Improving Fruit Quality of Mango Fruits cv. Zebda by Coating with Moringa and Green Tea Leaves Extracts under cold Storage

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ABSTRACT

This investigation aims to study the effect of moringa and green tea leaves extracts as naturally substance coating materials on fruit quality attributes of mature mango fruits cv. Zebda under cold storage periods of 2,4 and 6 weeks. A solution of 2.5, 5 and 10% of both moringa (Moringa oleifera) and green tea (Camellia sinensis) leaves extracts were prepared form 6 treatments beside the control. Mango fruit samples were harvested and randomly taken on mature stage (mid-August) then coated by extracts during two successive seasons. The treatments were as follows i.e., Moringa extract 2.5%, 5%, and 10%; Green Tea extract 2.5%, 5%, and 10%; plus the control (untreated fruits). The results showed that all treatments has a positive effect on reducing fruit weight loss %, fruit decay %, total acidity %, lipid peroxidation (MDA) content and increased T.S.S, T.S.S./acid ratio, vitamin C, antioxidant activity % (DPPH), PAL enzyme activity and total phenols content compared with the control. Moringa leaves extract 10% was the recommended treatment followed by green tea leaves extract 5% were improved high fruit quality of mango cv. Zebda under the cold storage periods (2, 4 and 6 weeks) during the two consecutive seasons of this research. During the cold storage period of 6 weeks of fruit storage, it was expected a high percentage of fruit weight loss and fruit decay occur and this period (6 weeks) is indicator for the maximum of oxidative damage or lipid peroxidation (MDA). In this regard, the results showed that the anti-oxidative criteria (PAL, total phenols, antioxidant activity) were increased by all treatments and it explains how they could overcome oxidative damage or lipid peroxidation (MDA) than the untreated ones during the storage period.

Keywords: coating, fruit quality, storability, cold storage, lipid peroxidation (MDA), PAL enzyme, antioxidant activity, total phenols

Introduction

Mango (Mangifera indica L.) is one of the popular and favorite fruits not only in Egypt but also the worldwide. Mango is a climacteric fruit and ripen rapidly after harvest, therefor the fruits are harvested hard and green, but fully mature because after harvest the fruit exhibits high ethylene accumulation stimulating onset of ripening and CO₂ accumulation as a result of high rate of fruit respiration (Blakey et al., 2012). Unfortunately, the postharvest losses considered the main problem of mango and other tropical fruits (Adetunji et al., 2012) and these losses occur due to high rate of biological process as well as fruit diseases. Where, the mango fruits are damaged during the handling, transport and storage due to the rapid deterioration which is a serious trouble facing the producers. As a result, many types of postharvest fruit treatments have been used to reduce the postharvest losses and instead improve fruit quality and shelf life (Tesfay, 2016). Therefore, mango fruits need for coating to maintain their quality during pre-storage after fruit handling which includes sorting, grading and washing, (Tesfay, 2016). In addition, the coating of mango fruits using naturally extracted substances rich in antioxidants is very effective for reducing the postharvest losses as a result to their properties, since they supply the fruit with a barrier against external elements and therefore it increases the shelf life of fruits (Guilbert et al., 1996) as well as they extend the shelf life of fruits by reducing gas exchange, loss of water, flavours and aroma beside it decrease the solute migration towards the cuticle (Saltveit, 2001).

In the past, the coating had been used in the form of water–wax microemulsions to increase the brightness and the colour of fruits as well as to control the water loss and theses uses were limited.
Debeaufort et al., 1998). Today, the coating using natural extracted materials which are wealthy in antioxidants to offer protection against postharvest diseases as well as cold damage under storage and can improve also the fruit quality under cold storage (Nussinovitch and Lurie, 1995). Recently, the coating is prepared from naturally occurring renewable sources such as polysaccharides, proteins, lipids and composites which we can eat without disposing them. In this respect, many trials are used the coating in the form of polysaccharides (biopolymers) such as pectin, chitosan, alginate and pullulan (Shiekh et al., 2013, Li et al., 2017), as well as in the form of proteins such as gelatin (Yousef et al., 2015), and in the form of lipids such as insect or vegetables waxes like beeswax or carnauba and candelilla wax (Hagenmaier, 2000, Rhim and Shellhammer, 2005) and in the form of natural plant oils like oil of lemongrass, peppermint, fenugreek seeds and jasmine (Abd El-Moneim et al., 2015, Zaki et al., 2017), as well as in the form of resins such as a high-gloss, shellac and wood resin for citrus coating (Baldwin et al., 1999, Hagenmaier, 2000) or shellac, rosin, gum Arabic for mandarins coating (Ali et al., 2015) and in the form of plant substances extracts such as mango leaves extract (Yousef et al., 2015). The main coating methods used for fruits and the other food industry are dipping, spraying, brushing (Dhanapal et al., 2012, Valdés et al., 2015) to protect fruits from microbial growth and to prolong their shelf life as well as to improve their quality including the appearance, attributes, and their freshness of contents (Hassan et al., 2018).

Latterly, moringa and green tea leaves extracts can be used as natural coating materials since they characterized with high content of antioxidants. The phenolic compounds and antioxidant properties in the moringa leaves were determined as follows: 16.14 mg GAE g⁻¹ as total phenolic content, 5.57 mg QE g⁻¹ as total flavonoid contents, 1.36 mg TE g⁻¹ as free radical scavenging activity, and 3.05 mg TE g⁻¹ as ferric reducing antioxidant power (Karim et al., 2018). Furthermore, the tea leaves (Camellia sinensis) rich in polyphenolic compounds which have high antioxidant capacity and overall antimicrobial activity, therefore these properties of moringa and green tea attractive us to use them as coating materials (Martín-Diana et al., 2008, Dang and Swinny, 2008).

Until now, little is known about using moringa and green tea leaves extract as fruit coating materials and this study aimed to evaluate them for coating mango fruits due to their properties as naturally substances rich in antioxidants and can be reduced the rapid deterioration which caused the postharvest losses as well as to investigate their effect on improving fruit quality and stress tolerance during cold storage.

Materials and Methods

Plant materials and coating treatments:
Mango mature fruit cv Zebda were harvested and randomly taken on mid-August (mature-green stage) from 12 years old trees budded on Sokkary rootstock grown in sandy soil at 4 × 4 meters apart under drip irrigation system in National Research Centre (NRC) orchard at km 110 Cairo-Alex desert road, Nubaria district, El-Behira Governorate, Egypt during the two successive seasons of 2017 and 2018. Undamaged fruits, free from visual blemishes, uniform in shape, weight, color and firmness were harvested, packed and transported immediately to the Lab. The fruit samples were washed using tap water, air-dried and coated within seven treatments as follows:

T1 = Moringa extract 2.5%.
T2 = Moringa extract 5%.
T3 = Moringa extract 10%.
T4 = Green Tea extract 2.5%.
T5 = Green Tea extract 5%.
T6 = Green Tea extract 10%.
T7 = Control (untreated fruits).

Then the fruit of all treatments including the control store at 10°C and 90-95% RH for 2, 4 and 6 weeks’ cold storage periods.

Coating materials preparation and coating method:
The moringa and green tea extracts and coating method were prepared as follows:
The preparation of moringa extract:

20 g of young moringa leaves was mixed with 675 ml of 80% ethanol as suggested by (Makker and Becker, 1996). Then, the suspension was stirred using a homogenizer to help maximize the amount of the extract and the solution was filtered by wringing the extract using a mutton cloth and was re-filtered using No. 2 Whatman filter paper according to the method described by Culver et al., (2012). Then, the extract was diluted with distilled water to 10, 5 and 2.5%.

The preparation of green tea extract:

Aqueous extract of green tea at 10% (w/v) (Dried leaves powder from Lipton Company) was prepared by boiling 100 g of dried leaves powder in Liter water for 5 minutes. After cooling, the solution was squeezed powerfully by gauze mesh to obtain the concentration of green tea 10%. Then the solution is diluted into two concentrations 5% and 2.5% by boiling water for 5 minutes.

The trail coating method:

The method of mango fruit coating in this study is dipping where, the fruits were putted for 5 minutes in the solutions of the different concentration (2.5, 5, 10%) for both extracts of green tea and moringa individually according to (Valdés et al., 2015).

Data recorded:

A sample of thirty fruits for each treatment (3 replicates, ten fruits per replicate) was randomly taken after the tested cold storage periods (2, 4 and 6 weeks) and were used to determine the following parameters:

**Fruit weight loss% (FWL %):** the fruits were weighed before cold storage to obtain the initial weight, and then weighed after each period of cold storage periods (2, 4 and 6 weeks). FWL % were calculated according to the following equation:

\[ \text{FWL} \% = \left( \frac{W_i - W_s}{W_i} \right) \times 100 \]

Where, \( W_i \) = fruit weight at initial date, \( W_s \) = fruit weight at sampling date (Ibrahim and Gad, 2015).

**Fruit decay %:** it was determined as percentage of rotted fruits by various fungi (Gad et. al., 2016).

**Total soluble solids (T.S.S %):** a hand refractometer was used to determine T.S.S.in the fruits and results were expressed as Brix°.

**Total acidity %:** titratable acidity was determined according to the method in A.O.A.C (1990), where 10 ml of the extracted juice was diluted to 100 ml and titrated 0.1N NaOH to pH 8.1.

**T.S.S /acid ratio.**

**Vitamin C (mg/100 ml):** ascorbic acid was determined using phenol indophenol dye method A.O.A.C (1990). Where, 10 g of the fresh samples was blended with 3% metaphosphoric acetic acid extracting solution to homogenous slurry, 5 ml of the filtrate extract were than titrated with standard indophenol to pink end point.

**Phenylalanine ammonia-lyase (PAL) enzyme in fruit extract:** The activity of phenylalanine ammonia lyase (PAL) was estimated according to the method adopted by Beaudoin-Egan and Thorpe (1985). The activity of PAL is defined as the amount of enzyme forming 1 m mol of transcinnamicacid from the substrate phenylalanine per min. PAL is determined as µmol/g fruit fresh wt.

**Total phenols in fruit extract:** The total phenolics were determined by the Folin-Cicalteau method as described by Singleton et al. (1999), with minor modifications, based on colorimetric oxidation/reduction reaction of phenols. Polyphenols extraction was carried out by adding 10 ml methanol (85%) to 1g fine grind of mango tissue. 250 µl of sterile distilled water was added to 250 µl of extract, and then 2.5 ml of diluted Folin-Cicalteau reagent (10%) and 2 ml of 7.5% sodium carbonate were added. The samples were shaked for 1.5 to 2 hours. The absorbance of samples was measured at 765 nm by a PG Instruments ltd- T80+UV/VIS spectrophotometer. Gallic acid was used for calibration curve. Results were expressed as mg. gallic acid/ 100 g fw.

**Antioxidant activity % in fruit extract (Redical scavenging activity DPPH):** The antioxidant activity was measured by the scavenging of 2, 2-diphenyl-2- picrylhydrazyl hydrate (DPPH) radicals (Ismail et al. 2009; Orabi et al. 2016). In the presence of antioxidant, the purple color intensity of DPPH solution declined. The change of absorbance was detected using spectrophotometer (PG Instruments ltd – T80+ UV/VIS) at 517 nm. Briefly, a 0.15 mM methanolic solution of DPPH was prepared. 2 ml of this solution was added to 1 ml of methylic extracts of mango fruits. The control was prepared by adding
2 ml of DPPH to 1 ml methanol. The contents of the tubes were mixed and followed to stand for 30 min (under dark condition) and absorbance was measured at 517 nm. The antioxidant activity is expressed in the form of the percentage of free radical scavenging.

**Lipid peroxidation (MDA) in fruit extract:** Lipid peroxidation was determined by estimating the malondialdehyde (MDA) content as described by Dhindsa et al. (1982). MDA is defined as μmol/g fruit fresh wt.

**Statistical Analysis**
Data were analyzed by analysis of variance (ANOVA), and means were compared using Duncan’s test at p < 0.05 to determine the significance of differences between the conducted treatments (Duncan, 1955).

**Results and Discussion**

**The effect on fruit weight loss (%):**

Table (1) indicates the effect of moringa and green tea leaves extract as coating material on fruit weight loss (%) of mango cv. Zebda under the cold storage periods of 2.4 and 6 weeks during two seasons. It is cleared from the data that all coating treatments (T1-T6) reduced fruit weight loss% under the cold storage periods condition than the control (T7) which recorded the highest percentage of fruit weight loss % under the same cold storage periods of 2, 4 and 6 weeks and reached to 4.58, 4.87 and 5.93% in the first year, respectively and 5.26, 5.51 and 6.76% in the second year, respectively. Coating fruits with moringa 10% (T3) was the best treatment reduced the fruit weight loss % under all periods of the cold storage 2, 4 and 6 weeks during the two seasons of this study and achieved 1.48, 2.52 and 3.54% during the 1st season, respectively and 1.71, 2.85 and 4.04% during the 2nd season, respectively. The coating with green tea extract 5% (T5) came in the second order in reducing the fruit weight loss% under the different cold storage periods of 2, 4 and 6 weeks and recorded 1.61, 2.63 and 3.73% in the first season, respectively and 1.85, 2.97 and 4.25% in the second season, respectively. However, there was no significant deference in reducing fruit weight loss % between coating with moringa extract 5% (T2) and green tea extract 5% (T5) under 2 weeks’ cold storage.

The fruit weight loss % attributed to moisture loss which was higher in the control fruits than coated ones and the fruit moisture loss was consistently declining for all treatments during cold storage. It could also be due to the nature of coating properties, which is hydrophilic, and it displays less resistance to water loss (Kester & Fennema, 1986). Coatings significantly conserved water content (Mahmoud and Savello, 1992, Mahmoud and Savello, 1992 and Avena-Bustillos et al., 1997). Also, coating materials act as a physical barrier to loss of moisture, thus reducing dehydration and fruit shrinkage (Zivanovic et al., 2007).

Post-harvest weight changes in fruits are usually due to the loss of water through transpiration. This loss of water can lead to wilting and shriveling which both reduce a commodity’s marketability. Coatings can also offer a possibility to extend the shelf life by providing a semi-permeable barrier to gases and water vapor and therefore, they can reduce respiration, enzymatic browning and water loss (Guilbert, 1986, Baldwin et al. 1995). In this respect, natural substances in moringa and green tea extracts which rich in antioxidants had a role as an electron donor produces free radical which decrease normal respiration and transpiration as well as stomata closing (Manthe et al., 1992, Sartaj et al., 2013). Our results are in agreement with those of Adetunji et al. (2013) on Citrus Sinensis found that moringa as coating material caused a significant decrease in weight loss compared with uncoated ones. Furthermore, Apriyanti et al.(2018) confirmed that the addition of green tea extract on the chitosan film can reduce the rate of fruit shrinkage. The lowest shrinkage was obtained in strawberries with 3% incremental chitosan film of 2.5% green tea extract which reduced weight loss 55% lower than fruit without coating. In addition, Baldwin et al. (1999) reported that polysaccharide as well as carnauba wax coating of mango fruit under storage showed less weight loss than control fruit. Also, Abd El-Moneim et al., (2015) used natural materials i.e. lemongrass oil 0.25 and 0.50%, peppermint oil 5 and 10% and gelatin 1, 2 and 4% in coating of Zaghloul date palm under cold storage and reported that all treatments decreased the fruit weight loss % as compared to control. Lemongrass oil 50% tended to be the most effective one in this concern. In addition, Adetunji et al. (2012) found that coating of Aloe vera gel reduced weight loss % of pineapple under cold storage compared to the uncoated ones. Ali et...
al. (2015) stated that weight loss % of coated kinnows mandarin under cold storage were less than the uncoated ones. The loss of fruit weight is mainly caused by fruit transpiration in which water moves out and results in wilted rind and a shriveled appearance (Wills et al., 2007). While, Water transfer is restricted by coating that act as barriers and protect fruit skin, thus delaying dehydration (Hernandez-Munoz et al., 2008). Radi et al., (2017), reported that weight loss in uncoated orange fresh cuts was significantly greater than those of coated with green tea 5% and 10% during storage period.

The effect on fruit decay (%):

Table (2) shows the effect of moringa and green tea extracts related to coating substances on fruit decay% of mango cv, zebda under the cold storage periods 2,4 and 6 weeks during two seasons. Data point out that all coating treatments (T1-T6) decreased fruit decay % than the control (T7) which recorded the highest fruit decay % for all storage periods (10.57, 15.87 and 20.44% for 2, 4 and 6 weeks in the 1st season, respectively as well as 12.15, 17.93 and 23.51% in the 2nd season, respectively). T3 had the lowest fruit decay% under cold storage periods 2,4 and 6 weeks (4.52, 5.45 and 6.44% in the first year, respectively as well as 5.19, 6.16 and 7.40% in the second year) followed by T5 (4.77, 5.63 and 6.76% in the 1st year, respectively and 5.49, 6.36 and 7.78 % in the 2nd year, respectively).

Table 2: Effect of moringa and green tea leaves extract on fruit decay (%) of mango cv. Zebda during the cold storage.

| Treatments       | 2017 Cold storage periods | 2018 Cold storage periods |
|------------------|---------------------------|---------------------------|
|                  | 2 weeks | 4 weeks | 6 weeks | 2 weeks | 4 weeks | 6 weeks |
| T1= Moringa 2.5 %| 1.72     | 2.81    | 3.96    | 1.98     | 3.17    | 4.52    |
| T2= Moringa 5 % | 1.67     | 2.73    | 3.78    | 1.92     | 3.09    | 4.31    |
| T3= Moringa 10 %| 1.48     | 2.52    | 3.54    | 1.71     | 2.85    | 4.04    |
| T4= Green Tea 2.5 %| 1.85   | 2.93    | 4.16    | 2.13     | 3.31    | 4.74    |
| T5= Green Tea 5 %| 1.61     | 2.63    | 3.73    | 1.85     | 2.97    | 4.25    |
| T6= Green Tea 10 %| 1.77    | 2.90    | 4.02    | 2.03     | 3.27    | 4.59    |
| T7= Control     | 4.58     | 4.87    | 5.93    | 5.26     | 5.51    | 6.76    |

Means within a column followed by different letter (s) are statistically different at 5 % level

The reduction of fruit decay% by the coating of moringa and green tea extracts related to decreasing the activity of cell wall degrading enzymes that increase postharvest cycle and delay fruit ripening (Khademi and Ershadi, 2013). Also, fruit ethylene production could be effectively decreased by these treatments accompanied with cell swelling (Serrano et al., 2012) and inducing systemic resistances against postharvest pathogen which extend storability of fruits with higher antioxidant activity that activates natural defense mechanism (Muzammil et al., 2015). The results in the same trend of those reported by Baldwin et al. (1999) stated that polysaccharide as well as carnauba wax coating of mango fruit under storage appeared to reduce postharvest decay. In addition, Li (2017) found that the decay rate of control remained significantly higher than polysaccharide coated fruits (chitosan, alginate and pullulan-coated). Meanwhile, the decay rate of chitosan-coated fruits was significantly
lower than that of alginate-coated and pullulan-coated fruits. Furthermore, Abd El-Moneim et al., 2015 used natural materials i.e. lemongrass oil 0.25, 0.50%, peppermint oil 5, 10% and gelatin 1,2 and 4% in coating of Zaghoul date palm under cold storage and found that coated fruits with lemongrass oil recorded the lowest fruit decay percentages, followed by 10% peppermint oil treatment in both seasons.

The effect on total soluble solids (T.S.S%):

Table (3) presents the effect of moringa and green tea leaves extract on total soluble solids (T.S.S) of mango cv. Zebda during the cold storage periods of 2, 4 and 6 weeks. Data confirmed that all coating treatments (T1-T6) increased T.S.S during the different cold storage periods of 2,4 and 6 weeks. In this respect, T3 had the highest T.S.S between all treatments including the control (T7) which had the lowest T.S.S% (13.80, 14.19 and 15.12% for 2, 4 and 6 weeks in 1st season, respectively and 14.49, 14.90 and 15.90 % in 2nd season, respectively). While, T3 had 17.69, 18.87 and 20.93 % for 2, 4 and 6 weeks in 1st year, respectively and 18.58, 19.81 and 21.88 % in 2nd year, respectively). Whereas, T5 took the second place and had 16.97, 17.93 and 19.94 % for 2, 4, 6 weeks in 1st season, respectively as well as 17.82, 18.83 and 20.84 % in 2nd season, respectively. However, the other coating treatments recorded medium value of T.S.S during the cold storage periods.

Increasing T.S.S attribute to fruit weight loss and subsequently fruit juice concentration (Khademi and Ershadi, 2013). Where, the decreasing of sucrose synthesis in coating fruits may result in lowered enzyme activity that reduced ethylene production (Martínez-Esplá et al., 2017). In addition, the increase in TSS of all treatments might be due to the conversion of organic acids to sugars through gluconeogenesis (Echeverria and Ismail, 1987), and the solubilization of cell wall constituents by galactosidases and glucosidases present in the fruit (Burns, 1990). The effect of coating on soluble solid content was probably due to decrease the respiration and metabolic activity, for this reason it retards the ripening process, modifies the internal atmosphere through reducing O₂ and/or elevating CO₂ and suppressing ethylene evolution (Dong et al., 2004). Moreover, the higher levels of total soluble solids in the fruit coated with moringa and green tea leaves extract may be due to protective O₂ barrier reduction of oxygen supply on the fruit surface, which inhibited respiration (Yonemoto et al., 2002). It could be explaining the increase in total soluble solids by moringa and green tea leaves extract coating due to their influence in increasing photosynthetic pigment, which reflected on photosynthesis process and led to increase in carbohydrate content (Fayed, 2011).

### Table 3: Effect of moringa and green tea leaves extract on total soluble solids (T.S.S%) of mango cv. Zebda during the cold storage.

| Treatments  | 2017 Cold storage periods | 2018 Cold storage periods |
|-------------|---------------------------|---------------------------|
|             | 2 weeks | 4 weeks | 6 weeks | 2 weeks | 4 weeks | 6 weeks |
| T1= Moringa 2.5 % | 16.00 d | 16.76 c | 18.64 d | 16.80 d | 17.60 c | 19.48 d |
| T2= Moringa 5 % | 16.71 e | 17.63 b | 19.51 c | 17.54 c | 18.51 b | 20.39 c |
| T3= Moringa 10 % | 17.69 a | 18.87 a | 20.93 a | 18.58 a | 19.81 a | 21.88 a |
| T4= Green Tea 2.5 % | 15.49 f | 15.90 d | 18.23 e | 16.27 f | 16.69 d | 19.05 e |
| T5= Green Tea 5 % | 16.97 b | 17.93 b | 19.94 b | 17.82 b | 18.83 b | 20.84 b |
| T6= Green Tea 10 % | 15.73 e | 16.57 c | 18.41 de | 16.52 e | 17.40 c | 19.24 de |
| T7= Control | 13.80 g | 14.19 e | 15.12 f | 14.49 g | 14.90 e | 15.90 f |

Means within a column followed by different letter (s) are statistically different at 5 % level.

These results agree with the findings of Radi et al., (2017), who noticed that the maximum increase in T.S.S. of orange fresh cuts was observed in samples coated with 5 and 10% green tea extracts. Moreover, Shaarawi et al., (2013) reported that coated Keitt mango with gelatin 2% showed a significant delay in the changes of soluble solid content compared to uncoated ones.

Also, Youssef et al., (2015) how mentioned that navel orange fruit coated with chitosan 1% showed the highest value of T.S.S, followed by coating with mango leaves extract plus gelatin 2% during storage period. In addition, treatment with antioxidants of Le Conte pear fruit increased T.S.S through the progress of the storage periods (Hafez et al., 2010). Furthermore, Abd El-Moneim et al., 2015 used natural materials i.e. lemongrass oil 0.25 and 0.50%, peppermint oil 5 and 10% and gelatin 1,2 and 4%
in coating of Zaghoul date palm under cold storage and confirmed that peppermint oil 5 and 10%, control (tap water dipping) and gelatin 1% coated fruits had the highest TSS content during two seasons.

Contrarily, non-significant effect of different coatings on TSS was observed in ‘Sai Nam Pheung’ tangerines by Seehanam et al., (2010). Also, Ranjarban et al., (2011) on grapes observed that salicylic acid treatment as one of antioxidant substances had no effect on T.S.S. As well as, Ali et al., (2015) found that coating has no significant effect on the TSS of ‘kinnow’ mandarins during cold storage. Meanwhile, Youssef et al., (2015) found that navel orange fruit coated with chitosan 0.1% had the lowest value of T.S.S. compared with untreated fruit during two seasons. Furthermore, Li et al., (2017) mentioned that all polysaccharide-coated treatments of chitosan, pullulan and alginate decreased TSS during the cold storage. However, the control had the lower T.S.S. % than coated treatments.

The effect on total acidity (%):

It’s clear from data in Table (4) that all coating treatments (T1-T6) reduced total acidity than the control (T7) which achieved the highest total acidity % during cold storage periods of 2,4 and 6 weeks and had 2.27, 2.37 and 3.27 % in 1st season, respectively and 2.34, 2.43 and 3.37 % in 2nd season, respectively. In this concern, T3 was the best coating treatment in decreasing the total acidity (1.17, 1.13 and 1.07 % in 1st year and 1.21, 1.16 and 1.10 % in 2nd year) followed by T5 which had 1.26, 1.23 and 1.14 % in 1st season and 1.29, 1.26 and 1.18 % in 2nd season. However, there were no significant differences between T2, T3 and T5 under cold storage period of 2 weeks during the two seasons. The other coating treatments came in the middle order of reducing total acidity %.

The titratable acidity is directly related to the concentration of organic acids present in the fruits (Kays, 1997) and the decreasing trend in the fruit acidity with the increasing storage period might be due to the oxidation of organic acid and its further utilization in metabolic processes (Obenland et al., 2011). Also, the decline in total acidity was probably due to the slow rate of respiration and metabolic processes converting citric acid into sugars as a function of applied coating with antioxidant materials (Martínez-Esplá et al., 2017, and Chanikan et al., 2015).

Table 4: Effect of moringa and green tea leaves extract on total acidity (%) of mango cv. Zebda during the cold storage.

| Treatments   | 2017 Total acidity % | Cold storage days | 2018 Total acidity % | Cold storage days |
|--------------|-----------------------|-------------------|-----------------------|-------------------|
|              | 2 weeks | 4 weeks | 6 weeks | 2 weeks | 4 weeks | 6 weeks |
| T1= Moringa 2.5 % | 1.47 cd | 1.43 d | 1.35 c | 1.52 cd | 1.48 d | 1.39 c |
| T2= Moringa 5 % | 1.37 cde | 1.33 e | 1.24 d | 1.41 cde | 1.37 c | 1.28 d |
| T3= Moringa 10 % | 1.17 e | 1.13 g | 1.07 e | 1.21 e | 1.16 g | 1.10 e |
| T4= Green Tea 2.5 % | 1.84 b | 1.64 b | 1.55 b | 1.89 b | 1.69 b | 1.59 b |
| T5= Green Tea 5 % | 1.26 de | 1.23 f | 1.14 de | 1.29 de | 1.26 f | 1.18 de |
| T6= Green Tea 10 % | 1.57 c | 1.52 c | 1.44 c | 1.62 c | 1.57 c | 1.48 c |
| T7= Control | 2.27 a | 2.37 a | 3.27 a | 2.34 a | 2.43 a | 3.37 a |

Means within a column followed by different letter (s) are statistically different at 5 % level.

The results are in harmony with those of Radi et al., (2017) mentioned that the decreasing of total acidity reached to 38–40% was noticed in the coated samples with 10% green tea extract. In addition, Youssef et al., (2015) reported that navel orange fruit coated with chitosan 0.1% showed the minimum acid value after 60 days of storage followed by those coated with mango leaves extract plus gelatin at 2%, mango leaves extract, chitosan 0.5 % and chitosan 0.1 % during two successive seasons, however control fruits recorded the highest acid value compared with treated fruits. In addition, Jiang et al., (2005) reported that coating of litchi fruits with chitosan decreased the titratable acidity during storage period. Hafez et al., (2010) reported that total acidity of Le Conte pear fruits showed a slight reduction up to 45 days of cold storage and a gradual statistically decrease as storage period advanced for antioxidants treated compared with untreated. Furthermore, Lin et al., (2008) stated that ‘Yali’ pear coating with antioxidants and stored helped maintain titratable acidity compared with control. The reduction in acidity by antioxidants treatments could be attributed to its influence on increasing the tissue respiration and increasing ripening-associated activities. Also, Ali et al., (2015) reported that the acidity of mandarin decreased with the increasing storage period for all the coating treatments.
On the other hand, Seehanam at al., (2010) and Boonyakiat et al., (2012) found a non-significant decrease in the fruit acidity of waxed and unwaxed “Sai Nam Peung” tangerine fruit during storage. Moreover, Jitareerat et al., (2007) confirmed that the higher levels of titratable acidity in coated fruit with gelatin at 2%, 4%, 8% and control may be due to protective O2 barrier or reduction of O2 supply to the fruit surface which inhibited respiration rate. Also, Abd El-Moneim et al., (2015) used natural materials i.e. lemongrass oil 0.25 and 0.50%, peppermint oil 5 and 10% and gelatin 1,2 and 4% in coating of Zaghloul date palm under cold storage and found that all treatments increased the total acidity than the control during two years. In addition, Li et al., (2017) reported that total acidity in polysaccharide-coated fruits were significantly higher than those in the control during cold storage.

The effect on T.S.S/acid ratio:
Table (5) clears the effect of moringa and green tea extracts as coating substances on T.S.S/acid ratio of mango cv, zebda under the cold storage periods 2,4 and 6 weeks during two seasons. In this regard, T3 had the highest ratio between all treatments during the different cold storage periods and achieved 15.08, 16.70 and 19.56 in 1st year and 15.37, 17.02 and 19.85 in 2nd year compared with the control (7) which recorded the lowest ratio and had 6.14, 6.00 and 4.66 in 1st season and 6.26, 6.11 and 4.73 in 2nd season, respectively. T5 came in the second order and had 13.50, 14.62 and 17.44 in 1st year and 13.77, 14.90 and 17.70 in 2nd year, respectively. There were significant differences between the concentration of coating material. In this respect, T.S.S/acid ratio was increased during all cold storage periods by increasing moringa extract concentration from 2.5% to 5% or 10% (T1, T2 and T3). However, medium concentration of green tea extract (T5) had the high T.S.S/acid ratio between all green tea treatments.

Our results agree with those of Sartaj et al., (2013) who found that antioxidant treatments were effective in retaining keeping quality of apricot especially T.S.S/acid ratio up to 12 days at ambient storage.

Table 5: Effect of moringa and green tea leaves extract on T.S.S/acid ratio of mango cv. Zebda during the cold storage.

| Treatments          | 2017                | 2018                |
|---------------------|---------------------|---------------------|
|                     | T.S.S /acid ratio   | T.S.S /acid ratio   |
|                     | 2 weeks  | 4 weeks  | 6 weeks  | 2 weeks  | 4 weeks  | 6 weeks  |
| T1= Moringa 2.5 %   | 10.91 d  | 11.70 d  | 13.78 d  | 11.12 d  | 11.92 d  | 13.98 d  |
| T2= Moringa 5 %     | 12.19 c  | 13.25 c  | 15.74 c  | 12.43 c  | 13.51 c  | 15.97 c  |
| T3= Moringa 10 %    | 15.08 a  | 16.70 a  | 19.56 a  | 15.37 a  | 17.02 a  | 19.85 a  |
| T4= Green Tea 2.5 % | 8.45 f   | 9.67 f   | 11.79 f  | 8.61 f   | 9.86 f   | 11.96 f  |
| T5= Green Tea 5 %   | 13.50 b  | 14.62 b  | 17.44 b  | 13.77 b  | 14.90 b  | 17.70 b  |
| T6= Green Tea 10 %  | 10.00 e  | 10.88 e  | 12.82 e  | 10.19 e  | 11.09 e  | 13.00 e  |
| T7= Control         | 6.14 g   | 6.00 g   | 4.66 g   | 6.26 g   | 6.11 g   | 4.73 g   |

Means within a column followed by different letter (s) are statistically different at 5 % level.

The effect on vitamin C content:
It’s noticed from Table (6) that all coating treatments (T1-T6) effected on vitamin C content of, zebda mango fruits under the cold storage periods of 2,4 and 6 weeks than the control (T7) during two years. The high content of vitamin C was achieved by T3 (39.73, 42.49 and 44.23 mg in 1st year and 40.23, 43.48 and 44.78 mg in 2nd year, respectively) followed by T5 (38.75, 41.10 and 42.86 mg in 1st season and 39.23, 41.61 and 43.40 mg in 2nd season, respectively) and the other coating treatments had medium content of vitamin C. While, the control (T7) had the lowest content of vitamin C (27.09, 28.79 and 29.76 mg in 1st year and 27.43, 29.15 and 30.13 mg in 2nd year, respectively). The concentration of coating materials effected on vitamin C during the cold storage period of 2, 4 and 6 weeks. In this respect, significant differences were found between the moringa extract treatments (T1, T2 and T3). Since, increase the concentration of moringa extract increased content of vitamin C during all cold storage periods. While, the medium concentration of green tea extract (T5) recorded the highest content of vitamin C during the cold storage periods between all green tea treatments (T4, T5 and T6) which were differed significantly in their effect. Ascorbic acid (vitamin C) is lost due to the activities of phenol oxidase and ascorbic acid oxidase enzymes during storage (Salunkhe et al., 1991). Also, Ascorbic acid
is highly sensitive to oxygen and is readily oxidized when exposed to it (Hossain et al., 2006). Coatings create a modified atmosphere and limit the exchange of gases thus reducing the amount of oxygen reaching to the interior of fruit that prevents the oxidation of ascorbic acid (Baldwin et al., 1999). Moringa and green tea extracts as antioxidant coating treatments were effective in reducing the vitamin C loss in mango fruits during all periods of storages due to its low oxygen permeability which reduced the activity of the enzymes and prevented oxidation of vitamin C.

These findings are in parallel with Adetunji et al. (2012) on Ananas Comosus (L.) and Adetunji et al. (2013) on Citrus Sinensis who mentioned that the reduction of vitamin C loss in coated fruits related to the low oxygen permeability of coating materials which lowered the activity of the enzymes and prevented oxidation of ascorbic acid. Also, Lu et al. (2011) reported that antioxidant treatments delayed the decline of ascorbic acid (vitamin C) content and prevented its destruction, so these treatments improve the fruit quality. Also, these results are in agreement with the previous findings of studies which found that the ascorbic acid contents of orange fresh cut coated with green tea 10% (Radi et al., 2017) as well as waxed and unwaxed tangerines (Arekemase and Oyejiola, 2011) and kinnow mandarin fruits (Mahajan et al., 2005, Mahajan et al., 2013) decreased during storage at low temperature and the coated fruits had higher ascorbic acid contents than the uncoated ones. Similarly, Youssef et al., (2015) confirmed that navel orange fruit coated with chitosan 1% had the maximum value of ascorbic acid followed by fruits coated with mango leaves extract plus 2% gelatin, then fruits coated with mango leaves extract followed by fruits coated with chitosan 0.5%, while untreated fruit recorded the minimum value of ascorbic acid content. Also, Li et al., (2017) reported that vitamin C in polysaccharide-coated fruits were significantly higher than those in the control under cold storage.

On the other hand, Ali et al., (2015) found that a gradual decline in vitamin C content of kinnow mandarin was noticed for coated treatments as compared to the control.

Table 6: Effect of moringa and green tea leaves extract on vitamin C of mango cv. Zebda during the cold storage.

| Treatments   | 2017 Cold storage periods | 2018 Cold storage periods |
|--------------|---------------------------|---------------------------|
|              | 2 weeks       | 4 weeks | 6 weeks | 2 weeks       | 4 weeks | 6 weeks |       |
| T1 = Moringa 2.5 % | 36.82 d       | 37.96 d | 39.55 b | 37.28 d       | 38.43 d | 40.05 b |       |
| T2 = Moringa 5 %  | 37.87 c       | 39.49 c | 40.57 b | 36.44 e       | 39.98 c | 41.07 b |       |
| T3 = Moringa 10 % | 39.73 a       | 42.94 a | 44.23 a | 40.23 a       | 43.48 a | 44.78 a |       |
| T4 = Green Tea 2.5 % | 34.63 f       | 35.73 e | 36.53 d | 35.26 f       | 36.18 e | 36.90 d |       |
| T5 = Green Tea 5 %  | 38.75 b       | 41.10 b | 42.86 a | 39.23 b       | 41.61 b | 43.40 a |       |
| T6 = Green Tea 10 % | 35.99 e       | 36.49 e | 38.06 d | 36.44 e       | 36.95 e | 38.53 e |       |
| T7 = Control     | 27.09 g       | 28.79 f | 29.76 e | 27.43 g       | 29.15 f | 30.13 e |       |

Means within a column followed by different letter (s) are statistically different at 5 % level.

The effect on PAL enzyme:

Table (7) shows the influence of moringa and green tea leaves extract as coating materials on PAL enzyme and total phenols in mango cv. Zebda at the end of cold storage period (after 6 weeks). Concerning the PAL enzyme, phenylalanine ammonia-lyase (PAL) is known as the principal enzyme of the phenylpropanoid pathway (Kacperska, 1993) which catalyze the transformation of L-phenylalanine into trans-cinnamic acid by deamination and it is also considered as the prime intermediary in the phenolic biosynthesis (Levine et al., 1994). Many authors considered this enzyme as one of the main lines of cell acclimation against stress (Kacperska, 1993; Leyva et al.,1995 and Orabi and Abdelhamid, 2016) because plants could accumulate phenolic substances as a result to oxidative stress (Rivero et al., 2001; Ali et al.,2007). In this respect, all treatment achieved high PAL content in the fruits after 6 weeks of cold storage through the two studied seasons (ranged from 9.64 to 12.58 μmol/g fruit fresh wt. in the 1st season and from 9.69 to 12.65 μmol/g fruit fresh wt. in the 2nd season) compared with the control which gave the lowest PAL content and had 8.38 and 8.42 μmol/g fruit fresh wt. during the two years, respectively. T3 had the highest content of PAL and recorded 12.58 and 12.65 μmol/g fruit fresh wt. during two seasons, respectively, followed by T5 which had 11.87 and 11.93 μmol/g fruit fresh wt. in the two studied years, respectively.
In this regard, it could explain the results due to the synthesis of polyphenolic phytotoxins increased the activity of phenylalanine ammonia lyase (PAL) which added to the low activity of polyphenol oxidase (PPO) that reduced the oxidation of phenolic substrates to quinones (Lattanzio et al., 2009). These results confirmed with Tesfay (2016) who studied the efficacy of combined application of edible coating and moringa extract in enhancing fruit quality of avocado under cold storage at 5.5°C for 21 days and found that the moringa 2% as well as carboxymethyl cellulose 1% with moringa 2% had the least PPO activity amongst the treatments. In addition, Soysal (2009) confirmed that the green tea extract had significant effect on the inhibition of apple PPO. Addition of 30 mg/mL green tea extract resulted in approximately 42% inhibition on apple PPO.

In contrast, the effect of antioxidants (salicylic acid) on the fruit quality of pineapple during cold storage inhibited the activities of phenylalanine ammonia lyase (Lu et al., 2011).

The effect on total phenols:

Table (7) presents that all treatments increased total phenols content in fruits after 6 weeks’ cold storage (0.71- 1.19 mg/g fruit fresh wt. in 1st year and 0.81-1.37 mg /g fruit fresh wt. in 2nd year, respectively) than the control which gave the lowest content (0.62 and 0.71 mg/g fruit fresh wt. during the two seasons). In this regard, T3 gave the highest content of total phenols in fruits (1.19 and 1.37 mg/g fruit fresh wt. during the two years) followed by T5 (1.04 and 1.20 mg /g fruit fresh wt. during the two seasons).

The results can be interpreted the coated fruits with moringa and green tea extracts overcame the chilling injury under the cold storage period till to 6 weeks due to increase the synthesis of phenolic substances which is enhanced as a result to response of fruits to avoid the stress of chilling injury.

The obtained data are in accordance with those of previous studies which revealed that, phenolic compounds present the act of antioxidants due to their properties as hydrogen giver for reduction and quenching of singlet O$_2$ (Rice-Evans et al., 1997). In general, phenolic compound synthesis is influenced by several biotic and abiotic stresses such as chilling (Orabi et al., 2014, 2015).

Also, polyphenolic compounds (which is present in moringa and green tea extracts) have showed potential antioxidant properties as a result to their redox potential; that enable them to act in many forms such as hydrogen donors, reducing agents, resultant oxygen quenchers, and chelating metal ions in numerous applications (Gramza et al., 2006). The active hydroxyl groups present in the molecular structure of polyphenols are the active components of moringa and green tea extracts that can interact with the free radicals to inhibit lipid oxidation (Mitsumoto et al., 2005). Furthermore, moringa and green tea polyphenols can exhibit scavenging activity against free radicals (Rice-Evans et al., 1997).

Table 7: Effect of moringa and green tea leaves extract on PAI enzyme and total phenols of mango cv. Zebda at the end of cold storage (6 weeks).

| Treatments            | PAL Enzyme (µmol/g fruit fresh wt.) | Total phenols (mg/g fruit fresh wt.) |
|-----------------------|-------------------------------------|-------------------------------------|
|                       | 2017      | 2018      | 2017      | 2018      |
| T1= Moringa 2.5 %     | 10.31 cd  | 10.36 cd  | 0.79 d    | 0.91 d    |
| T2= Moringa 5 %       | 11.41 abc | 11.46 abc | 0.90 c    | 1.04 c    |
| T3= Moringa 10 %      | 12.58 a   | 12.65 a   | 1.19 a    | 1.37 a    |
| T4= Green Tea 2.5 %   | 9.64 de   | 9.69 de   | 0.71 e    | 0.81 e    |
| T5= Green Tea 5 %     | 11.87 ab  | 11.93 ab  | 1.04 b    | 1.20 b    |
| T6= Green Tea 10 %    | 10.54 bcd | 10.59 bcd | 0.96 c    | 1.10 c    |
| T7= Control           | 8.38 c    | 8.42 e    | 0.62 f    | 0.71 f    |

Means within a column followed by different letter(s) are statistically different at 5 % level.

Also, polyphenolic compounds (which is present in moringa and green tea extracts) have showed potential antioxidant properties as a result to their redox potential; that enable them to act in many forms such as hydrogen donors, reducing agents, resultant oxygen quenchers, and chelating metal ions in numerous applications (Gramza et al., 2006). The active hydroxyl groups present in the molecular structure of polyphenols are the active components of moringa and green tea extracts that can interact with the free radicals to inhibit lipid oxidation (Mitsumoto et al., 2005). Furthermore, moringa and green tea polyphenols can exhibit scavenging activity against free radicals (Rice-Evans et al., 1997).

Also, the result is in parallel with those reported by Gacche et al., (2010) on vitis vinifera who confirmed that an increase in total phenols occurred under adverse conditions. Moreover, Taha et al., (2015) reported that foliar spray of moringa leaves extract 7 % on jojoba plants gave highest increment of total phenols, flavonoids and tannins (41.67%, 85.13% and 80.50%, respectively). Furthermore, Li et al., (2017) confirmed that total phenols value in polysaccharide-coated fruits were slightly higher than those in control under cold storage.
In addition, Apriyanti et al., (2018) found that the addition of green tea extract on chitosan coating material increased total phenolic contents. The addition of green tea extract 10% had the highest value of total phenolic compounds.

In contrast, the use of other substances rich in antioxidants (salicylic acid) as postharvest treatment under cold storage inhibited the activities of phenylalanine ammonia lyase (PAL) and poly phenol oxidase (PPO) of the pineapple fruits, thus reduced total phenols production and delayed conversion (Lu et al., 2011).

The effect on antioxidant activity % (DPPH):

Table 8 points out the effect of moringa and green tea leaves extract as coating material on antioxidant activity % (radical scavenging activity ‘DPPH’) and Lipid peroxidation (MDA) as oxidative damage of mango cv. Zebda at the end of cold storage (6 weeks). The reduction of diphenyl picryl hydrazine radical (DPPH) which had a purple coloured and changed to a yellow coloured compound in the mango fruit extract as a result of scavenging capacity. In this regard, the colour is changed depends on hydrogen donating ability of the antioxidants in response to coating treatment with moringa and green tea leaves extracts (Orabi et al., 2018a). Coating mango fruits with moringa leaves extract 10% (T3) achieved the maximum values of DPPH and reached to 83.95% in the first year and 84.79% in the second year followed by coating treatment with green tea 5% (T5) that achieved 81.18% in the first season and 81.98% in the second season. Mango fruits coated with moringa and green tea treatments (T1-T6) showed higher antioxidant activity in DPPH scavenging capacity (ranged from 70.21 to 83.95% in the 1st season and from 70.91 to 84.79% in the 2nd season) compared with the control which recorded the lowest value about 60.71 and 61.32% in the two studied years.

The results are in agreement with those found by Taha et al., (2015) who observed that jojoba plants treated with the moringa leaves extract (7%) exhibited the highest antioxidant activity (63.05%). In addition, many researchers found enhancement the content of total phenols related with increasing of antioxidant activity of fruits and plants (Maciel et al., 2011; Abd EL- Motty and Orabi, 2013; Orabi and Abdelhamid, 2016, Orabi et al., 2016, Orabi et al., 2017, Orabi et al., 2018).

From Table 7 and Table 8, it can be observed from the results that there was a strong relationship between total phenols and antioxidant activity % and this indicate that phenolic compounds were a major contributor of antioxidant activity. This finding is confirmed by Bendini et al. (2006), Wojdylo et al. (2007), Taha et al., 2015 and Orabi et al., (2015) who reported also this relationship and confirmed that the phenols are very important constituents because of their scavenging ability on free radicals due to their hydroxyl groups. Therefore, the phenolic content may be contributed directly to their antioxidant action, phenylpropanoid and flavonoid biosynthesis.

In addition, the increase in antioxidant activity due to application is found by Azevedo Neto et al. (2005) who stated that addition nutrient solution enhanced antioxidants activities of leaves and roots of plant. Also, Boukraa et al. (2014), Fayez and Bazaid (2014) and Orabi et al., (2015) observed that antioxidant activity mainly depends on the dissociation of hydrogen radical from phenolic compounds to form a stable compound with DPPH radical. Moreover, Chen et al., (1997), Larque-Saavedra and Martin-Mex, (2007) and Momeny et al., (2012) found an important link among plant antioxidant ability and the applied doses of natural substances activate the resistance system and increase the cell antioxidant capacity which lead to cell membrane protection and synthesis of photosynthetic pigments and finally improve the growth indexes and secondary metabolites synthesis. Furthermore, many studies proved the predominant role of some natural substances in the modulation of the response of plants towards abiotic and biotic stresses by induction of the antioxidant ability. In this respect, Orabi et al., (2013), Boukraa et al., (2014) and Asadi et al. (2013) reported that exogenous application some natural materials decreased lipid peroxidation rates with increasing antioxidant activity. Moreover, Li et al., (2017) confirmed that antioxidant activity in polysaccharide-coated fruits showed higher level compared to the control under cold storage. Also, Apriyanti et al., (2018) noticed that green tea extract addition to chitosan coating material increased antioxidant activity DPPH. The addition of green tea extract 10% had the highest value of DPPH.

The effect on lipid peroxidation (MDA):

Table 8 clears the effect of moringa and green tea leaves extracts as coating substances on mango fruits at the end of cold storage (after 6 weeks). The rate of lipid peroxidation (MDA) used as an
indicator to evaluate the plant damage during the oxidative stress. The coating treatments were potentially effective in inhibiting MDA (lipid peroxidation) in treated fruits. Lipid peroxidation (MDA) was highly activated in the control fruits (T7) and recorded 5.76 and 6.34 µmol/g fruit fresh wt in both seasons followed in descending order by T1 and T4 (4.82 and 5.07 µmol/g fruit fresh wt in 1st season and 5.30 and 5.57 in 2nd season, respectively). However, MDA (lipid peroxidation) was highly reduced in treated fruits with T3 that achieved 2.93 and 3.22 µmol/g fruit fresh wt in both seasons followed by T5 (3.61 and 3.97 µmol/g fruit fresh wt in both seasons) and T2 (3.40 and 3.74 µmol/g fruit fresh wt in both years as well as T6 (4.10 and 4.51 µmol/g fruit fresh wt in both seasons) in significant differences.

Table 8: Effect of moringa and green tea leaves extract on antioxidant activity % (radical scavenging activity ‘DPPH’) and MDA of mango cv. Zebda at the end of cold storage (6 weeks).

| Treatments       | Antioxidant activity (%) (Radical scavenging activity) (DPPH) | Lipid peroxidation (MDA) (µmol/g fruit fresh wt.) |
|------------------|---------------------------------------------------------------|-------------------------------------------------|
|                  | 2017  | 2018  | 2017  | 2018  |                  | 2017  | 2018  |                  |
| T1= Moringa 2.5 %| 70.21 d| 70.91 d| 4.82 b| 5.30 b|                  |
| T2= Moringa 5 % | 76.06 c| 76.82 c| 3.40 d| 3.74 d|                  |
| T3= Moringa 10 %| 83.95 a| 84.79 a| 2.93 e| 3.22 e|                  |
| T4= Green Tea 2.5 %| 67.29 d| 67.96 d| 5.07 b| 5.57 b|                  |
| T5= Green Tea 5 %| 81.18 ab| 81.98 ab| 3.61 d| 3.97 d|                  |
| T6= Green Tea 10 %| 77.05 bc| 77.82 bc| 4.10 c| 4.51 c|                  |
| T7= Control      | 60.71 e| 61.32 e| 5.76 a| 6.34 a|                  |

Means within a column followed by different letter(s) are statistically different at 5% level.

In this study, the increasing MDA content in untreated fruits (T7) confirmed the occurrence of oxidative damage. However, all treatments (T1-T6) reduced the oxidative damage compared with the control (T7). Generally, data cleared that T3 was the effective treatment in decreasing MDA followed by T5, T2 then T6, however T1 and T4 came in the last order and all of them obviously reduced MDA accumulation and exhibiting a good potential to alleviate oxidative stress lowering of lipid peroxidation (MDA).

The decreasing of MDA in the results related to the decomposition of polyunsaturated fatty acids production of plant membranes under cold storage and the rate of lipid peroxidation (MDA) used as an indicator to evaluate plant tolerance to oxidative stress (Jain et al., 2001). Therefore, increasing of lipid peroxidation rate (MDA) in plants exposed to the enzyme activities might have not been enough to prevent the peroxidation of membrane lipids caused by high levels of stress such as cold storage. In other words, the increase in MDA rate might also be correlated with inadequate activities of the antioxidant enzymes such as PAL (Masoumi et al., 2011). As well as, the environmental stresses always result in cellular membrane injuries including the increase of membrane permeability and MDA content due to oxidative damage and both of them are considered to be sensitive stress markers (He et al., 2009; Moskova et al., 2009).

These findings were in harmony with those reported by Tesfay (2016) who found that the moringa 2% as well as carboxymethyl cellulose 1% with moringa 2% as coating materials to enhance the fruit quality of avocado under cold storage had the least fruit lipid peroxidation. Therefore, the oxidation of polyunsaturated fatty acids results in oxidants, such as peroxide ions and malondialdehyde (MDA). The lipid peroxidation activation increases with stresses and depends on the degree of cold stress and fruit prone to chilling injury (CI). High fruit lipid peroxidation, accumulation of MDA is often taken as an indicator of CI (Wongsheerere et al., 2009), further affects the fruit quality. the pattern of MDA content of avocado during cold storage, followed by shelf life at ambient condition, tended to increase in the control fruit (Tesfay, 2016). Furthermore, Wei et al. (2011) found that coating application with materials reach in antioxidants enhances defense mechanisms and antioxidants production in fruit during cold storage in order to decrease MDA content of the cell membrane to maintain cell membrane structure. Moreover, Kabiri et al. (2014) found that treatment with materials contain antioxidant reduced the level of lipid peroxidation and leakage of electrolytes from plant tissues as well as growth processes compared with the untreated plants. Also, Li et al., (2017) stated that polysaccharide coated treatments inhibited an increase of MDA during storage period.
Also, the data is in agreement with Stevens et al. (2006) and Agamy et al. (2013) who mentioned that the decrease of MDA under treatments with substances rich in antioxidant is consistent application regulates and maintains the membrane functions. These treatments can also diminish any injuries in cell membranes due to enhance the antioxidant potential of plant under stress conditions and partly maintained membrane permeability as well as reduced the amount of ion leakage (Tasgin et al., 2006; Orabi et al., 2010; Orabi et al., 2013 and Orabi and Abdelhamid, 2016).

Many preliminary phytochemical studies of the of Moringa oleifera leaf extract showed the presence of alkaloids, tannins, flavonoids, terpenoids, and steroids (Surbhi et al., 2015). Our results of Moringa oleifera leaf extract that used as coating material for mango fruits related to their characteristics which is consider a good source of phytochemicals including flavonoids, phenolics, carotenoids and β-sitosterol (Saluja et al. 1978). Therefore, β-sitosterol in the leaves of Moringa oleifera is a bioactive phytoconstituents that accounts for the hypolipidemic influence of moringa oleifera extract (Saluja et al., 1978). Moreover, Moringa leaves act as a good source of natural antioxidant due to the presence of various types of antioxidant compounds such as ascorbic acid, flavonoids, phenolics and carotenoids (Anwar et al., 2007, Makkar and Becker, 1996). Therefore, Moringa oleifera could prevent the oxidation due to the high concentrations of ascorbic acid; oestrogenic substances and β-sitosterol; iron; calcium; phosphorus; copper; vitamins A, B and C; α-tocopherol; riboflavin; nicotinic acid; folic acid; pyridoxine; β-carotene; protein; and in particular essential amino acids such as methionine, cysteine, tryptophan, and lysine present in Moringa leaves and pods make it a virtually ideal dietary supplement (Makkar and Becker, 1996).

It could be explaining these findings of green tea extract in coating mango fruits as a result to the role of polyphenolic compounds (mainly flavanoids) which present in green tea leaves extract and have demonstrated potential antioxidant characteristics due to their redox potential that enable them to act in many forms such as hydrogen donors, reducing agents, resultant oxygen quenchers, and chelating metal ions in many applications (Gramza et al., 2005 and Gramza et al., 2006). The active hydroxyl groups present in the molecular structure of polyphenols are the active components of the green tea that can interact with the free radicals to inhibit lipid oxidation (Mitsumoto et al., 2005). Furthermore, green tea polyphenols can exhibit scavenging activity against free radicals (Rice-Evans et al., 1996 and Rice-Evans et al., 1997).

Generally, during the cold storage period of 6 weeks of fruit storage, it was expected a high percentage of fruit weight loss and fruit decay occur and this period (6 weeks) is indicator for the maximum of oxidative damage or lipid peroxidation MDA. In this respect, the results showed that the anti-oxidative criteria (PAL, total phenols, antioxidant activity) were increased by all treatments and it explains how they could overcome oxidative damage or lipid peroxidation (MDA) than the untreated ones during the storage period of 6 weeks.

Conclusion

All treatments were reduced the fruit weight loss%, fruit decay %, total acidity%, lipid peroxidation MDA (µmol/g fruit fresh wt.) and increased T.S.S, T.S.S./acid ratio, vitamin C, antioxidant activity % (DPPH), PAL enzyme (µmol / g fruit fresh wt.) and total phenols (mg /g fruit fresh wt.) than the control. Moringa leaves extract 10% followed by green tea leaves extract 5 % were the recommended treatments because both treatments achieved high value of storability and fruit quality of mango cv. Zebda under the cold storage of 2,4 and 6 weeks during two consecutive seasons. During the cold storage period of 6 weeks of fruit storage, it was expected a high percentage of fruit weight loss and fruit decay occur and this period (6 weeks) is indicator for the maximum of oxidative damage or lipid peroxidation MDA. In this regard, the results showed that the anti-oxidative criteria (PAL, total phenols, antioxidant activity) were increased by all treatments and it explains how they could overcome oxidative damage or lipid peroxidation MDA than the untreated ones during the storage period.

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