Effect of Chitosan Coating and Storage Temperature on Shelf-Life and Fruit Quality of Ziziphus Mauritiana

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ABSTRACT
Due to short shelf-life of ber fruits, developing postharvest protocols incorporating nonchemical compounds with the aim of extending its shelf life and maintaining quality is one of the major issues regarding ber fruit industry. The quality of ber fruits is greatly affected by postharvest factors especially temperature and fruit treatment. In the present study, the effect of chitosan coating and storage temperature on the physicochemical characteristics of ber fruits was investigated as a factorial experiment based on randomized complete block design with three factors (chitosan coating, storage temperature, and storage time). The ber fruits were soaked in 0%, 0.5%, and 1% chitosan solution and stored at 5 and 25°C for 28 days. Changes in fruit weight loss, shriveling, fruit firmness, total soluble solid (TSS), titratable acidity (TA), ascorbic acid as well as decay rate were periodically recorded. The results indicated that the chitosan coating significantly prevented from reducing of fruit weight, firmness, TSS, TA, and ascorbic acid content. Also, the chitosan coating controlled fruit decay. Chitosan at low temperature (5°C) had a greater positive effect on fruit shelf life and weight maintenance than 25°C. In the other words, storage temperature had influence on fruit quality and shelf life, so that the best temperature for storing of ber fruit was 5°C and fruits stored at 25°C were destroyed after two weeks. In general, the results showed that chitosan coating (1%) with low-temperature storage (5°C) is the most effective strategy for improving the physiological quality and prolong the shelf life of ber fruits.

KEYWORDS
Ber fruits; chitosan coating; low temperature; storage-life; weight loss

Introduction
Ziziphus fruits, which is among the important tropical and sub-tropical fruits, belong to the Ziziphus genus and Rhamnaceae family (Azam-Ali et al., 2006). Ber fruit (Ziziphus mauritiana Lamk.) are commonly eaten as fresh fruit. It also can be consumed as dried. The fruits begin to ripening after the harvesting in the green-golden-yellow stage. Ber fruit ripening occur with color change from green or golden-yellow to red or red-brown and has the best quality in green-mature or green-yellowish stage. This fruit has a short storage which is a major challenge in developing its industry (Rao et al., 2016). In the other words, postharvest handling and transportation loses its postharvest life become shorter and keeping possibility of fruit in the storage is not easily feasibly (Aboutalebi and Ramazani, 2014). Fresh fruits of Z. Mauritiana deteriorate fast and cannot be kept for more than 10 days under ambient conditions without serious deterioration (Kadzere et al., 2004; Pareek, 2001). Thus, the development of appropriate postharvest protocols and treatments is required to maintain ber fruit quality during handling and transportation of fresh produce. To maintain the physiological quality and prolong the...
shelf life of fresh Ziziphus fruits, many methods including lower temperature, controlled atmosphere storage, using preservative, or coating edible film were taken into account (Nallathambi et al., 2009; Rao et al., 2016; Wu et al., 2010; Zhang et al., 2014).

Instead of using chemical fungicides, Chitosan, a natural alkaline polysaccharide, has become one of the most popular edible film materials in recent years owing to its non-toxicity and superior biocompatibility. Chitosan is widely used as a food additive and a suitable alternative to synthetic fungicides for treating postharvest fruits and vegetables (Romanazzi et al., 2017). Chitosan as a natural and environmentally friendly compound is obtained from deacetylation of chitin (Khoshgozaran-Abras et al., 2012). Chitosan and its derivatives increase shelf life of a wide range of vegetables and fruits by inhibiting decay. So, one of interest application of this biopolymer is products preservation because of its ability to be used as coating materials (Chien et al., 2007; Devlieghere et al., 2004; Qiuping and Wenshui, 2007; Sabir et al., 2019). The function of chitosan as an antimicrobial material attributed to amino groups or hydrogen bonding between chitosan and extra cellular polymers (Hughes et al., 1994). As a biopolymer, chitosan has excellent film forming properties and is able to form a semipermeable film on fruit which may modify the internal atmosphere, as well as decrease weight loss and shriveling due to transpiration and improve overall fruit quality (El-Badawy and El-Sally, 2011; Hong et al., 2012; Xing et al., 2011a).

Chitosan coating maintains fruit quality during storage by preventing the loss of fruit weight, soluble solid contents, vitamin C, titratable acidity, and firmness (Chiabrando and Giacalone, 2013; Lin et al., 2020; Romanazzi et al., 2002). Krishna and Rao (2014) reported that chitosan treatment (1%) extending the shelf life of guava up to 7 days by delaying ripening and preventing physiological loss in weight. Chitosan formulated with cassava starch significantly preserved fruit weight, color, aroma and texture of mango and increased shelf life by decreasing the respiration rate without negative effect on the fruit ripening (Camatari et al., 2018). In addition to chitosan coating, temperature management is one of the most important tools for extending the shelf life of fruits and have the main environmental factor influence on fruit quality (Lee and Kader, 2000). Tembo et al. (2008) reported that storing fresh ber fruits at 5°C showed 48% of fruit weight loss compared to the control which showed 75% of weight loss during the entire 12-week storage.

The contribution of indigenous fruits is limited to areas where the trees grow naturally because of the absence of processing and preservation technologies and marketing opportunities. The ber fruits are high in vitamin A and C and other mineral nutrients. Due to the short storage life of these fruits, appropriate methods are required to maintain its postharvest quality which is not only increases the post-harvest life, but it can play an important role in time of marketing by delivering ber fruit to distant markets. Therefore, this study was carried out to evaluate the effect of chitosan coating and low temperature on maintaining fruit quality and increasing shelf life of ber during storage.

**Materials and Methods**

**Plant Material and Treatments**

Fresh Ber fruits (Ziziphus mauritiana cv. Seb) were harvested in green ripening stage (130 days after full bloom) as handpick from a commercial orchard in Bushehr province, Iran. Fruits were carefully transported immediately under ambient condition to the Postharvest Laboratory of Persian Gulf University, Bushehr, Iran. The harvested fruits were selected again for uniformity in size, color and freedom from external damage and free from defects. The experiment was conducted in a factorial in randomized complete block design composed of three factors with four replications (20 fruits per replication). The factors were three concentrations of chitosan (0%, 0.5%, and 1%), two storage temperature (5 and 25°C) and four storage time (7, 14, 21 and 28 days). The chitosan (Sigma-Aldrich) solutions were prepared based on the method described by Jiang and Li (2001). Glacial acetic acid was used to dissolve the chitosan. Also, the pH of the solution was adjusted to pH = 6. The ber fruits were soaked in the desired chitosan solution for 5 minutes. Distilled water was used for control
treatment. After applying chitosan treatment, fruits were allowed to dry for 2 h at 25°C and placed within plastic packages and stored at 5°C and 25°C with relative humidity of 80% for 28 days.

**The Studied Traits**

The characteristics were measured at intervals of 7 days from storage time. At each sampling time, weight loss, shriveling, fruit firmness, total soluble solid content, titratable acidity, ascorbic acid as well as decay rate were counted. For the decay and shriveling fruits, the total number of fruits and the number of decayed and shriveled fruits were counted, respectively. Fruit samples were weighed using a digital balance at the start of experiment and at the end of each storage interval. The difference between initial and final fruit weight was considered as total weight loss during that storage interval. The calculations were made in percentages on fresh weight basis. The decay rate, shriveling and percentage of weight loss calculated by using the following formula, respectively:

- Fruit weight loss = \((\text{initial weight-secondary weight})/\text{initial weight}\) ×100.
- Fruit decay = (number of decayed fruits/total number of fruits) ×100.
- Fruit shriveling = (number of shriveling fruits/total number of fruits) ×100.

Fruit firmness, as the force required to puncture the fruit, was measured using an Instron-Universal testing machine (Model 4201, USA) and expressed as kg per cm². The peeled fruit was used to record fruit firmness. The Total Soluble Solids (TSS) of fruit juice was determined by a digital refractometer (Model PAL-3, Japan) at 20°C (AOAC, 2003). Titratable acidity was determined by titration with 0.1 M NaOH to pH 8.2 and expressed as citric acid (mg) on the basis of fresh weight (FW). Ascorbic Acid (Vitamin C) contents were determined by the Indophenol’s titration method (Ruck, 1963).

**Statistical Analysis**

The data were grouped at a defined time for analysis by analysis of variance (ANOVA) using SPSS software (SPSS Inc., Chicago, IL, USA). Means comparison were determined using a Duncan’s Multiple Range Test at 5% probability level.

**Result and Discussion**

**Fruit Weight Loss and Shriveling**

The results showed the main effects of factors (storage temperature, chitosan and storage time) on the studied traits were significant at 1% probability level. Also, the interaction effects of storage temperature, chitosan and storage time were significant on fruit weight loss, decay, shriveling, vitamin C, total soluble solid \((P<.01)\), firmness and titratable acidity \((P<.05)\) (Table 1).

The results showed that low storage temperature significantly reduced weight loss of ber fruits over the 28 days of storage. In other words, uncoated fruits stored at 5°C lost only 10.57% of their weight after 28 days of storage; while, uncoated fruits stored at 25°C lost 16.05% after 14 days of storage (Figure 1a). Temperature management after harvesting is the most important factor in maintaining fruit quality after harvesting and during storage (Arah et al., 2015). As a result of high temperatures, transpiration causes water loss and fruit weight loss. Our results showed that increasing temperature increase fruit weight loss. A previous study on the effect of storage temperature on shelf life of *Ziziphus mauritiana* cv. Emran showed that the best condition was the use of polyethylene boxes and cool temperature (Meena et al., 2009). The rate of water loss depends on the water pressure gradient between the fruit tissue and the surrounding atmosphere and the storage temperature (Hernandez-Munoz et al., 2008).

Based on our results, chitosan-coated ber fruits (1%) presented the lowest weight loss (3.6%) after 28 days of storage at 5°C. In addition, chitosan significantly reduced weight loss of ber fruit even at 25°C. Unlike the control and 0.5% chitosan, higher chitosan concentration (1%) led to increase in storage.
Table 1. Variance analysis of effect of chitosan and storage temperature on shelf life and some quality traits of ber fruit.

| S.O.V           | df | Weight loss | Fruit shriveling | Fruit decay | Fruit firmness | TSS          | Vitamin C | Total acidity |
|-----------------|----|-------------|------------------|-------------|----------------|--------------|------------|--------------|
| Block           | 3  | 3.2 ns      | 5.3 ns           | 4.1 ns      | 0.02 ns        | 0.50 ns      | 5.4 ns     | 0.003 ns     |
| Temperature (A) | 1  | 9235.2**    | 63930**          | 12235.1**   | 29.09**        | 1.01**       | 6240.4**   | 0.234**      |
| Chitosan (B)    | 2  | 181.5***    | 1168.4**         | 268.9**     | 0.24**         | 4.56**       | 153.8**    | 0.049**      |
| Storage time (C)| 3  | 1609.4***   | 13180.7**        | 9946.3**    | 14.05**        | 18.36**      | 145.3**    | 0.035**      |
| A × B           | 2  | 143.7***    | 779.6**          | 176.4**     | 0.09**         | 0.47*        | 38.4**     | 0.001*       |
| A × C           | 3  | 804.9***    | 12771.4**        | 8716.3**    | 1.43**         | 0.87*        | 101.0**    | 0.005*       |
| B × C           | 6  | 42.8**      | 135.5**          | 221.0**     | 0.05*          | 0.39ns       | 45.2**     | 0.005*       |
| A × B × C       | 6  | 30.4**      | 78.9**           | 167.0**     | 0.11*          | 0.90**       | 56.3**     | 0.007*       |
| Error           | 23 | 4.0         | 8.2              | 4.6         | 0.03           | 0.14         | 3.1        | 0.001        |
| CV (%)          |    | 19.2        | 11.4             | 18.8        | 10.5           | 2.7          | 7.8        | 10.5         |

*ns not significant, * and ** significant at 5% and 1% probability levels, respectively.

Figure 1. Effect of storage temperature and chitosan coating on the cumulative weight loss (a) and shriveling (b) of Ber fruits. Each value is the mean for three replicates and vertical bars indicate the standard errors.

Life of ber fruit up to 21 days, whereas in the control and 0.5% chitosan treatments, the fruits were rot at the end of the second week (14 days of storage). Fruits without chitosan coating (control) showed the highest weight loss (10.57%) at same temperature (5°C) (Figure 1a). Chitosan coating significantly maintained fruit weight and this effect was significantly higher at 1% chitosan which were consistent with previous studies on ber fruit (Dutta et al., 2016), and grapes (Sabir et al., 2019). Generally, chitosan coating can be considered as a suitable commercial edible film to maintain fruit weight in cold storage (Kou et al., 2019). Chitosan coating could serve as a commercial semi-permeable layer which reduces gas exchange and moisture led to reduces respiration and water loss during the postharvest storage of fruits (Dutta et al., 2016; Xing et al., 2011b). Bhomick et al. (2015) reported that uncoated ber fruits lost 24.46% of their weight at 12 days after storage, whereas the weight losses for samples coated with 0.5%, 1%, and 2% of chitosan were 14.18%, 13.38%, and 12.48%, respectively. Camatari et al. (2018) also reported that mango coated with a higher level of chitosan (0.5%) presented lower weight loss during storage.

During the experiment, low temperature (5°C) led to a significant decrease in fruit shriveling. Also, chitosan coating tended to maintain significantly lower rates of shriveling than control during storage period. Ber fruits treated by the chitosan coating (especially 1% chitosan) presented the lowest rates of shriveling (7.5%) after 28 days of storage at 5°C. However, the untreated fruits (control) which are stored at 25°C had the highest rates of shriveling (47.43%) at the end of storage. So that, the untreated ber fruits being stored at 25°C were completely unmarketable in 14 days after storage and so, they were not suitable to
be considered to continue the experiment. Mani et al. (2018) reported that the coating of ber fruits led to a decrease in fruit shrinkage and the maximum shrinkage was observed in uncoated fruits that our obtained results confirmed. Chitosan coatings act as barrier, thereby restricting water transfer and protecting fruit skin from mechanical injuries, as well as sealing small wounds and thus delaying dehydration (Hernandez-Munoz et al., 2006). Fruits stored at low temperature had a low proportion of shriveled fruits compared to ambient temperature conditions. High temperatures led to increased water loss from fruits resulting in fruit shriveling and loss of fresh appearance (Wills et al., 1989). Visual fruit shriveling can occur when water loss reaches 3% to 5% of initial fruit weight (Kader and Mitchell, 1989). Ber fruits are climacteric and therefore produce ethylene during storage, which accelerates senescence and shriveling. Low temperatures reduce the sensitivity of fruits to ethylene, thus delaying fruit senescence and shriveling (Wills et al., 1989).

**Decay Rate and Fruit Firmness**

The results revealed that chitosan and low temperature decreased the decay and effectively increased life storage of *Ziziphus mauritiana*. At low storage temperature (5°C), fruits didn’t show decay symptom after 14 days of storage. In addition, fruits treated with chitosan (1%) and stored at 5°C had no decay symptom until 21 days of storage. At the end of the experiment, fruits treated with chitosan showed the lowest decay and with increasing concentration of chitosan, the decay decreased significantly. The decay rate increases during storage period, so that the highest decay percentage was observed at the end of experiment which had significant difference with other sampling times (Figure 2a). Previous studies confirmed the antimicrobial properties of chitosan (Camatari et al., 2018) which had the potential to control decay of many fruits such as mango (Camatari et al., 2018; Chien et al., 2007), jujube (Wang et al., 2014), strawberry (Romanazzi et al., 2013), sweet cherries, table grape (Romanazzi, 2010) and apple (Li et al., 2015). Chitin is a common component of fungal cell walls. Chitosan induces chitinase as a defense enzyme which catalyzes the hydrolysis of chitin, thus preventing the growth of fungi on the fruit (El-Ghaouth et al., 1991). Chitosan coating can form a protective barrier on the surface of fresh fruit, and bring about to decrease microbial growth that causes fruit rotting (Qiuping and Wenshui, 2007 and Dutta et al., 2009). In addition to this direct effect, chitosan as an exogenous elicitor increases the resistance to future pathogen infections by increasing peroxidase (POD) and polyphenol oxidase (PPO) activities (Li et al., 2015). Devlieghere et al. (2004) found that the antimicrobial activity of chitosan will depend on several factors such as the kind of chitosan, storage temperature, and food components.

According to the results, the reduction of fruit flesh firmness during storage was observed for all treatments. Storage temperature significantly had a negative effect on fruit flesh firmness and fruit firmness decreased with increasing storage temperature. Compared to the control, ber fruits treated with chitosan

![Figure 2](image_url)

Figure 2. Effect of storage temperature and chitosan coating on decay percentage (a) and firmness (b) of Ber fruits. Each value is the mean for three replicates and vertical bars indicate the standard errors.
exhibited significantly lower fruit flesh firmness. The highest reduction percentage (74.11%) of fruit flesh firmness was recorded in control at the end of storage (Figure 2b). In general, chitosan coating is able to prevent the reduction of fruit firmness especially at low storage temperature. Fruit texture properties are affected by cell turgidity and the structure and composition of the cell wall polysaccharides (Van Buren, 1979). The current study confirms that fruits stored at the cold storage condition had better fruit firmness and acceptable organoleptic quality during low‐temperature storage compared to storage at room temperature. Low temperature reduces respiration and metabolic processes thereby slowing down losses in the rate of fruit firmness during fruit storage (Brizzolara et al., 2020). The better firmness of coated ber fruits as compared to untreated ones can probably be explained by degradation of insoluble propectins to soluble pectin and pectic acid (Yaman and Bayoudhrlı, 2002). During fruit ripening, de polymerization or shortening of chain length of pectin substances occurs with an increase in pectin‐esterase and polygalacturonase activities (Kashappa and Hyun, 2006). Also, chitosan coating led to reduce oxygen availability which reduce these enzymes and increased retention of fruit firmness during storage (Abbasi et al., 2009).

**Chemical Analysis of Ber Fruits**

The present study showed that the ber fruits coated with chitosan had higher vitamin C content than the control samples at the end of the storage period. The initial vitamin C content of both coated and uncoated fruits was 39.3 mg per 100 g FW. After 28 days of storage, ascorbic acid contents in samples coated with 0.5% and 1% of chitosan decreased to 12.6 and 22.12 mg per 100 g FW at 5°C, respectively; whereas it was 8.23 mg per 100 g FW in uncoated fruits at same temperature. Vitamin C content of ber fruit juice also decreased with increasing storage temperature and time. So that, the lowest vitamin C was observed in uncoated fruits at 25°C (Figure 3a). Ascorbic acid has characteristics of unstable molecule that may undergo auto-oxidation into dehydroascorbic acid, which although being reversible, may cause losses in product quality and lead to increased and decreased contents in stored fruits. Oxidation of ascorbic acid may be caused by several factors including exposure to oxygen, metals, light, heat and alkaline pH and inhibited by low storage temperature and fruit coating (Sritananan et al., 2005). Chitosan as a protective layer controls the permeability of O₂ and CO₂ (Srinivasa et al., 2002).

Based on the results, the total soluble solids of ber fruit generally decreased during fruit ripening in storage (Dutta et al., 2016). However, at first it showed an increasing trend and then a significant decreasing trend. Chitosan coating treatment delayed the decrease in concentrations of total soluble solids. Also, fruits stored at the cold storage condition showed the lowest reduction of total soluble solid (Figure 3b). The decline of carbohydrates and pectins, decomposition of glycosides and hydrolysis of

![Figure 3.](image-url) Effect of storage temperature and chitosan coating on Vitamin C (a) and TSS (b) of Ber fruits. Each value is the mean for three replicates and vertical bars indicate the standard errors.
protein are some of main reason of decreasing of TSS during fruit storage (Wongmetha et al., 2015). Bautista-Banos et al. (2006) reported the effect of chitosan coating on TSS content of fruit juice depended on fruit species. So that, chitosan decreased the TSS of fruit juice in mango and banana and increases in peaches (Du et al., 1997; Kittur et al., 2001; Srinivasa et al., 2002).

The titratable acidity of ber fruits decreased by 27.6% and 67.3% in fruits stored at 5°C and 25°C storage temperature, respectively. Fruits stored under low temperature maintained a higher level of titratable acidity (P <.01) during the storage time. The titratable acidity decreased significantly along with increased storage time in both coated and uncoated fruits (Bhowmick et al., 2015). The results showed that chitosan coating slowed the reduction of titratable acidity (Figure 4) which is consistent with the results of previous reports on pomegranates (Salama et al., 2012) and pineapple (Ibrahim et al., 2014). The effect of chitosan on trend of TA of ber fruit is due to the semi-permeable film of chitosan on fruit which changes the fruit internal atmosphere (CO2 and O2 concentration) and thus reduces respiration rate (Abbasi et al., 2009). Romanazzi (2010) reported that chitosan coating inhibited respiration of sweet cherries, grapes and strawberries. Thus, the higher levels of titratable acidity in the fruits coated with chitosan found in this study may be due to the reduction of the oxygen supply on the fruit surface which inhibited respiration (Chiabrando and Giacalone, 2013; Yonemoto et al., 2002).

**Conclusion**

In conclusion, chitosan coating is able to maintain the quality of ber fruit to increase its storage time. Chitosan increases the shelf-life of ber fruit by preventing fruit shriveling, water loss and controlling decay. It also maintains the biochemical quality of ber fruits by preventing the reduction of soluble solids content, vitamin C, and acidity. The positive effect of chitosan on postharvest quality of ber fruits was enhanced when the higher concentration (1%) used along with low-temperature storage. Based on the results, low storage temperature is one of the main strategies for increasing shelf-life and improving postharvest quality of ber fruits. In general, chitosan coating (1%) along with low temperature (5°C) is the best strategy for extending shelf-life and improving the physiological quality of ber fruits. The ber fruits were well stored under these conditions for more than 28 days, which needs to be examined in future studies.
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References
Abbasi, N.A., Z. Iqbal, M. Maqbool, and I.A. Hafiz. 2009. Postharvest quality of mango (Mangifera indica L.) fruit as affected by chitosan coating. Pak. J. Bot. 41(1):343–357.
Aboutalebi, A., and M. Ramazani. 2014. Effect of temperature and storage duration on qualitative properties of Indian Ziziphus (Ziziphus mauritiana Lam., cv. ‘Seb’). Ind. J. Fund. Appl. Life Sci. 4(4):93–96.
AOAC. 2003. Association of official analytical chemists official methods of analysis. 17th ed. Association of Analytical Washington, DC, USA.

Arah, I.K., H. Amaglo, E.K. Kumah, and H. Ofori. 2015. Preharvest and postharvest factors affecting the quality and shelf life of harvested tomatoes: A mini review. Int. J. Agro. 2015:1–6. doi: 10.1155/2015/478041.

Azam-Ali, S., E. Bonkongou, C. Bowe, C. De Kock, A. Godara, and J.T. Williams. 2006. Fruits for the future 2: Ber and other Jujubes. International Centre for Underutilized Crops. University of Southampton, Southampton, UK.

Bautista-Banos, S., A.N. Hernandez-Lauzardo, M.G. Velazquez-Del Valle, M. Hernández-López, E.A. Barka, E. Bosquez-Molina, and C.L. Wilson. 2006. Chitosan as a potential natural compound to control pre and postharvest diseases of horticultural commodities. Crop Prot. 25(2):108–118. doi: 10.1016/j.cropro.2005.03.010.

Bhownick, N., A. Ghosh, P. Dutta, and K. Dey. 2015. Efficacy of edible coatings on the shelf life of ber (Ziziphus mauritiana Lamk.) fruits at ambient condition. Int. J. Agric. Environ. Biotechnol. 8(3):601–608. doi: 10.5958/2230-732X.2015.00066.2.

Brizzolar, S., G.A. Manganaris, V. Fotopoulos, C.B. Watkins, and P. Tonutti. 2020. Primary metabolism in fresh fruits during storage. Front. Plant Sci. 11. doi: 10.3389/fpls.2020.00080.

Camatari, F.O.D.S., L.C.L.D.A. Santana, M.A.G. Carnelossi, A.P.S. Alexandre, M.L. Nunes, M.O.F. Goulart, N. Narain, and M.A.A.P.D. Silva. 2018. Impact of edible coatings based on cassava starch and chitosan on the post-harvest shelf life of mango (Mangifera indica) ‘Tommy Atkins’ fruits. Food Sci. Technol. 38:86–95. doi: 10.1590/1678-457x.16417.

Chibarando, V., and G. Giacalone. 2013. Effect of different coatings in preventing deterioration and preserving the quality of fresh-cut nectarines (cv Big Top). J. Food. 11(3):285–292. doi: 10.1080/19476337.2012.745096.

Chien, P.J., F. Sheu, and F.H. Yang. 2007. Effects of edible chitosan coating on quality and shelf-life of sliced mango fruit. J. Food Eng. 78(1):225–229. doi: 10.1016/j.jfoodeng.2005.09.022.

Devlieghere, F., A. Vermeulen, and J. Debevere. 2004. Chitosan: Antimicrobial activity, interactions with food components and applicability as a coating on fruit and vegetables. Food Micro 21(6):703–714. doi: 10.1016/j.fm.2004.02.008.

Du, J.M., H. Gemma, and S. Iwahori. 1997. Effects of chitosan coating on the storage of peach, Japanese pear, and kiwifruit. J. JPN. Soc. Hort. Sci. 66:15–22. doi: 10.2503/jjshs.66.15.

Dutta, P., K. Dey, A. Ghosh, N. Bhownick, and A. Ghosh. 2016. Effect of edible coatings for enhancing shelf-life and quality in Ber (Ziziphus mauritiana Lamk.) fruits. J. Nat. Appl. Sci. 8(3):1421–1426. doi: 10.31018/jans.v8i3.976.

Dutta, P. K., S. Tripathi, G.K. Mehrotra and I. Dutta. 2009. Perspectives for chitosan based antimicrobial films in food applications. Food Chem 114(4):1173–1182. doi: 10.1016/j.foodchem.2008.11.047.

El-Badawy, H.E.M., and F.T.A. El-Sally. 2011. Physical and chemical of canine apricot fruits during cold storage as influenced by some postharvest treatment. Aust. J. Basic Appl. Sci. 5(9):537–548.

El-Ghaouth, A., J. Arul, R. Ponnampalam, and M. Boulet. 1991. Chitosan coating effect on storability and quality of fresh strawberries. J. Food Sci. 56(6):1618–1621. doi: 10.1111/j.1365-2621.1991.tb08655.x.

Hernandez-Munoz, P., E. Almenar, M.J. Ocio, and R. Gavara. 2006. Effect of calcium dips and chitosan coatings on postharvest life of strawberries (Fragaria ananassa). Post. Biol. Tec. 39:247–253. doi: 10.1016/j.foodchem.2008.02.020.

Hernandez-Munoz, P., E. Almenar, V. Del Valle, V. Velez, and R. Gavara. 2008. Effect of chitosan coating combined with post-harvest calcium treatment on strawberry (Fragaria ananassa) quality during refrigerated storage. Food Chem. 110:428–435. doi: 10.1016/j.foodchem.2008.02.020.

Hong, K., J. Xie, L. Zhang, D. Sun, and D. Gong. 2012. Effects of chitosan coating on postharvest life and quality of guava (Psidium guajava L.) fruit during cold storage. Sci. Hort. 144:172–178. doi: 10.1016/j.scienta.2012.07.002.
Hughes, J., D.K. Ramsden, and J.M. Boulby. 1994. The role of cellullosics in chitosan flocculation of Zymomonas mobilis. Biotechnol. Tech. 8(8):541–546. doi: 10.1016/BF00152142.

Ibrahim, S.M., S. Nahar, J.M.M. Islam, M. Islam, M.M. Hoque, R. Huque, and M.A. Khan. 2014. Effect of low molecular weight chitosan coating on physico-chemical properties and shelf life extension of pineapple (Ananas sativus). J. Forest Prod. Ind. 3(3):161–166.

Jiang, Y., and Y. Li. 2001. Effect of chitosan coating on postharvest life and quality of longan fruit. Food Chem. 73:139–143. doi: 10.1016/S0308-8146(00)00246-6.

Kader, A.A., and F.G. Mitchell. 1989. Post-harvest physiology, p. 158–164. In: J.H. LaRue and R.S. Johnson (Eds.). Peaches, plums and nectarines. Growing and handling of fresh market. University of California. Oakland, CA, USA. Kadhize, I., L. Hove, T. Gatsi, M.T. Masarirambi, L. Tafumaneyi, E. Maforibmo, and I. Magumise. 2004. Current status of post-harvest handling and traditional processing of indigenous fruits in Zimbabwe, p. 353–363. In: R.M.R. Kwekwa (ed.). Proc regional Agroforestry conference on Agroforestry impacts on livelihoods in Southern Africa: Putting research into practice. World Agroforestry Centre (ICRAF), Nairobi, Kenya.

Kashappa, D.G., and P.J. Hyun. 2006. Study of gamma irradiation effects on chitosan microparticles. Drug Deliv 13 (1):39–50. doi: 10.1080/10717540500309123.

Khoshgozaran-Abras, S., M.H. Azizi, Z. Hamidy, and N. Bagheripour-Fallah. 2012. Mechanical, physicochemical and color properties of chitosan based-films as a function of Aloe-vera gel incorporation. Carbohydr. Polym. 87 (3):2058–2062. doi: 10.1016/j.carbpol.2011.10.020.

Kittur, F.S., N.H. Saroja, R.N. Tharanathan, and R. Tharanathan. 2001. Polysaccharide-based composite coating formulations for shelf-life extension of fresh banana and mango. Eur. Food Res. Technol. 213:306–311. doi: 10.1007/s0021700100363.

Kou, X., Y. He, Y. Li, Y.X. Chen, Y. Feng, and Z. Xue. 2019. Effect of abscisic acid (ABA) and chitosan/nano-silica/ sodium alginate composite film on the color development and quality of postharvest Chinese winter jujube (Zizyphus jujuba Mill. cv. Dongzao). Food Chem. 270:385–394. doi: 10.1016/j.foodchem.2018.06.151.

Krishna, K.R., and D.S. Rao. 2014. Effect of chitosan coating on the physiochemical characteristics of guava (Psidium guajava L.) fruits during storage at room temperature. Ind. J. Sci. And Technol. 7(5):554. doi: 10.17485/ijst/2014/v7i5/49467.

Lee, S.K., and A.A. Kader. 2000. Pre-harvest and post-harvest factors influencing Vitamin C content of horticultural crops. Postharvest Biol. Tech. 20:207–220. doi: 10.1016/S0925-2514(00)00133-2.

Li, H., Y. Wang, F. Liu, Y. Yang, Z. Wu, H. Cai, Q. Zhang, Y. Wang, and P. Li. 2015. Effects of chitosan on control of postharvest blue mold decay of apple fruit and the possible mechanisms involved. Sci. Hort. 166:77–83. doi: 10.1016/j.scienta.2015.02.014.

Lin, Y., N. Li, H. Lin, M. Lin, Y. Chen, H. Wang, M.A. Ritenour, and Y. Lin. 2020. Effects of chitosan treatment on the storability and quality properties of longan fruit during storage. Food Chem. 306:125627. doi: 10.1016/j.foodchem.2019.125627.

Mani, A., V.S.S. Prasanna, S. Halder, and J. Praveena. 2018. Efficacy of edible coatings blended with aloe vera in retaining post-harvest quality and improving storage attributes in Ber (Ziziphus mauritiana Lamk.). Int. J. Chem Stud. 6(6):1727–1733.

Meena, H.R., A.R.P. Kingsly, and R.K. Jain. 2009. Effect of postharvest treatments on shelf life of Ber fruits. Ind. J. Hort. 66(1):58–61.

Nallathambi, P., C. Unamaheswari, B.B.L. Thakore, and T.A. More. 2009. Post-harvest management of ber (Ziziphus mauritiana Lamk) fruit rot (Alternaria alternata Fr. Keissler) using Trichoderma species, fungicides and their combinations. Crop. Protec. 28(6):525–532. doi: 10.1016/j.cropro.2009.02.002.

Pareek, O.P. 2001. Fruit for the future 2: Ber. International Centre for Underutilised crops. University of Southampton, Southampton, UK, 290.

Qiuping, Z., and X. Wenshui. 2007. Effect of 1-methylcyclopropene and/or chitosan coating treatments on storage life and quality maintenance of Indian jujube fruit. LWT-Food Sci. Technol. 40(3):404–411. doi: 10.1016/j.lwt.2006.01.003.

Rao, T.R., N.S. Baraiya, P.B. Vyas, and D.M. Patel. 2016. Composite coating of alginate-olive oil enriched with antioxidants enhances postharvest quality and shelf life of Ber fruit (Ziziphus mauritiana Lamk. Var. Gola). J. Food Sci. Technol 53(1):748–756. doi: 10.1007/s13197-015-2045-3.

Romanazzi, G. 2010. Chitosan treatment for the control of postharvest decay of table grapes, strawberries and sweet cherries. Fresh Produce 4:111–115.

Romanazzi, G., E. Feliziani, M. Santini, and L. Landi. 2013. Effectiveness of postharvest treatment with chitosan and other resistance inducers in the control of storage decay of strawberry. Postharvest Biol. Technol. 75:24–27. doi: 10.1016/j.postharvbio.2012.07.007.

Romanazzi, G., E. Feliziani, S.B. Baños, and D. Sivakumar. 2017. Shelf-life extension of fresh fruit and vegetables by chitosan treatment. Crit. Rev. Food Sci. 57(3):579–601. doi: 10.1080/10408398.2014.900474.

Romanazzi, G., F. Negro, A. Ippolito, D. DiVenere, and M. Salerno. 2002. Effects of pre-and postharvest chitosan treatments to control storage grey mold of table grapes. J. Food Sci. 67(5):1862–1867. doi: 10.1111/j.1365-2621.2002.tb08737.x.
Ruck, J.A. 1963. Chemical methods for analysis of fruits and vegetables. Res. State Summer Land, Res. Branch Canada, Dept. Agri. Publication No. 1154.

Sabir, F.K., A. Sabir, S. Unal, M. Taytak, A. Kucukbasmaci, and O.F. Bilgin. 2019. Postharvest quality extension of minimally processed table grapes by chitosan coating. Int. J. Fruit Sci. 19(4):347–358. doi: 10.1080/15538362.2018.1506961.

Salama, M.E.I., H.M. Ayaad, H.E. Aboul-Anean, and H.M. Fahmy. 2012. Effect of edible coating as a carrier of essential oils and ultraviolet light (UVC) on improving quality of minimally processed Manfalouty pomegranate. Res. J. Agric. Biol. Sci. 8(2):315–324.

Srinivasa, P.C., R. Baskaran, M.N. Ramesh, K.V. Prashanth, and R. Tharanathan. 2002. Storage studies of mango packed using biodegradable chitosan film. Eur. Food Res. Technol. 215:504–508. doi: 10.1007/s00217-002-0591-1.

Sritananan, S., A. Uthairatanakij, P. Jitareerat, S. Photchanachai, and S. Vongcheerre. 2005. Effects of irradiation and chitosan coating on physiological changes of mangosteen fruit stored at room temperature. International Symposium on New Frontier of Food and Non-Food Products, 22–23 Sept, KMUTT, Bangkok, Thailand.

Tembo, L., Z.A. Chiteka, I. Kadzere, F.K. Akinnifesi, and F. Tagwira. 2008. Storage temperature affects fruit quality attributes of Ber (Ziziphus mauritiana Lamk.) in Zimbabwe. Afr. J. Biotechnol. 7(17):3092–3099. doi: 10.5897/AJB08.321.

Van Buren, J.P. 1979. The chemistry of texture in fruits and vegetables. J. Texture Stud. 10(1):1–23. doi: 10.1111/j.1745-4603.1979.tb01305.x.

Wang, L., H. Wu, G. Qin, and X. Meng. 2014. Chitosan disrupts Penicillium expansum and controls postharvest blue mold of jujube fruit. Food Control. 41:56–62. doi: 10.1016/j.foodcont.2013.12.028.

Wills, R.B.H., W.B. McGlasson, D. Graham, T.H. Lee, and E.G. Hall. 1989. Postharvest: An introduction to the physiology and handling of fruits and vegetables. CABI Pres, Reinhold, New York. doi:10.1079/9781786391483.0000.

Wongmetha, O., L.S. Ke, and Y.S. Liang. 2015. The changes in physical, bio-chemical, physiological characteristics and enzyme activities of mango cv. Jinhwang during fruit growth and development. NJAS-Wageningen J. Life Sci. 72:7–12. doi: 10.1016/j.njas.2014.10.001.

Wu, H., D. Wang, J. Shi, S. Xue, and M. Gao. 2010. Effect of the complex of zinc (II) and cerium (IV) with chitosan on the preservation quality and degradation of organophosphorus pesticides in Chinese jujube (Zizyphus jujuba Mill. cv. Dongzao). J. Agri. Food Chem. 58(9):5757–5762. doi: 10.1021/jf100537k.

Xing, Y., Q. Xu, Z. Che, X. Li, and W. Li. 2011a. Effects of chitosan oil coating on blue mold disease and quality attributes of jujube fruits. Food Funct. 2(8):466–474. doi: 10.1039/C1FO10073D.

Xing, Y., X. Li, Q. Xu, J. Yun, Y. Lu, and Y. Tang. 2011b. Effects of chitosan coating enriched with cinnamon oil on qualitative properties of sweet pepper (Capsicum annuum L.). Food Chem. 124(4):1443–1450. doi: 10.1016/j.foodchem.2010.07.105.

Yaman, O., and L. Bayoudirli. 2002. Effects of an edible coating and cold storage on shelf-life and quality of cherries. LWT-Food Sci. Technol 35(2):146–150. doi: 10.1016/S0023-6438(01)00140-7.

Yonemoto, Y., H. Higuchi, and Y. Kitano. 2002. Effects of storage temperature and wax coating on ethylene production, respiration and shelf-life in cherimoya fruit. J JPN Soc. Hortic. Sci. 71:643–650. doi: 10.2503/jjshs.71.643.

Zhang, S., Y. Yu, C. Xiao, X. Wang, and Y. Lei. 2014. Effect of ultraviolet irradiation combined with chitosan coating on preservation of jujube under ambient temperature. LWT-Food Sci. Technol 57(2):749–754. doi: 10.1016/j.lwt.2014.02.046.