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Effect of hydrogen peroxide (H_2O_2) treatment on physicochemical characteristics of tomato fruits during post-harvest storage

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Abstract

Tomato is a perishable vegetable crop and it faces several problems during marketing and storage. Postharvest losses during storage of tomato fruits are mainly due to decay. In this study, the effect of postharvest application of hydrogen peroxide on quality and decay of tomato fruits during storage under two storage temperatures (10 ºC and 20 ºC) was studied. Tomato fruits (Red rose cv.) at light red maturity stage were dipped in a solution of hydrogen peroxide (0, 5 and 15 mM) for 30 min, then air-dried at room temperature and stored at room temperature (20ºC) for three weeks in fridge (10ºC) for 4 weeks. A factorial (3 x 2) complete randomized design with three replications was used. The results showed that Hydrogen peroxide treatments reduced weight loss and disease incidence percentage of fruits compared with control treatment (0 mM hydrogen peroxide). Moreover, hydrogen peroxide treatments had slight effect on fruit firmness. Regarding TSS% and ascorbic acid content, there were no significant differences among treatments. In addition, storage temperature affected tomato fruit quality during storage time. Therefore, the use of hydrogen peroxide in postharvest treatments is useful to keep quality of tomato fruits under storage conditions.

Keywords: ascorbic acid, fruit decay, H_2O_2, Shelf life, tomato quality, weight loss
Abbreviations: H_2O_2: hydrogen peroxide; TSS: Total soluble of solids; mM: 10^{-3} Mole; ROS: Reactive oxygen species

Introduction

Tomato is the second most important vegetable crop after potato (FAO Stats 2015). Furthermore, it has also been recently demonstrated that it is supplementary source of antioxidants and minerals in human health. In Saudi Arabia, a total area of 16859 hectares is used for tomato cultivation in open field and under greenhouses according to the 27th Agriculture statistical year book, 2014, Ministry of Agriculture, Saudi Arabia. Tomato is highly perishable, which faces several problems during storage and marketing (Ruth and Lurie, 1986). There is an increasingly demand in the market for high quality products from consumers side. Various factors such as storage temperature and some post-harvest treatments limit the tomatoes storage life (Mutari and Debbie, 2011). Hydrogen peroxide (H_2O_2) is an environment friendly compound whose activity is based on oxidation of fungi and bacteria. It was successfully used to control vegetable pathogens during storage. It has been considered as an important signalling molecule that mediates various physiological and biochemical processes in plants. The role of H_2O_2 in plant biochemistry and physiology has been widely described in literature (Apel and Hirt, 2004; Hung et al., 2005; Slesak et al., 2007; Khan et al., 2018). Recent studies have demonstrated that H_2O_2 is a key signalling molecule in several biochemical pathways associated with abiotic stress response. A number of studies has shown that H_2O_2 could respond to abiotic stresses such as drought (Hameed and Iqbal, 2014; Ashraf et al., 2015) and salinity (Mohamed et al., 2015). It is also a key regular in a broad range of biological processes such as seedling growth and antioxidant enzymes activity under salt stress (Li et al., 2011 and Bagheri et al., 2019). In this regard, Liu et al. (2010) reported that pre-treatment with low concentration of H_2O_2 increased the enzymatic antioxidant activity and accumulation of ascorbate and reduced glutathione in plant. Postharvest treatments with hydrogen peroxide have been proposed as alternative to chemical treatments for disinfecting fresh fruits. It is clear that, H_2O_2 acts as signalling molecule in plants. It is a form of reactive oxygen species (ROS) generated as a results of oxidative stress. It is a compound allowed for use in organic crop production. In fresh-cut tomato, Kim et al. (2007) found that H_2O_2 has increased ascorbic acid level, after 7 days of storage compared to untreated fruits. In addition, Bhagwat (2006) found that H_2O_2 extended the shelf life of fresh-cut melon fruits by four to five days, compared to treatment with chlorine. Cold storage is the main postharvest method for longing shelf life of vegetable crops. Pinheiro et al. (2013) found that storage temperature had significant effect on tomato fruit quality such as firmness, total phenol and weight loss. The important quality parameters of tomato

fruits are TSS, acidity, fruit weight, firmness and ascorbic acid content (Okolie and Sanni, 2012). The aim of this study was to investigate the influence of different hydrogen peroxide concentrations on some physico-chemical parameters of tomato fruits stored at 10 and 20 °C.

Results and discussion

Effect of H_2O_2 treatments and storage temperature on weight loss of fruits

Wight loss of tomato fruits can affect the economic return. Our results indicated that there was a progressive increase in fruit weight loss during storage under both temperatures. In addition, fruits treated with H2O2 recorded low values of weight loss compared to untreated fruits. Fruits stored at 10 °C and treated with 5 mM and 15 mM of H_2O_2 lost 5.34% and 6.1 % of their initial weight after 28 days, while the untreated fruit lost 8.2 % of initial fruit weight during the same storage period. Generally, the weight loss was less in fruits stored at 10°C compared to those at 20 °C in all treatments. In general, the weight loss was affected by storage time and storage temperature. Okolie and Sanni (2012) obtained similar results. They reported that physical weight loss was less under cold storage as compared to ambient storage. Storage of tomato fruits at different temperature conditions affected the weight loss (Pinheiro et al., 2013). Mujtaba and Masud (2014); Kapsiya et al. (2015) stated that fruit weight loss was increased with increasing storage period, while H_2O_2 treatments had a slight effect on decreasing weight loss (Fig. 1). Fruit weight loss is due to transpiration and respiration. Storage temperature affects fruit ripening and it has a direct effect on respiration rate. Tasdelen and Bayindeirli (1998) reported that fruits stored at cold storage (10 °C) had low weight loss due to the effect of temperature on the vapour pressure differences and increased water retention. The effect of H_2O_2 on the reducing weight loss of bell pepper fruits may be due to reducing the respiration rate during storage (Du et al., 2007). Desikan et al. (2004) reported that H_2O_2 retarded the fruit ripening and decreased the respiration rate and induced stomatal closing of guard cells. The ability of guard cells to generate H_2O_2 has been reported in tobacco and tomato (Desikan et al., 2004).

Effect of H2O2 treatments and storage temperature on TSS (Brix)

Initially, the total soluble content of tomato fruits was 5.55%. A slight increasing in TSS% was noticed from H_2O_2 treatments during the first week of storage under both storage temperatures and after a slight decrease was observed (Fig. 2). This increment may be due to the increasing of water loss (weight loss) during storage (Bayoumi, 2008). Akhtar et al. (2010) reported that increasing TSS content is due to concentrated juice content, convenient marketing and storage techniques including temperature and relative humidity control which can help to minimize the rate of water loss. Regarding the effect of H_2O_2 on TSS%, there were no significant differences among treatments under both temperatures after 7 days of storage.

Effect of H_2O_2 treatments and storage temperature on ascorbic acid content

Ascorbic acid is an important antioxidant for human diet (Frei et al., 2012) and its content is sensitive to decomposition as a result of its oxidation during storage. Under both temperatures, all treatments recorded continuously increasing in the content of ascorbic acid during the first two weeks of storage, after which it was decreased (Fig 3). The differences among treatments were not significant. Kim et al. (2007) reported that H_2O_2 produced an initial decline in ascorbic acid content in fresh-cut tomato. In pepper, Bayoumi (2008) found that 15 mM of H_2O_2 has significantly increased the ascorbic acid content during storage. The increase in ascorbic acid content is thought to be indication that the fruit is still in ripening process (Pila et al., 2011). In addition, Massote et al. (2010) found that ascorbic acid content has been increased during ripening. In contrast, Moneruzzaman et al. (2008) reported that as the tomato fruit ripens, the ascorbic acid content may decrease. Ascorbic acid content of tomato fruits was significantly influenced by various post-harvest treatments and storage conditions (Okolie and Sanni, 2012).

Effect of H_2O_2 treatments and storage temperature on fruit firmness

It is important to preserve the quality characteristics of fruits at their peak during storage. It was clear from Fig 4. that firmness of fruits stored at 10 °C maintained its firmness during storage until 7 days and then constant decrease in fruit firmness was noticed in all treatments, while, firmness of fruits stored at 20 °C started to decrease from the beginning of storage (Fig 4).

During fruit ripening, one of the most notable changes is softening which is related to biochemical processes in the cell wall. In this concern, tomato stored at low temperature revealed delay of ripening in terms of firming and weight loss (Pinheiro et al., 2013). Firmness of tomato strongly influences purchase and consumer acceptance. Moreover, it strongly influences fruit shelf life and transportation (Seymour et al., 2002; Causse et al., 2010). Bertin and Genard (2018) reported that after harvest, the texture gets involved rapidly, while the membrane and cell wall breakdown occurs due to less turgor and enzyme orchestrated cell wall loosing.

Effect of H_2O_2 treatments and storage temperature on percentage of disease incidence

Under both temperatures, there were significant differences among the H_2O_2 treatments. The control treatment recorded the maximum incidence percentage, while the minimum percentage was recorded in either of H_2O_2 treatments (Table 1). The percentage of decayed fruits was higher at 20 °C than 10 °C. The decreasing of decay by using hydrogen peroxide attributed to that H_2O_2 as ROS plays a significant role in resistance to plant disease. None of decayed fruits was found until the 5th day of storage, after the progressive increase in fruit decay, which was noticed from the 10th days. Kapsiya et al. (2015) obtained similar results. In pepper fruits, Bayoumi (2008) found that H_2O_2

Table 1. Disease incidence percentage as affected by treatments of H_2O_2 under both storage temperatures after 20 days of storage.

Treatments	Fruit stored at 10°C	Fruit stored at 20°C
0 mM H_2O_2	14.6 a	19.3 a
5 mM H_2O_2	10.3 b	15.2 b
15 mM H_2O_2	9.7 b	12.8 c

Values with common letter in the same column are not significantly different at 5% level

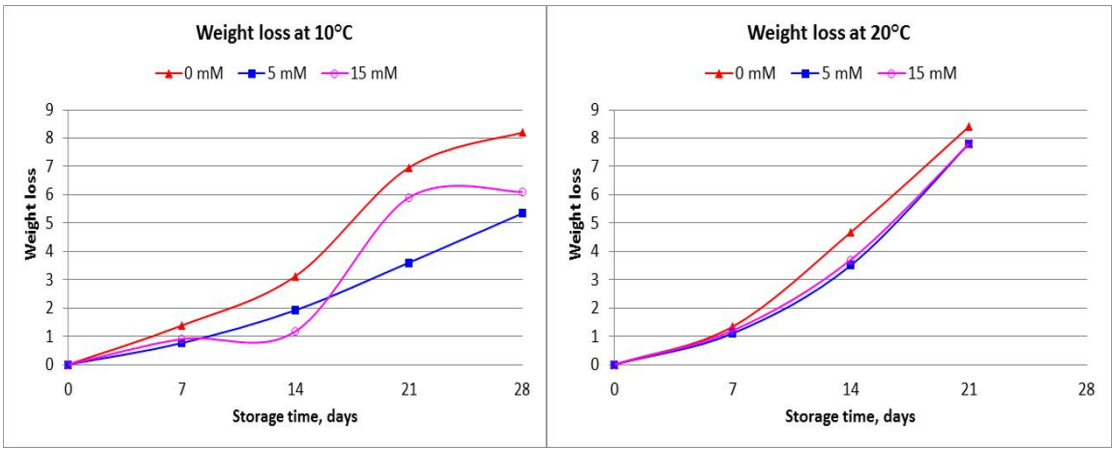

Fig 1. Weight loss of tomato fruits was affected by H_2O_2 treatments during storage at 10°C and 20°C (LSD 10°C: 1.21, LSD at 20°C: 1.33).

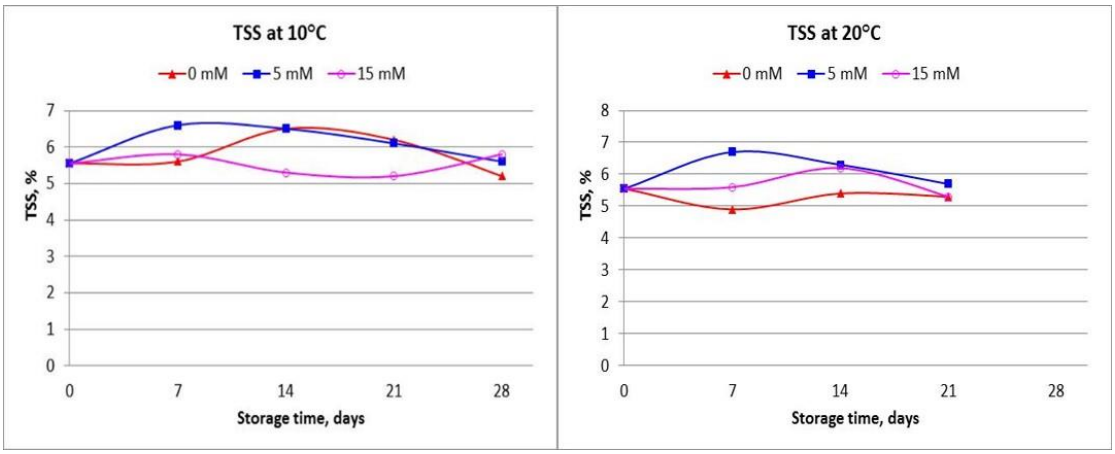

Fig 2. TSS% of tomato fruits was affected by H_2O_2 treatments during storage at 10°C and 20°C. (LSD 10°C: 0.92; LSD at 20°C: 1.12).

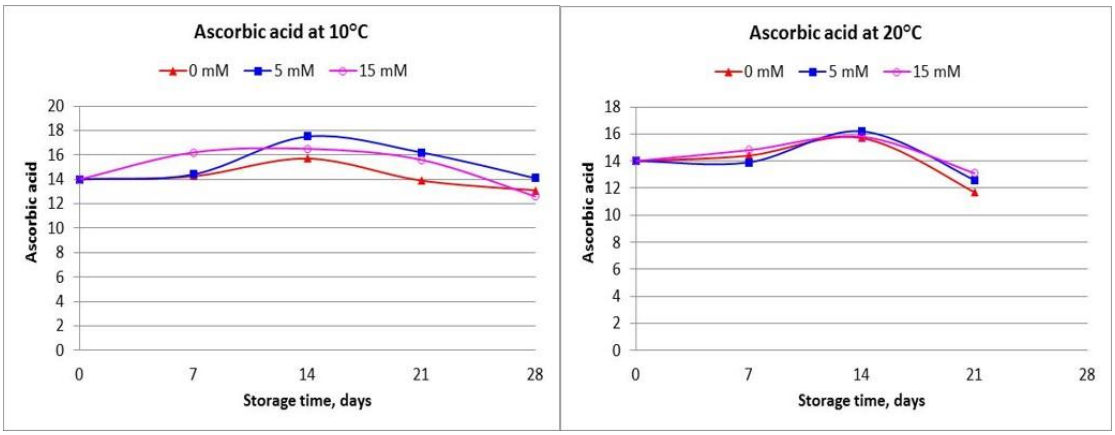

Fig 3. Ascorbic acid content of tomato fruits as affected by H_2O_2 treatments during storage at 10°C and 20°C. (LSD 10°C: 0.73; LSD at 20°C: 0.64).

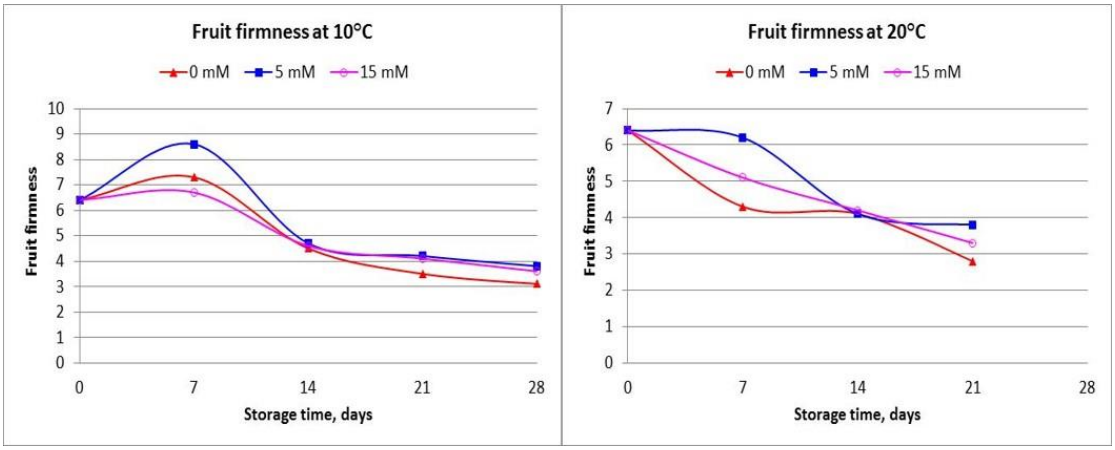

Fig 4. Firmness of tomato fruits was affected by H_2O_2 treatments during storage at 10°C and 20°C. (LSD 10°C: 0.73; LSD at 20°C: 0.85).

treatments decreased fruits decomposition and extended their shelf life. Isaac and Maalekuu (2013) found that 0.5% H_2O_2 dip for 3 minutes was very effective in controlling decay of carrots. Hydrogen peroxide is a direct antimicrobial agent and it activates the disease resistance reaction of tomato to infection with a pathogen (Malolepsza and Rozalska, 2005). Slesak et al. (2007) mentioned also that H_2O_2 is crucial component involved in the regulation of plant defense. In another study, Bagheri et al (2019) found that H_2O_2 treated plants have enzymatic activity higher than untreated plants. In general, H_2O_2 treatments have beneficial effects on fruit quality such as delaying ripening (Bayoumi, 2008) by increasing antioxidants content in fruits and H_2O_2 can reduce ethylene production. This reduction keeps the appearance of fruits in the best state (Saltveit and Sharaf, 1992).

Materials and Methods

Plant materials

This experiment was carried out in the Central Lab, College of Agricultural and Food Sciences, King Faisal University, Saudi Arabia. Tomato fruits (Red Rose cv.) at light red mature stage were manually picked from plants grown under greenhouse conditions. Fruits of uniform size and color, undamaged and free from diseases were selected for this study. The fruits were washed to remove dust and after that air-dried.

Treatments and conduction of study

Treatments in this study were two storage temperatures (10 and 20 ºC) and three hydrogen peroxide concentrations as follows.

1. Fruits dipped in 0 mM H2O2 and stored at 10ºC
2. Fruits dipped in 0 mM H2O2 and stored at 20ºC
3. Fruits dipped in 5 mM H2O2 and stored at 10ºC
4. Fruits dipped in 5 mM H2O2 and stored at 20ºC
5. Fruits dipped in 15 mM H2O2 and stored at 10ºC
6. Fruits dipped in 15 mM H2O2 and stored at 20ºC

All fruits were dipped in the H_2O_2 solutions for 30 mins then directly air-dried at room temperature. All treated fruits were divided into two groups, one stored at 10ºC for 28 days and the other one stored at 20ºC for 21 days. All treatments were arranged in three replicates, each one containing six fruits.

Parameters of investigation included

Weight loss: the weight of fruits was weekly recorded and the variation in weight loss was expressed as a percentage of accumulative weight loss from the initial weight of the fruits TSS, Total soluble solids and content (Brix) which were measured using a Refractometer (Atago Co., Tokyo, Japan). Fruit firmness was determined using Digital Fruit Firmness Tester, Penetrometer (FHP-803, Agriculture Solutions LLC, USA). Measurements were done in triplicate. Ascorbic acid content ($mg100g^{-1}$ fresh weight) was measured using 2,6-Dichloroindophenol dye according to (AOAC, 2006). After 20 days of storage, disease incidence (percentage) was calculated as the percentage of decayed fruits per total number of fruits.

Experimental design and statistical analysis

A factorial (3 x 2) complete randomized design with three replications was used. The data generated were subjected to analysis of variance (ANOVA), and the means were compared by the least significant differences (LSD) as described by Snedecor and Cochran (1980).

Conclusion

The results of the present study showed that the quality of tomato fruits in terms of weight loss, ascorbic acid content, TSS percentage, fruit firmness and decay is dependent on storage time and storage temperature. Generally, hydrogen peroxide treatments showed to be useful in postharvest to keep quality of tomato fruits under storage conditions.

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