3 ab	211.3 a-d	173.0 e	111.0 gh	85.0 k-n	69.0 no	144.4 ABC
1% Chit + 4% $CaCl_2$	221.0 a	205.0 a-d	177.0 e	113.0 gh	87.7 j-m	68.7 no	145.4 ABC
Means	215.3 A	205.8 B	168.1 C	106.9 D	89.6 E	67.2 F	
Season 2015							
Water only (control)	208.3 b-e	129.8 klm	117.5 m-q	89.7 tuv	58.3 xy	47.7 y	108.6 C
2000 ppm potassium silicate (KSi)	232.5 a	203.3 c-f	180.0 g	86.7 uv	76.0 vw	63.7 wx	140.4 B
3000 KSi	189.2 fg	205.7 b-f	162.5 h	118.6 m-p	100.6 q-u	90.9 s-v	144.6 AB
2% calcium chloride ($CaCl_2$)	195.0 efg	198.6 def	151.7 hi	122.5 l-o	106.3 o-t	97.3 r-u	145.2 AB
4% $CaCl_2$	205.0 b-f	191.8 efg	149.2 hij	122.6 l-o	108.8 n-s	87.3 uv	144.1 AB
1% chitosan (Chit)	219.2 abc	197.1 efg	147.5 hij	123.6 l-o	98.3 r-u	87.6 uv	145.5 AB
1% Chit + 2000 KSi	215.0 bcd	191.0 efg	144.0 ijk	134.3 i-m	103.9 p-u	95.9 r-u	147.4 A
1% Chit + 3000 KSi	208.3 b-e	202.3 c-f	148.9 hij	126.1 lmn	109.3 n-r	93.6 r-u	148.1 A
1% Chit + 2% $CaCl_2$	221.7 ab	194.5 efg	151.7 hi	127.1 klm	100.3 q-u	91.9 r-v	147.9 A
1% Chit + 4% $CaCl_2$	218.3 abc	194.5 efg	139.2 i-l	131.9 j-m	105.9 o-t	94.9 r-u	147.5 A
Means	211.3 A	190.9 B	149.2 C	118.3 D	96.8 E	85.1 F	

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

These results are in accordance of Chitarra et al. (2001), Kittur et al. (2001), Singh et al. (2007), Wang et al. (2007), Zhu et al. (2008) and Abbasi et al. (2009) on mango fruits. Moreover, these results are in line with those mentioned by Chien et al. (2007) on citrus fruits. Also, these results are in harmony with those obtained by Fatma-Shaaban (2006), El-Badawy (2007) and Hong et al. (2012) on guava and mango fruits and Anderson et al. (2005) and Tesfay et al. (2011) on avocado fruits. They reported that, chitosan, KSi and $CaCl_2$ coating treatments showed better firmness as compared to untreated fruits during storage. Also, they reported that, fruits firmness gradually and significantly decreased with the progress of storage period.

Fruit skin and flesh colour

Data shown in Tables 5 and 6 illustrated that, mango fruit skin colour, represented as hue angle value, changed directly from green (more than 90) to greenish yellow or yellow (less than 90) while mango fruit flesh colour changed directly from white to yellow or orange (around 65) with prolonging of storage period during both experimental seasons in this research.

Data also cleared that, all pre-harvest coating treatments significantly reduced fruit skin and flesh colour changing rate during the two seasons in this investigation as compared to untreated fruits. Moreover, fruits treated with the combination treatments significantly had the lowest colour changing rate during the two seasons under this study.

Data also approved that, there was a significant interaction among treatments and storage periods for skin and flesh colour of mango fruits during the two seasons in this study.

Edible coating created a semi-permeable film around the fruit and modified the internal atmosphere by decreasing oxygen and increasing carbon dioxide productions (De S. Medeiros et al., 2012). Elevated carbon dioxide levels around the fruit retarded ripening process by inhibiting the activity of ethylene synthesis (Ali et al., 2011). In the same way, the retardation of colour development in mango cv. 'Zibda' fruit treated with chitosan, potassium silicate and calcium chloride treatments especially in combination treated fruits could be attributed to the slow rate of respiration and reduced ethylene production. Therefore, delayed the ripening and senescence process consequently, reduced colour change by decreased biosynthesis of carotenoids and preservation of chlorophyll content.

TABLE 5. Effect of pre-harvest coating treatments on changes in skin colour of 'Zibda' mango fruits represented as hue angle during storage at 13°C plus 3 days shelf life at 22-28°C

Pre-harvest coating treatments	Storage period (days)													
	0		7		14		21		28		35		Means	
Season 2014														
Water only (control)	107.8	fgh	101.0	hij	87.6	lmn	73.2	p	78.1	op	77.7	op	87.6	C
2000 ppm potassium silicate (KSi)	128.2	bc	123.8	c	112.4	def	102.0	hij	93.8	j-m	83.2	no	107.2	B
3000 KSi	130.3	abc	125.7	c	111.0	d-g	94.5	jkl	88.9	k-n	94.7	jkl	107.5	B
2% calcium chloride ($CaCl_2$)	128.8	bc	125.7	c	111.3	d-g	97.0	ijk	90.1	k-n	87.8	lmn	106.8	B
4% $CaCl_2$	130.8	abc	124.9	c	113.4	def	94.9	jkl	91.4	klm	86.4	mn	107.0	B
1% chitosan (Chit)	136.7	a	124.0	c	108.0	e-h	96.4	ijk	90.8	k-n	90.4	k-n	107.7	B
1% Chit + 2000 KSi	135.1	ab	127.1	c	115.9	de	107.6	fgh	96.7	ijk	94.6	jkl	112.8	A
1% Chit + 3000 KSi	130.8	abc	124.7	c	116.6	d	111.7	d-g	100.3	hij	94.6	jkl	113.1	A
1% Chit + 2% $CaCl_2$	129.8	abc	125.6	c	115.0	def	104.0	ghi	101.7	hij	96.8	ijk	112.2	A
1% Chit + 4% $CaCl_2$	130.5	abc	127.3	bc	114.8	def	104.4	ghi	101.0	hij	97.0	ijk	112.5	A
Means	128.9	A	123.0	B	110.6	C	98.6	D	93.3	E	90.3	F		
Season 2015														
Water only (control)	118.3	d-h	92.7	t-y	79.7	z	79.1	z	75.7	z	73.2	z	86.5	C
2000 ppm potassium silicate (KSi)	129.9	a	110.5	i-m	104.6	mno	100.0	o-s	95.4	q-w	88.6	wxy	104.8	B
3000 KSi	128.9	a	115.3	f-j	103.7	m-p	95.8	q-v	93.5	s-x	94.6	r-w	105.3	B
2% calcium chloride ($CaCl_2$)	127.7	ab	113.1	h-k	108.9	j-n	94.7	r-w	94.9	q-w	86.5	y	104.3	B
4% $CaCl_2$	123.4	a-e	113.3	h-k	108.8	j-n	99.0	o-t	96.2	q-v	89.9	v-y	105.1	B
1% chitosan (Chit)	126.0	abc	121.5	b-f	97.4	p-u	106.0	l-o	91.5	u-y	92.0	t-y	105.7	B
1% Chit + 2000 KSi	127.7	ab	122.1	b-f	116.7	e-i	108.9	j-n	103.6	m-p	87.7	xy	111.1	A
1% Chit + 3000 KSi	129.0	a	125.1	a-d	117.5	e-h	108.4	k-n	99.0	o-t	93.6	s-x	112.1	A
1% Chit + 2% $CaCl_2$	124.8	a-d	120.4	c-g	111.6	h-l	103.8	m-p	100.7	o-r	101.1	o-r	110.4	A
1% Chit + 4% $CaCl_2$	129.6	a	122.1	b-f	114.6	g-k	104.3	m-p	101.9	n-q	96.2	q-v	111.5	A
Means	126.5	A	115.6	B	106.4	C	100.0	D	95.2	E	90.4	F		

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

These results are in agreement with those obtained by Zhu et al. (2008) on mango fruits and Chien et al. (2007) on citrus fruits and Salazar & Serrano (2013) on banana fruits. Moreover, these results are in line with those mentioned by Fatma-Shaaban (2006), El-Badawy (2007) and Hong et al. (2012) on guava and mango fruits. Also, these results are in harmony with those obtained by Ali et al. (2011) on papaya fruits, Yan et al. (2011, 2012) on jujube fruits and Irfan et al. (2013) on figs. They mentioned that, chitosan, and calcium chloride coating treatments showed a beneficial effect on the reduction of colour changes as compared to untreated fruits during storage. Moreover, they mentioned that, fruit skin colour changed from green and greenish yellow to yellow with the progress of cold storage period.

Fruit chemical characteristics

Total soluble solids (TSS), titratable acidity (TA) and TSS/TA ratio

Data in Tables 7, 8 and 9 demonstrated that, mango fruit contents in total soluble solids and TSS/TA ratio gradually and significantly increased, while TA gradually and significantly decreased with the advanced of storage period during the two seasons in this trial.

Data also cleared that, all pre-harvest coating applications significantly reduced total soluble solids, titratable acidity and TSS/TA ratio fruit contents changing rate during cold storage. Moreover, fruits treated with the combination treatments significantly had the lowest mango fruit contents in TSS and TSS/TA ratio and the highest TA content during the two seasons under this investigation. A rapid reduction in TA content and the rapid increment in TSS and TSS/TA ratio of mango fruits during storage are associated with fast senescence of fruits (Abbasi et al., 2009).

Data also showed that, there was a significant interaction among among treatments and storage periods for TSS, TA and TSS/TA ratio of mango fruits in both seasons under this investigation.

TABLE 6. Effect of pre-harvest coating treatments on flesh colour of 'Zibda' mango fruits represented as hue angle during storage 13°C plus 3 days shelf life at 22-28°C

Pre-harvest coating treatments	Storage period (days)						
	0	7	14	21	28	35	Means
	Season 2014						
Water only (control)	84.0 b-j	79.3 g-q	72.2 q-v	72.4 p-v	57.9 y	51.6 z	69.6 F
2000 ppm potassium silicate (KSi)	86.3 a-g	83.2 c-m	76.0 m-t	76.5 k-t	76.1 l-t	67.5 vwx	77.6 CDE
3000 KSi	84.1 b-j	81.2 d-o	77.1 j-t	79.0 h-q	78.2 j-s	68.7 u-x	78.0 B-E
2% calcium chloride ($CaCl_2$)	83.2 c-l	79.9 f-o	74.2 o-v	80.5 f-o	75.9 n-t	64.2 wx	76.3 DE
4% $CaCl_2$	83.8 b-j	79.6 g-p	76.4 k-t	74.7 n-u	74.9 n-u	63.6 xy	75.5 E
1% chitosan (Chit)	90.3 ab	83.4 b-k	79.6 g-p	74.5 n-u	75.0 n-u	70.1 t-w	78.8 A-D
1% Chit + 2000 KSi	93.0 a	87.8 a-e	78.4 i-r	76.0 m-t	77.7 j-s	70.9 s-v	80.6 AB
1% Chit + 3000 KSi	92.5 a	86.8 a-f	80.8 e-o	78.0 j-s	75.2 n-u	71.4 r-v	80.8 A
1% Chit + 2% $CaCl_2$	88.1 a-d	85.6 b-h	80.5 f-o	74.5 n-u	77.0 j-t	74.8 n-u	80.1 ABC
1% Chit + 4% $CaCl_2$	90.0 abc	85.5 b-i	81.6 d-n	76.3 k-t	78.3 j-r	71.2 r-v	80.5 AB
Means	87.5 A	83.2 B	77.7 C	76.2 CD	74.6 D	67.4 E	
	Season 2015						
Water only (control)	81.9 b-l	75.8 i-p	70.2 n-s	63.3 stu	61.1 tu	57.6 u	68.3 D
2000 ppm potassium silicate (KSi)	84.2 a-g	82.3 a-k	76.4 h-o	74.7 l-p	69.2 o-s	64.6 rst	75.2 C
3000 KSi	89.6 a	83.4 a-h	72.4 m-q	74.6 l-p	72.4 m-q	69.4 o-s	77.0 BC
2% calcium chloride ($CaCl_2$)	83.5 a-h	81.7 b-l	74.9 l-p	74.5 l-p	69.0 p-s	65.9 q-t	74.9 C
4% $CaCl_2$	86.4 abc	85.2 a-e	75.6 i-p	71.7 m-r	66.1 q-t	66.7 q-t	75.3 C
1% chitosan (Chit)	86.6 abc	80.9 c-l	78.4 e-m	75.0 k-p	75.9 i-p	66.1 q-t	77.1 BC
1% Chit + 2000 KSi	87.2 abc	82.9 a-i	88.5 ab	80.2 c-l	74.6 l-p	69.6 o-s	80.5 A
1% Chit + 3000 KSi	84.5 a-f	87.1 abc	84.0 a-g	77.7 f-m	78.8 d-m	72.1 m-q	80.7 A
1% Chit + 2% $CaCl_2$	83.9 a-g	80.0 c-l	80.3 c-l	77.1 g-n	78.2 e-m	75.4 j-p	79.1 AB
1% Chit + 4% $CaCl_2$	86.1 a-d	84.3 a-g	77.2 f-n	81.3 b-l	82.4 a-j	72.3 m-q	80.6 A
Means	85.4 A	82.4 B	77.8 C	75.0 D	72.8 E	68.0 F	

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

TABLE 7. Effect of pre-harvest coating treatments on total soluble solids content (°Brix) of 'Zibda' mango fruits during storage at 13°C plus 3 days shelf life at 22-28°C

Pre-harvest coating treatments	Storage period (days)						
	0	7	14	21	28	35	Means
Season 2014							
Water only (control)	10.50 pqr	11.43 no	13.93 def	15.13 abc	13.23 f-j	9.73 s	12.33 BC
2000 ppm potassium silicate (KSi)	11.10 opq	10.83 o-r	12.87 h-l	13.70 efg	14.10 de	12.10 lmn	12.45 ABC
3000 KSi	11.00 o-r	11.04 opq	12.03 mn	13.70 efg	14.53 cd	12.23 klm	12.42 ABC
2% calcium chloride ($CaCl_2$)	10.50 pqr	11.10 opq	13.03 g-j	13.50 e-h	15.77 ab	12.27 klm	12.69 A
4% $CaCl_2$	10.27 rs	10.93 o-r	12.80 h-l	13.27 f-i	15.83 a	12.50 j-m	12.60 AB
1% chitosan (Chit)	10.77 o-r	11.07 opq	12.17 klm	12.73 i-m	15.50 ab	12.23 klm	12.41 ABC
1% Chit + 2000 KSi	10.40 qr	11.10 opq	12.50 j-m	12.77 h-m	15.07 bc	12.03 mn	12.31 BC
1% Chit + 3000 KSi	10.93 o-r	10.93 o-r	12.17 klm	12.87 h-l	14.00 de	12.67 i-m	12.26 C
1% Chit + 2% $CaCl_2$	10.50 pqr	10.97 o-r	11.23 op	12.70 i-m	15.33 ab	12.93 h-k	12.28 C
1% Chit + 4% $CaCl_2$	10.73 o-r	10.87 o-r	11.43 no	12.83 h-l	14.63 cd	13.03 g-j	12.26 C
Means	10.67 F	11.03 E	12.42 C	13.32 B	14.80 A	12.17 D	
Season 2015							
Water only (control)	10.70 t-w	11.23 q-v	12.93 i-m	16.33 a	12.30 lmn	11.37 p-u	12.48 B
2000 ppm potassium silicate (KSi)	11.30 q-u	11.87 n-q	13.17 g-k	13.47 c-j	14.23 bc	13.30 e-j	12.89 A
3000 KSi	10.87 s-w	11.30 q-u	13.23 f-k	14.03 b-f	14.07 b-e	13.43 d-j	12.82 A
2% calcium chloride ($CaCl_2$)	10.70 t-w	11.47 o-t	13.27 e-j	13.87 b-g	14.30 b	13.67 b-i	12.88 A
4% $CaCl_2$	10.47 vw	11.47 o-t	12.93 i-m	13.80 b-g	14.30 b	14.03 b-f	12.83 A
1% chitosan (Chit)	10.63 uvw	11.50 o-s	12.87 j-m	13.87 b-g	14.30 b	13.17 g-k	12.72 AB
1% Chit + 2000 KSi	10.60 uvw	11.07 r-w	12.47 k-n	13.30 e-j	13.90 b-g	13.77 b-h	12.52 B
1% Chit + 3000 KSi	11.13 q-w	11.87 n-q	12.10 nop	12.87 j-m	13.17 g-k	13.63 b-j	12.46 B
1% Chit + 2% $CaCl_2$	10.37 w	11.80 n-r	12.27 lmn	13.43 d-j	13.73 b-h	13.53 b-j	12.52 B
1% Chit + 4% $CaCl_2$	10.60 uvw	11.10 q-w	12.20 mno	13.00 h-l	14.13 bcd	13.87 b-g	12.48 B
Means	10.74 E	11.47 D	12.74 C	13.80 A	13.84 A	13.38 B	

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

The effect of coating treatments in maintaining TA and reducing the accumulation of TSS and TSS/TA ratio of mango fruit was probably due to an premium semi permeable membrane around the fruit, modulate the internal atmosphere by reducing oxygen and elevating carbon dioxide, slowing down of respiration, suppressing ethylene production rates and metabolic activity. Hence retarding the ripening process (Singh et al.., 2007, Wang et al.., 2007, Abbasi et al., 2009, Zhu et al., 2008, De S. Medeiros et al., 2012, Hong et al., 2012, Yu et al., 2012, Elsabee & Abdou, 2013 and Shi et al., 2013). Therefore, treated mango fruits with chitosan, potassium silicate and calcium chloride coatings especially treated with the combination treatments appeared to inhibited the metabolic processes, thus delayed the reduction in TA content and constricted changing rate of TSS content of mango fruits during storage.

Also, the higher increment of mango fruits content in TSS with the progress of storage period could be attributed to hydrolysis of carbohydrates to sugars because of moisture loss and decrease in acidity (Golding et al., 2005). In addition, the reduction in fruit acidity content due to the conversion of citric acid into sugars and their further utilization in metabolic process of the fruits, Doreyappy-Gowda & Huddar, 2001 and Rathore et al., 2007).

These results are in line with those obtained by Chitarra et al. (2001), Kittur et al. (2001), Singh et al. (2007), Wang et al. (2007), Zhu et al. (2008), Abbasi et al. (2009) and Hojo et al. (2009) on mango fruits. They mentioned that, chitosan, KSi and $CaCl_2$ maintained TA content and reduced TSS and TSS/TA ratio of fruit during storage. Moreover, they reported that, fruit content in TA gradually and significantly declined, while TSS and TSS/TA ratio gradually and significantly increased with the progress of cold storage period.

TABLE 8. Effect of pre-harvest coating treatments on titratable acidity content (g citric acid/100 ml juice) of 'Zibda' mango fruits during storage at 13°C plus 3 days shelf life at 22-28°C

Pre-harvest coating treatments	Storage period (days) 0	7	14	21	28	35	Means
				Season 2014			
Water only (control)	1.43 b	0.96 fgh	0.77 j-n	0.62 rst	0.56 tu	0.44 v	0.80 D
2000 ppm potassium silicate (KSi)	1.26 c	1.03 f	0.89 hi	0.75 k-o	0.67 o-r	0.55 tu	0.86 C
3000 KSi	1.43 b	1.01 fg	0.82 ijk	0.73 l-q	0.68 n-r	0.51 uv	0.86 C
2% calcium chloride ($CaCl_2$)	1.51 a	0.98 fg	0.82 ijk	0.71 m-q	0.68 n-r	0.58 stu	0.88 C
4% $CaCl_2$	1.56 a	1.16 de	0.99 fg	0.75 k-o	0.65 p-s	0.57 tu	0.95 B
1% chitosan (Chit)	1.43 b	0.94 gh	0.83 ij	0.74 k-p	0.65 qrs	0.51 uv	0.85 C
1% Chit + 2000 KSi	1.55 a	1.22 cd	0.99 fg	0.77 j-n	0.74 k-p	0.53 u	0.97 AB
1% Chit + 3000 KSi	1.57 a	1.24 c	0.99 fg	0.81 i-l	0.74 k-o	0.58 stu	0.99 A
1% Chit + 2% $CaCl_2$	1.56 a	1.11 e	0.89 hi	0.79 j-m	0.71 m-q	0.62 rst	0.95 B
1% Chit + 4% $CaCl_2$	1.57 a	1.21 cd	1.00 fg	0.79 j-m	0.75 k-o	0.62 rst	0.99 A
Means	1.49 A	1.09 B	0.90 C	0.74 D	0.68 E	0.55 F	
				Season 2015			
Water only (control)	1.45 b	1.08 d-g	0.84 m-p	0.65 r	0.40 vw	0.33 w	0.79 C
2000 ppm potassium silicate (KSi)	1.28 c	0.95 ijk	0.91 j-n	0.87 k-o	0.62 rs	0.44 uv	0.84 B
3000 KSi	1.42 b	1.07 efg	0.92 j-m	0.75 q	0.63 rs	0.44 uv	0.87 B
2% calcium chloride ($CaCl_2$)	1.46 b	1.08 d-g	0.86 l-p	0.82 opq	0.57 rst	0.40 vw	0.87 B
4% $CaCl_2$	1.41 b	1.06 fg	0.95 ijk	0.78 pq	0.57 rst	0.46 uv	0.87 B
1% chitosan (Chit)	1.45 b	1.01 ghi	0.96 hij	0.83 opq	0.52 tu	0.47 uv	0.87 B
1% Chit + 2000 KSi	1.56 a	1.30 c	1.09 d-g	0.83 nop	0.59 rst	0.43 v	0.97 A
1% Chit + 3000 KSi	1.59 a	1.29 c	1.11 def	0.82 opq	0.55 st	0.46 uv	0.97 A
1% Chit + 2% $CaCl_2$	1.58 a	1.15 de	1.09 d-g	0.94 i-l	0.58 rst	0.44 uv	0.96 A
1% Chit + 4% $CaCl_2$	1.59 a	1.16 d	1.04 fgh	0.92 j-m	0.65 r	0.46 uv	0.97 A
Means	1.48 A	1.12 B	0.98 C	0.82 D	0.57 E	0.43 F	

Means followed by the same letters within pre-harvest coating 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 pre-harvest coating treatments on total soluble solids/titratable acidity ratio of 'Zibda' mango fruits during storage at 13°C plus 3 days shelf life at 22-28°C

Pre-harvest coating treatments	Storage period (days) 0	7	14	21	28	35	Means
				Season 2014			
Water only (control)	7.35 vwx	11.90 pqr	18.14 j-m	24.63 a	24.02 a-d	21.98 b-g	18.00 A
2000 ppm potassium silicate (KSi)	8.85 t-x	10.57 p-u	14.61 no	18.40 j-m	21.26 e-i	22.10 a-g	15.96 BC
3000 KSi	7.73 vwx	10.98 p-u	14.72 no	18.89 i-l	21.39 d-i	23.90 a-d	16.27 BC
2% calcium chloride ($CaCl_2$)	6.99 wx	11.41 p-t	15.91 mn	19.18 h-l	23.20 a-e	21.67 b-h	16.39 BC
4% $CaCl_2$	6.58 x	9.42 r-w	12.89 op	17.74 klm	24.27 ab	22.18 a-g	15.51 CD
1% chitosan (Chit)	7.55 vwx	11.75 pqr	14.64 no	17.31 klm	23.96 a-d	24.22 abc	16.57 B
1% Chit + 2000 KSi	6.73 x	9.12 s-x	12.61 op	16.62 lmn	20.51 f-j	22.57 a-f	14.69 DE
1% Chit + 3000 KSi	6.95 wx	8.81 u-x	12.37 opq	15.85 mn	18.86 i-l	21.99 b-g	14.14 E
1% Chit + 2% $CaCl_2$	6.73 x	9.87 q-v	12.63 op	16.08 mn	21.59 c-h	20.99 e-i	14.65 DE
1% Chit + 4% $CaCl_2$	6.84 wx	8.98 s-x	11.46 p-s	16.26 mn	19.65 g-k	21.15 e-i	14.06 E
Means	7.23 E	10.28 D	14.00 C	18.09 B	21.87 A	22.27 A	
				Season 2015			
Water only (control)	7.40 uvw	10.37 p-t	15.38 i-l	25.23 f	31.03 c	34.47 a	20.64 A
2000 ppm potassium silicate (KSi)	8.88 s-w	12.59 m-p	14.53 j-m	15.49 i-l	23.14 fg	30.25 c	17.48 B
3000 KSi	7.70 uvw	10.62 p-t	14.36 j-m	19.09 h	22.46 g	30.69 c	17.49 B
2% calcium chloride ($CaCl_2$)	7.38 uvw	10.61 p-t	15.45 i-l	16.99 hi	24.95 f	33.96 ab	18.22 B
4% $CaCl_2$	7.43 uvw	10.86 p-t	13.68 k-n	17.79 hi	25.35 f	30.78 c	17.65 B
1% chitosan (Chit)	7.36 uvw	11.35 n-s	13.38 l-o	16.80 ij	27.50 e	27.83 de	17.37 B
1% Chit + 2000 KSi	6.78 vw	8.58 t-w	11.46 n-r	16.05 ijk	23.78 fg	32.21 bc	16.48 C
1% Chit + 3000 KSi	6.99 vw	9.18 r-v	10.96 o-t	15.64 i-l	23.88 fg	29.91 cd	16.09 C
1% Chit + 2% $CaCl_2$	6.56 w	10.29 p-t	11.22 o-s	14.35 j-m	23.57 fg	31.15 c	16.19 C
1% Chit + 4% $CaCl_2$	6.68 vw	9.57 q-u	11.77 n-q	14.17 klm	21.87 g	29.99 cd	15.67 C
Means	7.32 F	10.40 E	13.22 D	17.16 C	24.75 B	31.12 A	

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

Fruit ascorbic acid content

Data shown in Table 10 illustrated that, ascorbic acid content of mango fruits gradually and significantly declined with prolonging of storage period of both experimental seasons in this study. The rapid reduction of mango fruit content in ascorbic acid during storage is associated with the fast senescence of fruits (Abbasi et al., 2009).

Moreover, data also demonstrated that, all pre-harvest coating treatments significantly reduced the deterioration mango fruit content in ascorbic acid during storage in both seasons in this study as compared to untreated fruits (control). The highest ascorbic acid content was observed in fruits treated with the combination coating.

Data also cleared that, there was a significant interaction among treatments and storage periods for ascorbic acid content of mango fruits during the two seasons in this work.

Coating treatments served as a protective layer and controlled the permeability of oxygen and carbon dioxide, thus led to change the internal atmosphere of the fruits, which delayed the metabolic processes and consequently retarded fruit senescence. Thereby delayed the deteriorative oxidation reaction of ascorbic acid (Anderson et al., 2005; Wang et al., 2007; Zhu et al., 2008; Abbasi et al., 2009; Tesfay et al., 2011; De S. Medeiros et al., 2012; Hong et al., 2012; Yu et al., 2012; Salazar & Serrano, 2013; Shi et al., 2013; Wang et al., 2014 and Kumari et al., 2015). Analogously, calcium may regulate respiration and other metabolic process of fruits (Chitarra et al., 2001 and Singh et al., 2007). Therefore, treated mango fruit with chitosan, potassium silicate and calcium chloride coatings especially in combination treatments could be inhibited the metabolic processes and delayed the declined in ascorbic acid content of mango fruits during storage. Moreover, the loss in ascorbic acid content during storage could be attributed to the increase in ascorbate oxidase activity and conversion of L-ascorbic acid into dihydro-ascorbic acid (Cardello & Cardello, 1998 and Davey et al., 2000).

TABLE 10. Effect of pre-harvest coating treatments on ascorbic acid content (mg/100 ml juice) of 'Zibda' mango fruits during storage at 13°C plus 3 days shelf life at 22-28°C

Pre-harvest coating treatments	Storage period (days)						
	0	7	14	21	28	35	Means
				Season 2014			
Water only (control)	62.88 a	54.20 d	46.80 ef	38.17 l-q	21.13 u	19.57 u	40.46 D
2000 ppm potassium silicate (KSi)	59.58 abc	53.80 d	46.77 ef	41.00 jkl	32.26 st	30.89 t	44.05 C
3000 KSi	61.23 a	54.60 d	42.47 g-k	38.83 k-o	36.11 n-s	34.79 qrs	44.67 C
2% calcium chloride ($CaCl_2$)	61.05 a	55.60 d	45.25 f-i	39.33 j-n	35.01 p-s	34.19 rst	45.07 BC
4% $CaCl_2$	60.13 abc	53.20 d	45.50 fgh	40.17 j-m	34.82 qrs	34.12 rst	44.66 C
1% chitosan (Chit)	60.87 a	55.40 d	46.12 efg	40.83 j-m	34.09 rst	32.79 st	45.02 BC
1% Chit + 2000 KSi	61.05 a	55.20 d	49.67 e	42.67 g-j	38.59 l-p	34.46 q-t	46.94 A
1% Chit + 3000 KSi	60.13 abc	56.60 cd	49.37 e	45.50 fgh	37.17 m-r	33.26 st	47.01 A
1% Chit + 2% $CaCl_2$	60.32 ab	57.00 bcd	47.42 ef	41.83 h-l	37.19 m-r	33.92 rst	46.28 AB
1% Chit + 4% $CaCl_2$	59.77 abc	56.60 cd	45.30 f-i	41.67 i-l	39.52 j-n	35.46 o-s	46.38 AB
Means	60.70 A	55.22 B	46.46 C	41.00 D	34.59 E	32.34 F	
				Season 2015			
Water only (control)	67.37 a	51.72 c	41.07 ghi	38.93 g-l	23.57 p	20.67 p	40.55 C
2000 ppm potassium silicate (KSi)	70.10 a	52.07 bc	43.27 efg	41.80 f-i	38.50 g-m	23.33 p	44.84 B
3000 KSi	69.30 a	56.87 b	41.43 f-i	39.97 g-k	38.50 g-m	31.67 o	46.29 AB
2% calcium chloride ($CaCl_2$)	71.13 a	55.00 bc	41.43 f-i	40.70 ghi	37.80 h-n	22.67 p	44.79 B
4% $CaCl_2$	68.63 a	53.50 bc	41.77 f-i	39.80 g-k	34.97 k-o	32.00 o	45.11 B
1% chitosan (Chit)	67.90 a	50.70 cd	42.47 e-h	40.77 ghi	39.73 g-l	33.27 no	45.81 AB
1% Chit + 2000 KSi	68.63 a	54.70 bc	47.00 de	39.60 g-l	37.13 i-n	35.33 j-o	47.07 A
1% Chit + 3000 KSi	69.93 a	54.27 bc	46.13 ef	40.33 g-j	38.13 g-n	34.73 l-o	47.26 A
1% Chit + 2% $CaCl_2$	70.97 a	53.40 bc	43.27 efg	41.37 f-i	40.17 g-j	33.33 no	47.08 A
1% Chit + 4% $CaCl_2$	71.17 a	53.57 bc	42.97 e-h	41.37 f-i	39.83 g-k	33.67 mno	47.09 A
Means	69.51 A	53.58 B	43.08 C	40.46 D	36.83 E	30.07 F	

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

These results are supported by the findings of Chitarra et al. (2001), Kittur et al. (2001), Singh et al. (2007), Wang et al. (2007), Zhu et al. (2008) and Abbasi et al. (2009) on mango fruits. Moreover these results are in agreement with those mentioned by Chien et al. (2007) on citrus fruits. Also, these results are in harmony with those obtained by Fatma-Shaaban (2006), El-Badawy (2007) and Hong et al. (2012) on guava and mango fruits. They mentioned that, chitosan, KSi and $CaCl_2$ succeeded in maintaining fruit ascorbic acid content during storage. Moreover, they added that, ascorbic acid content fruit gradually and significantly declined with the progress of storage period.

Conclusion

The present study illustrated that, pre-harvest coating of chitosan, potassium silicate and calcium chloride especially combinations treatments as applications are the promising strategy for the management postharvest fruit quality of mangoes cv. 'Zibda' during storage at 13°C and increased its storage life up to five weeks.

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محمود على أحمد محمد* ، أحمد فتحي عبد الخالق وحسن جابر المحرات*****
*معهد بحوث البساتين - مركز البحوث الزراعية ، **قسم البساتين - كلية الزراعة - جامعة طنطا
و***المعمل المركزي للزراعة العضوية - مركز البحوث الزراعية - القاهرة - مصر.

تم دراسة تأثيرات معاملات الشيتوزان أو سليكات البوتاسيوم أو كلوريد الكالسيوم على القدرة التخزينية لثمار المانجو صنف زبده خلال موسمي 2014 و2015. عوملت ثمار المانجو قبل الحصاد بأسبوعين بأي من الشيتوزان بتركيز 1 % أو سليكات البوتاسيوم بتركيز 2000 أو 3000 جزء في المليون أو كلوريد الكالسيوم بتركيز 2 أو 4 % بصوره منفردة أو الشيتوزان مشتركاً مع المعاملات الأخرى أو بالماء فقط (كنترول). تم رش أشجار المانجو بهذه المعاملات قبل الحصاد المتوقع بأسبوعين. تم حصاد الثمار بعد أسبوعين من المعاملات السابقة ونقلت إلى المعمل حيث تم غسيلها وتجفيفها بالهواء باستخدام المراوح لمدة ساعة ثم تم تعبئتها وتخزينها على درجة 13 مئوية ± 1 ورطوبة نسبية 85 إلى 90 % لمدة خمسة أسابيع. تم اخذ عينات دورية من الثمار عند الحصاد وكل أسبوع أثناء التخزين لتقييم جودة الثمار وكذلك قدرتها التخزينية. أوضحت هذه الدراسة أن معاملة ثمار المانجو صنف زبده بأي من المعاملات المدروسة كان له تأثيرا إيجابياً على تقليل التدهور في الخصائص الفيزيائية والكيماوية التي تحدث للثمار بعد الحصاد. كما أكدت هذه الدراسة على أن استخدام المعاملات المشتركة كانت أكثر فعالية في تحقيق هذا الهدف وذلك مقارنة بالثمار المعاملة بصوره منفردة أو الثمار غير المعاملة (كنترول). أوضحت هذه الدراسة أيضاً أن استخدام المعاملات المشتركة من الشيتوزان بتركيز 1 % مع سليكات البوتاسيوم بتركيز 2000 أو 3000 جزء في المليون أو كلوريد الكالسيوم بتركيز 2 أو 4 % قبل الجمع بأسبوعين من الطرق الواعدة للمحافظة علي جودة ما بعد الحصاد وزيادة القدرة التخزينية لثمار المانجو صنف زبده لمدة تصل إلي خمسه أسابيع علي درجة 13 مئوية ورطوبة نسبية 85 إلى 90 %.