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Late Swelling peaches storagability improvement with chitosan and modified atmosphere packing

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Abstract: The maintenance of Late Swelling peaches quality attributes during shipping and storage was investigated. Fruits harvested at early ripe stage were either dipped in chitosan solution (Chi.1 and Chi.2) or put in modified atmosphere packages (MAP1, MAP2 and MAP3) and then held in storage room for 10 days (simulating transport or shipping conditions) or 32 day (simulating storage conditions) at 10°C ± and 85-90% RH. The treatments effect on the fruit ability for transport and storage, as well as the fruit physicochemical characters was investigated. MAP showed positive influences on the different measured parameters especially those expressing the fruit transport and storagability where lower percentages of weight loss, unmarketable fruits and off-flavor incidence were obtained, with the MAP2 type indicating better results than MAP1 and MAP3. Also, chitosan especially Chi.2 resulted in positive influences on the transport and keeping quality of the peach fruits. Also, changes in the fruit physicochemical characteristics were at minimum by the MAP and Chi. treatments during 10 days storage, especially firmness, color and acidity content.

Keywords: Chemical dipping, packaging, postharvest quality, transportability

Introduction

Much attention is now been placed on the postharvest practices for maintaining fresh fruit quality attributes especially its nutritive value. As fruit cells are still alive after harvest, they undergo several physiological and biochemical changes that may result in quantitative and qualitative losses reaching about 15-25% (Barkai-Golan 2001). Accordingly, reducing such losses would be of great significance to both growers and consumers. A peach fruit is approximately 87% water next to carbohydrates, organic acids, pigments, volatiles, nutritive minerals and trace amounts of proteins and lipids. It also contains immeasurable diversity of biologically bioactive compounds such as vitamin C, carotenoids, flavonoids, and complex phenolics that act as antioxidants and make it very attractive to consumers (FAO, 2011). However, it is a soft-fleshed climacteric fruit that has limited postharvest life. Its high moisture content makes it inherently more liable to deteriorate rapidly at room temperature. Accordingly, for fresh consuming, peach fruits require to be handled with much care to minimize losses. During marketing or shipping, the fruits suffer from high susceptibility to flesh softening, weight and flavor loss, and pathogens attack as well as higher respiration rates. Due to the public concern about food safety, human health and environment, as well as the emergence of new races of pathogens, more restrictions are recently made on the use of synthetic fungicides in fresh produce. Efforts are made to find effective and safe alternatives techniques to fungicides in order to control fruit postharvest diseases and enhance its marketing ability and storage life. In this view, it has been stated that fruits can be induced to develop enhanced resistance to pathogen infection by postharvest treatments with organic chemical elicitors such as chitosan (El Ghaouth *et al*., 2004). Chitosan is concerned for its non-toxic, biodegradable, and biocompatible properties (Jianglian & Shaoying, 2013). It would modify the internal atmosphere, decrease transpiration losses and thus regulating the postharvest fruit quality (Olivas & Barbosa-Ca´novas, 2005). It is also recorded to have a broad-spectrum of antimicrobial activity (Ait *et al*., 2004). Nevertheless, modified atmosphere packaging (MAP) is indicated to alter the air surrounding the fruit by using polymeric films with different permeability's to oxygen and carbon dioxide leading to the delay of fruit deterioration by slowing down its respiration activity, ripening process and the incidence of various physiological disorders and pathogenic infestations.

In accordance, the present investigation is conducted on Late Swelling peach which is a late season cultivar planted in Egypt that suffers from accelerated softening and exhibits short handling period after harvest which limits its commercial potential and the acceptability by consumer. Hence this study aims at investigating the effect of chitosan coating and or MAP on the fruit shelf life and marketability of this cultivar when stored under 10 ºC and 85-90% RH for 32 days.

Materials and Methods

Plant material and postharvest treatments

The present study was carried out during 2016 and 2017 postharvest seasons on peach (*Prunus persica* L.) fruits cv. Late Swelling. Fruits were harvested at the early ripe stage (during the first week of June) and immediately transported to the postharvest laboratory, washed, air dried and sorted to remove any unsuitable ones (mechanical damage, injured and discolored). Sorted fruits were either dipped for one minute in water (control) or in two concentrations of chitosan solution (Chi.1 or Chi.2) then air dried or fruit packing in three types of modified atmosphere bagging (MAP1, MAP2 and MAP3). The Chi.1 was 1.5 and 3 while the Chi.2 was 3 and 6 g /L in the first and second season, respectively. The types of MAP are illustrated in Table (1). Six postharvest treatments (2 Chi. × 3 MAP) were arranged in a randomized complete block design (RCBD) and 24 experimental units (6 treatments × 4 replicates, 18kg fruit per replicate) were held in storage room either for 10 days (simulating transport or shipping conditions) or 32 day (simulating storage conditions) at 10 °C ±1 and 85-90% R.H. in order to investigate the effect of the different treatments on the fruit ability for transport and storage as well as, the fruit physicochemical characters.

Fruit physicochemical characteristics

A fruit sample of 2 kg from each replicate was taken after 10 days of storage for measuring the fruit physicochemical characteristics; Fruit firmness (Newton) was measured by a pressure tester with a probe 8 mm in diameter and fruit color was recorded by Minolta, Chroma Meter CR-200 and expressed as Lightness (L*), Chroma (C) and hue angle (*h*°). the percentage of soluble solids content (SSC) was measured by hand refractometer model ATAGO, model. N-1e. Japan T. Vitamin C (V.C.), titratable acidity (T.A.), reducing (R.), non-reducing (NR.) and total (T.) sugars content (%) were determined (AOAC 2012). Also, fruit bioactive properties were defined by determining calorimetrically fruit total chlorophyll (T.Chl.), total carotenoids (T. Car.), anthocyanin (An.) and total phenols (T. Phl.) as mg $100g^{-1}$ and measured using a spectrophotometer (Spectronic model.20, Milton Roy Co., USA) according to David (1978), Britton (1995), Ozgen (2008) & Moyo, (2012), respectively.

Fruit transport- and storagability

Fruit transport- and storagability was expressed as follows: Fruit peel electrolyte leakage (E.L.%) at 10 days storing according to Whilton *et al*. (1992), fruit weight loss and unmarketable fruits (%) after 10, 21 and 32 days. The unmarketable fruits were estimated by sorting any defected fruit such as decayed, off-flavored, shriveled, external browning, etc. As off-flavor signs started to appear after 10 days storage in all MAP treatments, off-flavor incidence was recorded during the rest of the storage period (until 32 day) and the off-flavor percentage was calculated.

Statistical analysis

One-way analysis of variance (ANOVA) according to Petersen (1985) was carried out by Statistical Analysis System (SAS Institute In C.). The differences among the treatments were separated and compared using the least significant differences (LSD) at 0.05 level of significance (Snedecor & Cochran, 1989).

Results

Fruit transport- and storagability

A general decrease in the percentage of fruit electrolyte leakage was obtained by all MAP and chitosan treatments (Table 2). Moreover, all MAP types markedly decreased fruit weight loss in comparison with the control and the chitosan treated fruits, with no significant difference among them after 10 days storage. The MAP treated fruits were the only ones lasting until 32 days, however, fruit weight loss increased with extending the storage period (Fig.1). In addition, all MAP and Chi. treatments decreased the percentage of the unmarketable fruits after 10 days as compared with the control which reached a percentage of almost 50%. In the meantime, all MAP types showed a significantly lower unmarketable fruit percentage than Chi, with the MAP2 and MAP3 types indicating markedly lower percentages than the MAP1. In the meantime, after 21 days, the MAP2 indicated the lowest unmarketable fruit percentage compared to the other types and was the only treatments that lasted for 32 days, but normally the percentage of unmarketable fruits increased with extending storage period (Fig.2). In addition, off-flavor incidences appeared in all types of MAP treated fruits after 21 days of storage, with the MAP2 indicating the lowest percentages after 21 and 32 days as compared to the MAP1 and MAP3 (Fig.3).

Fruit physicochemical characters

The effect of modified atmosphere packaging (MAP) and chitosan (Chi.) dipping on the fruit physiochemical characters held for 10 days at 10^{o}C and 85-90% R.H is presented in Tables (3 & 4). Fruits under all types of modified atmosphere packing had higher firmness values than the control and the chitosan treated ones. In the meantime, the MAP2 and MAP3 packing types indicated higher firmness values than the MAP1 in 2017. In addition, fruit dipped in both chitosan concentrations (Ch.1 and Chi.2) indicated higher firmness than the control ones in 2017. Meaning that both MAP and chitosan treatments maintained peach fruit firmness from declining when holding for 10 days at 10^{o}C and 85-90% R.H. As for fruit color, only the MAP1, MAP2 and Chi.2 treatments in the 2016 season resulted in significant high L* value in comparison with the control. In general, all MAP types indicated higher h^{o} value than the control and chitosan treated fruits with the difference being significant in 2017, and no differences among them. However, Chi. dipping had no significant effect on the h^{o} value. As for the C value, all packaging types, as well as Chi. treatments resulted in decreasing the C value compared to the control fruits in 2016, with no significant differences occurred neither among the MAP types nor between both Chi. concentrations.

In addition, all types of MAP indicated significantly high (in 2016) and similar (in 2017) fruit acidity content compared to the control fruits, which means that MAP maintained fruit acidity levels during holding the peach fruits for 10 days at 10^{o}C and 85-90% R.H. without significant difference occurring among the MAP types. Also, both Chi. treatments indicated higher fruit acidity content than the control, and the Chi2 treated fruits had significantly higher acidity content than all MA packed fruits in 2017. In general, all MAP types resulted in high fruit soluble solids content comparing to the control fruits with MAP2 resulting in higher SSC than MAP3 in 2016 only. In the meantime, fruits dipped in both chitosan concentrations either maintained fruit SSC unchanged (in 2016) or high (in 2017) when compared to the control fruits, with no significant difference between both concentrations. Furthermore, fruit reducing and non-reducing sugars contents maintained unchanged by all MAP and Chi applications when compared to the control fruits. Fruits packed in all types of MAP, as well as dipped in chitosan had significantly lower total sugars content than the control ones. In general, all MAP types resulted in higher total chlorophyll content than the control and chitosan treated fruits. The MAP2 indicated higher chlorophyll content than MAP3. The Chi.1 and Chi.2 treatments either increased (in 2016) or maintained (in 2017) chlorophyll content as compared to the control with significant difference between both concentrations occurring in 2016 only.

Regarding the fruit bioactive properties, the MAP2 and MAP3 as well as Chi2 (in 2016) indicated higher vitamin C content than the control and the MAP1 and Chi.1 treatments. In addition, all MAP and chitosan treated fruits had lower anthocyanin content than the control, with no significant differences occurring neither among the MAP types nor between both chitosan concentrations. All MAP and Chi treated fruits indicated similar carotenoids content to the control ones. Also, all MAP treatments (except MAP1 in 2017) kept fruit total phenols content unchanged compared to the control, while both chitosan concentrations resulted in high phenols content in 2017.

Discussion

Modified atmosphere

Results obtained in the present study showed positive influences of the MAP treatments on the different measured parameters especially those expressing the fruit transport and storagability. The marked decrease in fruit weight loss in MA packed fruits is obtained due to the limitation of gas exchange and to water vapor accumulation within the package, which maintain moisture levels inside the packages (Valero *et al.*, 2014). In the meantime, Artes (2000) reported that MAP may lower respiratory activity and ethylene production, delay ripening and softening, limit weight losses, and decrease the incidence of physiological disorders and decay-causing pathogens. As MAP alters air composition surrounding the fruit in the package (low O2 and high CO2), levels of CO2 higher than 1% are reported to work as is an antagonist of ethylene action, thus prevent its autocatalytic synthesis and consequently retard fruit ripening and deterioration (Artes *et al*., 2006). In addition, studies on peaches and nectarines showed that MAP diminishes fruit tissues deterioration through decreasing respiration rate and browning development (Santana *et al*.; 2010, Bal, 2012), thereby extending storage life (Bodbodak & Moshfeghifar, 2016). This is clearly shown in the result of the present study were all MAP decreased the electrolyte leakage and thus altered fruit deterioration. Similarly, An *et al.* (2007) packed honey peaches in different-thickness low density polyethylene bags stored at 2 °C and stated that MAP treatments inhibited the climacteric peak, decreased the development of softness, and retarded the reduction of membrane integrity. In addition, the off-flavor appeared by the MAP treatments would probably be associated to the exposure of the packed fruits to high CO_2 and low O_2 levels accumulated during the longer storage period (21 days and more) compared to the shorter one (10 days). Ares *et al*. (2007) concluded that extreme reduction of O_2 concentration leads to an increase in the potential risk for the growth of pathogenic anaerobic microbes, and excessive reduction of O2 concentration (<1%) intensifies anaerobic respiration, which leads to off-flavor production and tissue deterioration or visible tissue damage. Nevertheless, the physicochemical characteristics of the Late Swelling peaches was maintained by the MAP treatments according to its positive influences in delaying ripening process by slowing down changes in fruit firmness. The effect of MAP on fruit firmness could be attributed to the beneficial effects of atmospheres with low O_2 and/or high CO_2 content on reducing softening (Bal, 2016). Fruit softening would be an ethylene-mediated effect as reported by Diaz-Mula *et al*. (2011) who referred softening reduction in plums to the inhibition of ethylene metabolism by the MAP to a greater extent.

Additionally, results of MAP on the fruit chemical content clear its influence in decreasing the rate of fruit metabolism, especially respiration, by reducing hydrolysis of organic acid leading to the maintenance of respiration substrates and in turn delaying postharvest ripening process (Ding *et al*., 2002; Amoros *et al*., 2008). Also, the high SSC indicated by MAP might be referred to the low sugars consumption due to the decreased respiration rate (Diaz-Mula *et al*., 2011). Altering fruit bioactive properties was also kept at minimum by the MAP application which is reported to be effective in suppressing ascorbic acid losses and therefore keeping the antioxidant potential in fruits (Singh & Rao, 2005; Amoros *et al*., 2008). The delay in phenolic compounds increase in several stone fruits during storage under MAP conditions was previously stated (di Vaio *et al*., 2008; Diaz-Mula *et al*., 2009; Serrano *et al*., 2009). Similar to the obtained results, Bodbodak & Moshfeghifar (2016, 2017) stated that MAP lowered fruit color changes associated with ripening process during storage in many fruits. In over all, it is clear that reduced O_2 level by the MAP can delay compositional changes such as fruit pigment development, softening, hardening, and development of flavor due to a decrease in the activity of oxidative enzymes such as glycolic acid oxidase, ascorbic acid oxidase, and polyphenol oxidase (Kader, 1986), and that modified atmosphere and low temperature conditions enhance fruit storability by slowing down all physiological activities, especially respiration rate and the activity of fruit softening enzymes and thus delaying senescence (Pongener *et al*., 2011; Ullah *et al*., 2015).

Chitosan

Chitosan is reported to have diverted effects and actions on the different parameters that influences fruit ripening and deterioration during storage. It is known to slow down fruit decay by its direct toxic effect on many phytopathogens as it inhibits spore germination, germ tube elongation, and mycelia growth (Ben-Shalom *et al*., 2003; Xu *et al*., 2006). Another way that chitosan works is the elicitation of fruits biochemical defense responses, as well as having antimicrobial properties by impeding the movement of microbial cells (Liu *et al*., 2007). It is also reported to decrease respiration rate (Jiang & Li., 2001). In the meanwhile, chitosan reduces water loss and increases resistance to water vapor transmission because of its dense films structure that works effectively as gas barrier (Wong *et al*., 1992; Morillon *et al*., 2002). A common feature accompanying senescence is increased membrane permeability, expressed as increasing leakage of ions (Saltveit, 2002). It is therefore not surprising that electrolyte leakage has been recommended as a valuable criterion for identification of fruit postharvest quality as it is reported to express injury degree of harvested fruits (Jiang *et al*., 2005) and several studies showed the positive influence of chitosan dipping in eliminating cell wall degradation and thus slowing down fruit softness and maintaining its postharvest firmness (Sun *et al*., 2010; Plainsirichai *et al*., 2014) and as found in the present investigation especially with higher concentration. Furthermore, in line with Plainsirichai *et al*. (2014) who worked on Rose apple, chitosan affected positively fruit firmness over a storage period of 10 days as well as, it generally maintained changes in fruit color indicators (L, *h*° and C) during storage. Diverse effects of chitosan on fruit color changes are explained by the film capacity of chitosan that probably may change the fruit surface reflection properties (Plainsirichai *et al*., 2014; Placido *et al*., 2016), or its effect on reducing respiration rate and ethylene production (Ali *et al*., 2011). Furthermore, organic acids are limiting components beside sugars that play an important role in the organoleptic properties of a fruit. The fruit organic acids content decreases during ripening due to the respiratory metabolism and accordingly, the higher the metabolic respiration, the higher would be the decline in acidity content (Chiabrando & Giacalone, 2016). Obtained results showed that chitosan kept high fruit acidity content which would mean slowing down the use of organic acids as substrates for respiration metabolism during storage (Diaz-Mula *et al.*, 2012). Similar low acidity loss in chitosan-coated fruits during storage is stated in other studies (Li & Yu, 2001; Dong *et al*., 2004; El Guilli *et al*., 2016). In the meantime, better retention of fruit SSC, sugars, V.C. and chlorophyll as a result of chitosan application was reported by Qiuping & Wenshui (2007) and Sun *et al*. (2010). Finally, chitosan influence mainly depends on its chemical composition, the timing and rate of application (Malerba & Cerana, 2016).

Conclusion

According to the results obtained, it might be concluded that chitosan dipping could be a tool for preserving peach fruits in good marketable quality for 10 days, while MAP might help in extending the postharvest quality of the peach fruits for about 32 days with putting in consideration the packing type.

References

[1]. Ait E, Eullaffroy P, Clement C, Vernet G, 2004. Chitosan improves development, and protects *Vitis vinifera* L. against *Botrytis cinerea*. Plant Cell Reports 22: 608-614.

[2]. Ali A, Mahmud M, Kamaruzaman S, Yasmeen S, 2011. Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya* L.) fruit during cold storage. Food Chem 124: 620-626.

[3]. Amoros A, Pretel T, Zapata P, Botella A, Romojaro F, Serrano M, 2008. Use of modified atmosphere packaging with microperforated polypropylene film to maintain postharvest loquat quality. Food Sci Tech Int 14: 95-103.

[4]. An J, Zhang M, Zhan Z, 2007. Effect of packaging film on the quality of 'Chaoyang' honey peach fruit in modified atmosphere packages. Packaging Tech Sci 20: 71-76.

[5]. A.O.A.C, 2012. Official methods of analysis, 24th Ed., Association of official analysis chemists, Washington, D.C., USA.

[6]. Ares G, Lareo C, Lema P, 2007. Modified atmosphere packaging for postharvest storage of mushrooms. A review. Fresh Produce 1(1): 32-40.

[7]. Artés F, Tomás-Barberán A, 2000. Postharvest technological treatments of pomegranate and preparation of derived products. In: Melgarejo-Moreno, P. et al. (eds.), Production, processing and marketing of pomegranate in the Mediterranean Region. 199 -204pp.

[8]. Artés F, Gomez A, Artés-Hernandez F, 2006. Modified atmosphere packaging of fruits and vegetables. Stewart Postharvest Review 5. 2 pp.

[9]. Bal E, 2012. Effects of modified atmosphere packaging on storage of summer Super Star nectarine. Preservation and marketing of horticultural crops Symposium V Izmir (Turkey), Sept 18-21. pp: 325-330.

[10]. Bal E, 2016. Combined treatment of modified atmosphere packaging and salicylic acid improves postharvest quality of nectarine (*Prunus persica* L.) Fruit J Agric Sci Tech 18: 1345-1354.

[11]. Barkai-Golan R, 2001. Postharvest diseases of fruits and vegetables. Development and control. In: Elsevier Science, B. V. Amsterdam (The Netherlands).

[12]. Ben-Shalom N, Ardi R, Pinto R, Aki C, Fallik E, 2003. Controlling grey mould caused by *Botrytis cinerea* in cucumber plants by means of chitosan. Crop Prot 22: 285–290.

[13]. Bodbodak S, Moshfeghifar M, 2016. Advances in modified atmosphere packaging of fruits and vegetables. Eco Friendly Tech Postharvest Produce Quality. http://dx.doi.org/10.1016/B978-0-12-804313-4.00004-9.

[14]. Britton G, 1995. UV/visible spectroscopy. In Britton, G., Liaaen-Jensen, S.& Pfander, H. (eds). Carotenoids: spectroscopy, vol. 1B. Birkhauser Verlag, Basel, 13-63pp.

[15]. Chiabrando V, Giacalone,G, 2016. Effect of edible coatings on quality maintenance of fresh-cut nectarines. J Food Agric 28(3): 201-207.

[16]. David TP, 1978. An introduction to practical biochemistry. Mc Graw-Hill company, UK. 316 pp.

[17]. di Vaio C, Graziani G, Marra L, Cascone A, Ritieni A, 2008. Antioxidant capacities, carotenoids and polyphenols evaluation of fresh and refrigerated peach and nectarine cultivars from Italy. Europ Food Resh Tech 227: 1225-1231.

[18]. Diaz-Mula M, Zapata J, Guillén F, Martinez-Romero D, Castillo S, Serrano M, Valero V, 2009. Changes in hydrophilic and lipophilic antioxidant activity and related bioactive compounds during postharvest storage of yellow and purple plum cultivars. Postharvest Biol Tech 51: 354-363.

[19]. Diaz-Mula M, Martinez-Romero D, Castillo S, Serrano M, Valero D, 2011. Modified atmosphere packaging of yellow and purple plum cultivars. 1. Effect on organoleptic quality. Postharvest Biol Tech 61 (2-3): 103-109.

[20]. Diaz-Mula M, Serrano M, Valero D, 2012. Algent coatings preserve fruit quality and bio active compounds during storage sweet cherry fruit. Food Bioprocess Tech 5: 2990-2997.

[21]. Ding K, Chachin K, Ueda Y, Imahori Y, Wang Y, 2002. Modified atmosphere packaging maintains postharvest quality of loquat fruit. Postharvest Biol Tech 24: 341-348.

[22]. Dong H, Cheng L, Tan J, Zheng K, Jiang Y, 2004. Effects of chitosan coating on quality and shelf life of peeled litchi fruit. J Food Engin 64: 355-358.

[23]. El Ghaouth A, Wilson C, Wisniewski M, 2004. Biologically-Based alternatives to synthetic fungicides for the control of postharvest diseases of fruit and vegetables. Diseases of Fruits and Veget 2: 511-535.

[24]. El Guilli M, Hamza A, Clément C, Ibriz, M, Barka E.A, 2016. Effectiveness of postharvest treatment with chitosan to control Citrus green mold. Agriculture 6.p. 12. DOI:10.3390/agriculture6020012

[25]. Eshghi S, Hashemi M, Mohammadi A, Badii F, Mohammadhoseini Z, Ahmadi K, 2014. Effect of nanochitosan-based coating with and without copper loaded on physicochemical and bioactive components of fresh strawberry fruit *(Fragaria* x *ananassa* Duchesne) during storage. Food and Bioprocess Tech 7(8): 2397-2409.

[26]. Eweis M, Elkholy SS, Elsabee MZ, 2006. Antifungal efficacy of chitosan and its thiourea derivatives upon the growth of some sugar-beet pathogens. Int J Biol Macromolecules 38: 1-8.

[27]. FAO, 2011. Food and Agriculture Organization of the United Nations Internet site. Agricultural statistics. www.fao.org.

[28]. Jiang Y, Li Y, 2001. Effects of chitosan coating on postharvest life and quality of longan fruit. Food Chem 73: 139–143.

[29]. Jiang YM, Li JR, Jiang WB, 2005. Effects of chitosan coating on shelf life of cold-stored litchi fruit at ambient temperature. LWT- Food Sci Tech 38: 757-761.

[30]. Jianglian D, Shaoying Z, 2013. Application of chitosan-based coating in fruit and vegetable preservation: A Review. J Food Processing Tech 4: 227

[31]. Kader AA, 1986. Biochemical and physiological basis for effects of controlled and modified atmospheres on fruits and vegetables. Food Tech 40: 99–104.

[32]. Li H, Yu T, 2001. Effect of chitosan on incidence of brown rot, quality and physiological attributes of postharvest peach fruit. J Sci Food Agric 81(2):269 – 274.

[33]. Liu J, Tian SP, Meng XH, Xu Y, 2007. Effects of chitosan on control of postharvest diseases and physiological response of tomato fruit. Postharvest Biol Tech 44: 300–306.

[34]. Malerba M, Cerana R, 2016. Chitosan effects on plant systems. Int J Mol Sci 17(7): 996. DOI: 10.3390/ijms17070996

[35]. Morillon V, Debeaufort F, Blond G, Capelle M, Voilley A, 2002. Factors affecting the moisture permeability of lipid-based edible films: a review. Crit Rev Food Sci 42: 67-89.

[36]. Olivas GI, Barbosa-Cánovas GV, 2005. Edible coatings for fresh-cut fruits. Crit Rev Food Sci Nut 45 (7/8): 657=670.

[37]. Ozgen M, Durgac C, Scrce S, Kaya C, 2008. Chemical and antioxidant properties of pomegranate cultivars grown in the Mediterranean region of Turkey. Food Chem 111: 703-706.

[38]. Petersen RG, 1985. Design and analysis of experiments. Marcel Dekker, Inc. New York: 253-301pp.

[39]. Plácido GR, Silva RM, Cagnin C, CavalcanteMD, Silva MAP, Caliari M, Lima MS, Nascimento LE, 2016. Effect of chitosan-based coating on postharvest quality of tangerines (*Citrus deliciosa* Tenore): Identification of physical, chemical, and kinetic parameters during storage. Afric J Agric Res 11(24): 2185-2192.

[40]. Plainsirichai M, Leelaphatthanapanich S, Wongsachai,N, 2014. Effect of chitosan on the quality of rose Apples (Syzygium Agueum Alston) cv. Tabtim Chan stored at an ambient temperature. APCBEE Procedia 8: 317 – 322.

[41]. Pongener A, Mahajan BVC, Singh H, 2011. Effect of different packaging films on storage life and quality of peach fruits under cold storage conditions. Ind J Hort 68(2): 240-245.

[42]. Qiuping Z, Wenshui X, 2007. Effects of 1-methylcyclopropene and/or chitosan coating treatments on storage life and quality maintenance of Indian jujube fruit. LWT 40: 404-411.

[43]. Saltveit ME, 2002. The rate of ion leakage from chilling-sensitive tissue does not immediately increase upon exposure to chilling temperatures. Postharvest Biol Tech 26: 295-304.

[44]. Santana LRR, Benedetti BC, Sigrist JMM, 2010. Sensory characteristics of 'Douradao' peaches submitted to modified atmosphere packaging. Revista Brasileira de Fruticultura Jaboticabal 32(3): 700-708.

[45]. Serrano M, Diaz-Mula HM, Zapata PJ, Castillo S, Guillén F, Martinez-Romero D, Valverde JM, Valero D, 2009. Maturity stage at harvest determines the fruit quality and antioxidant potential alter storage of sweet cherry cultivars. J Agric Food Chem 57: 3240–3246.

[46]. Snedecor GW, Cochran WG,1989. Statistical Methods, 8th Edition, Iowa State University Press.

[47]. Sun D, Liang G, Xie J, Lei,X, Mo Y, 2010. Improved preservation effects of litchi fruit by combining chitosan coating with ascorbic acid treatment during postharvest storage. Afric J Biotech 9(22): 3272-3279.

[48]. Ullah S, Khan AS, Malik AU, Shahid M, Razzaq K, 2015. Cultivar, harvest location and cold storage influence fruit softening and antioxidative activities of peach fruit [(*Prunus persica* (L.) batsch]. Pak J Botan 47 (2), 699-709.
[49]. Valero D, Mirdehghan SH, Sayyari M, Serrano S, 2014. Vapor treatments, chilling, storage and antioxidant in pomegranate. In: Preedy, V. R. (ed.). Processing and impact on active components in food. Academic press, London. 189-196 pp.
[50]. Whilton TH, Bassuk NL, Ranney TG, Reichert DL, 1992. An improved method for using electrolyte leakage to access membrane competence in plant tissues. Plant Physiol 98: 198-205.
[51]. Wong D, Gastineau F, Gregorsk KS, Tillin SJ, Pavlath, AE. 1992. Chitosan–lipid films microstructure and surface energy. Food Chem 40: 540–544.
[52]. Xu JG, Zhao XM, Han XW, Du YG, 2006. Antifungal activity of oligochitosan against *Phytophthora capsici a*nd other plant pathogenic fungi in vitro. Pest Biochem Physiol 87: 220–228.

Table 1. Types of modified atmosphere packaging
* = Water vapor transmission, ** = water vapor permeability

Modified atmosphere Packaging (MAP)	Thickness (mm)	slope	Area (m^2)	WVTR*	WVP** (g. mm m^{-2}. day. mmHg)	O2 Permeability (m3 m-1.day.mmHg)	CO2 Permeability (m3m-1.day.mmHg)
MAP 1 (low density polyethylene 40 micro/Nano calcium carbonate)	0.074	0.0049	0.0013	0.0003	0.0693	2.25E-05	2.53E-07
MAP 2 (low density polyethylene)	0.033	0.0087	0.0013	0.0002	0.0549	3.26E-06	8.48E-08
MAP 3 (low density polyethylene + liner polyethylene)	0.083	0.0017	0.0013	0.0001	0.0270	7.70E-07	1.53E-06

Table 2. Effect of chitosan (Chi.) dipping and modified atmosphere packaging (MAP) on vitamin C (V.C.), anthocyanin (An.), total carotenoids (T. Car.), total phenols (T. Phl.) and electrolyte leakage (E.L.) of peach fruits after 10 days at 10 ˚C and 85-90 % R.H

Treatments	V.C (%)		An. ($mg100g^{-1}$)		T. Car. ($mg100g^{-1}$)		T. Phl. ($mg100g^{-1}$)		E.L. (%)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Control	14.6	13.3	3.48	5.38	0.17	0.28	0.21	0.38	80.5	79.9
MAP 1	15.5	13.9	2.14	2.33	0.16	0.26	0.39	0.53	68.3	73.8
MAP 2	16.7	16.7	2.17	2.61	0.15	0.27	0.44	0.44	53.6	76.0
MAP 3	16.1	17.0	2.17	2.90	0.16	0.27	0.47	0.48	57.4	71.1
Chi 1	14.6	13.6	2.39	3.54	0.17	0.27	0.40	0.57	76.2	70.4
Chi 2	14.4	16.7	2.25	3.50	0.16	0.28	0.37	0.68	75.1	71.1
L.S. D. 0.05	1.1	2.1	0.27	0.72	0.02	0.05	0.33	0.12	8.2	6.3

Table 3. Effect of chitosan (Chi.) dipping and modified atmosphere packaging (MAP) on fruit firmness, color, titratable acidity of peaches after 10 days at 10 ˚C and 85-90 % R.H

Treatments	Firmness				Color				Acidity	
	(N)		(L*)		(*h*˚)		(C)		(%)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Control	28.0	15.9	63.6	60.8	109.2	61.8	17.5	11.9	0.47	0.33
MAP 1	55.7	28.9	65.2	59.8	111.9	76.9	15.0	11.6	0.54	0.31
MAP 2	54.9	40.8	65.4	61.8	112.5	77.9	14.6	11.2	0.53	.34
MAP 3	54.7	41.2	63.7	59.2	110.8	71.1	14.2	11.7	0.54	0.34
Chi.1	27.9	18.7	64.9	62.0	110.5	53.8	15.7	11.4	0.50	0.36
Chi.2	27.0	17.8	66.6	60.4	108.7	58.9	15.6	11.2	0.51	0.37
L.S.D. 0.05	2.4	1.1	1.4	3.2	2.8	7.3	1.3	0.9	0.04	0.03

Table 4. Effect of chitosan (Chi.) dipping and modified atmosphere packaging (MAP) on fruit soluble solids (SSC), reducing (R.), non-reducing (N.R.) and total (T.) sugars, total chlorophyll (T. Chl.) of Late Swelling peaches after 10 days at 10 ˚C and 85-90 % R.H

Treatments	SSC				Sugars (%)				T. Chl.	
	(%)		R.		N.R.		T.		(%)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Control	14.4	11.1	2.12	2.24	7.41	7.58	9.53	9.82	106.3	65.7
MAP 1	15.1	12.7	2.17	1.67	7.00	7.11	9.17	9.09	175.9	114.1
MAP 2	15.5	12.1	2.02	1.89	6.77	7.14	8.79	9.02	193.3	125.7
MAP 3	14.7	12.8	1.93	1.84	7.10	6.80	9.03	8.64	168.2	102.5
Chi.1	14.2	13.1	1.99	2.22	7.20	7.82	9.18	10.04	129.5	81.2
Chi.2	14.5	12.6	1.86	2.18	8.29	6.96	10.16	9.13	170.1	73.0
L.S.D. 0.05	0.5	0.8	0.4	1.1	0.80	0.70	0.63	0.51	21.2	19.2

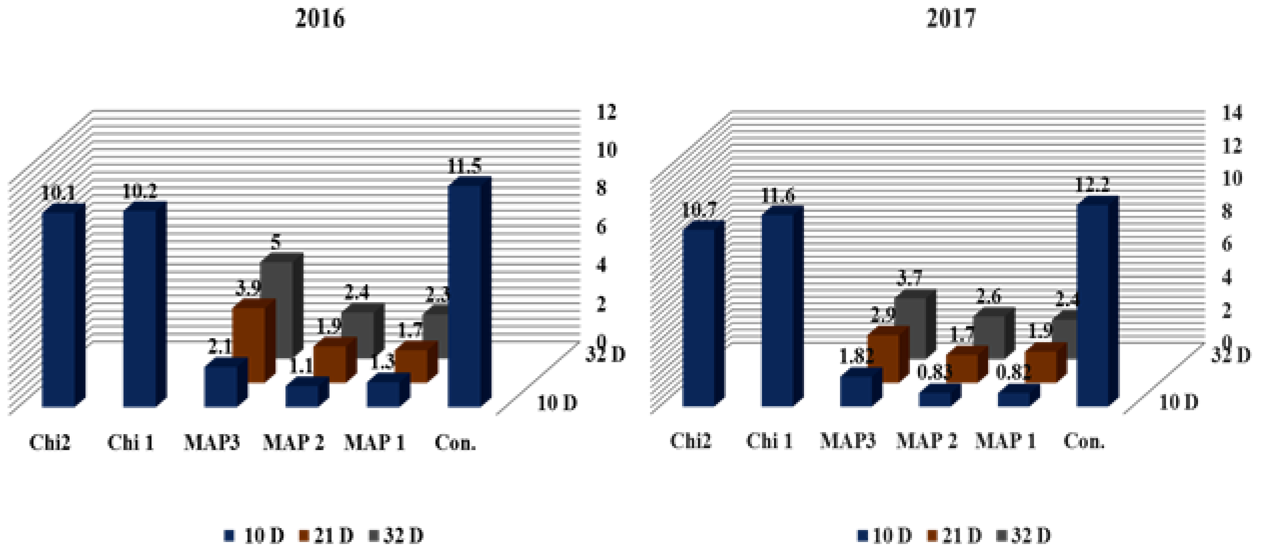

Fig. 1. Effect of chitosan (Chi.) postharvest dipping and modified atmosphere packaging (MAP) on fruit weight loss (%) after 10 days in 2016 and 2017

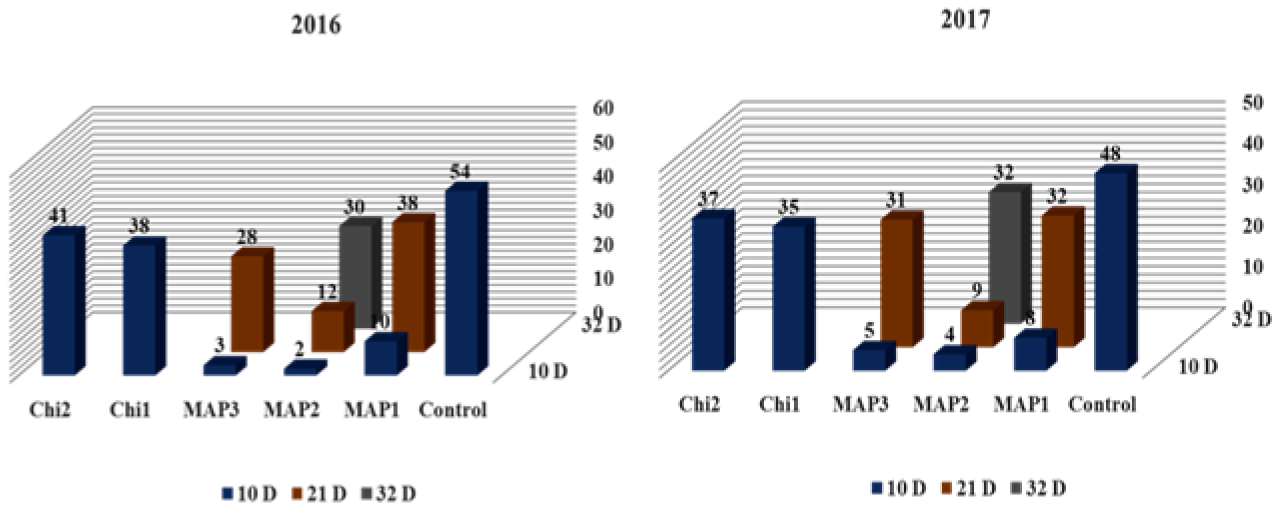

Fig. 2. Effect of chitosan (Chi.) postharvest dipping and modified atmosphere packaging (MAP) on Unmarketable fruits (%) after 10, 21 and 32 days in 2016 and 2017

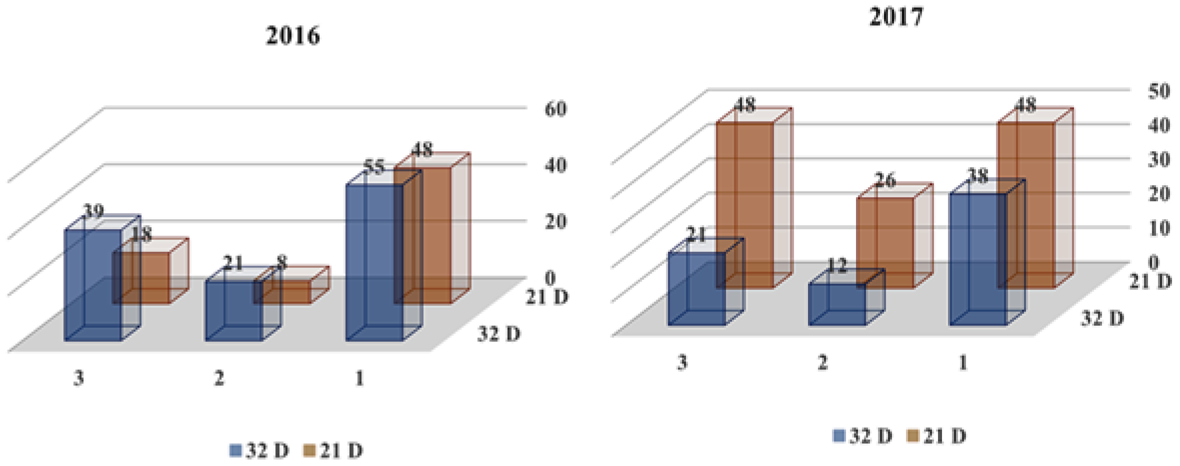

Fig. 3. Effect of chitosan (Chi.) postharvest dipping and modified atmosphere packaging (MAP) on off flavour (%) after 21 and 32 days in 2016 and 2017