

Research Article

Composite Solution of Tea Polyphenols and Sodium Alginate for Coating Preservation of Strawberries

Cuili Gao, Ying Ding, Jinhua Li, Zonghua Wang, Dongwei Han and Yanzhi Xia
Department of Chemical Science and Engineering, Qingdao University, Qingdao,
Shandong 266071, China

Abstract: Strawberries were coated with composite solution of tea polyphenols and sodium alginate. During the storage of 20 days, seven preservation indexes, including weight loss rate, decay index, firmness, total soluble solids, titratable acidity and ascorbic acid, as well as respiratory intensity, were tested every 2 days. Strawberries treated with 1% sodium alginate and 0.4% tea polyphenols showed the best quality. After keeping the strawberries under the ordinary temperature for 20 days, the weight loss rate, the decay index, the firmness, respiratory rate, ascorbic acid content, titratable acidity, total soluble solids were 0.595, 8.8%, 0.85 kg/cm², 42.7 mg/(kg·h), 94.3 mg/100 g, 0.69%, 8.4%, respectively and the fresh-keeping effect was better than other groups.

Keywords: Coating preservation, sodium alginate, strawberries, tea polyphenols

INTRODUCTION

Strawberries are a highly perishable fruit with a short postharvest life, which are mainly due to fungal decay. The shelf-life of fresh strawberries at low temperatures (0-4°C) is usually around 24 h. In order to extend fruit shelf-life, cold storage combined with controlled and modified atmospheres has been studied (Holcroft and Kader, 1999; Sanz *et al.*, 1999; Pérez and Sanz, 2001). Edible coatings act as a barrier to gas transport and in this sense, edible film technology is an alternative method to extend commercial shelf-life of coated products by modifying their internal atmosphere (Park, 1999).

Edible coatings of different composition have been tested and used to prolong storage life of fresh and fresh-cut fruit, reducing metabolic processes and retarding microbial growth and can also create a protective barrier to reduce respiratory and transpiration rates, retarding senescence while reserving quality (Fisk *et al.*, 2008; Gonzalez-Aguilar *et al.*, 2008; Vargas *et al.*, 2008; Antunes *et al.*, 2012; Dhall, 2013; Valencia-Chamorro *et al.*, 2013).

Alginate is a salt of alginic acid, a polymer of D-mannuronic acid and L-guluronic acid and is produced from brown algae. The ability of alginate presents advantages due to its unique colloidal properties and can form strong gels or insoluble polymers through cross-linking with calcium (Rhim, 2004). Alginate is a GRAS substance (FDA) and has been used to enhance the antioxidant activity in sweet cherry (Diaz-Mula *et al.*, 2012) and to keep quality and prolong the shelf

life of rainbow trout fillets (Hamzeh and Rezaei, 2012). Azarakhsh *et al.* (2014) also suggest using 1.29% sodium alginate with 0.3% lemongrass oil as a biofungicide for controlling the microbial counts in fresh-cut pineapple.

MATERIALS AND METHODS

Materials: The strawberries (Laoshan Mingbao strawberry), harvested in Mountain Lao, were chosen for this study. They were bought in a local farmers' market in Qingdao and selected for uniformity of size and ripeness without apparent injuries.

In this study all of these materials used for the coating were of food-grade. Sodium Alginate (SA) (viscosity: 250-300cps; G/M = 0.5, Qingdao Chemical Reagent CO. LTD., Qingdao, China), was the biopolymer used for coating formulations. Tea polyphenol (Chengdu Greeshia Chemical Reagent CO. LTD., Chengdu, China), was bacteriostat and antioxidant, increasing the effect of preservation.

Edible coatings: The coating-forming solutions based on sodium alginate were prepared by modification of the method used by Pavlath *et al.* (1999). Tea polyphenol was used to increase the effect of preservation.

Six different formulations of edible coatings were prepared. Tea polyphenol (0.1, 0.2, 0.3, 0.4 and 0.5 g, respectively) was dissolved into 100 mL of 50°C distilled water with mechanical agitation respectively, formulating five different concentration tea polyphenol

Corresponding Author: Cuili Gao, Department of Chemical Science and Engineering, Qingdao University, Qingdao, Shandong 266071, China

This work is licensed under a Creative Commons Attribution 4.0 International License (URL: <http://creativecommons.org/licenses/by/4.0/>).

solution. And then sodium alginate (1 g) was added into the above five different tea polyphenol solutions respectively, forming five different composite solutions, named 1#, 2#, 3#, 4# and 5#.

Each strawberry was carefully washed with water to remove debris on the surface and then dried in the ambient air before coating. Coating experiments were carried out on the same day as the date of purchase. The strawberries were divided into seven groups. There were at least 10 fruits in each group. The seven groups were defined as the following: the untreated group was blank group CK₀ and the group coated with sodium alginate only (the concentration of SA = 1:100) was named as CK. The other groups coated with the solution of 1#, 2#, 3#, 4#, 5#, were named as A, B, C, D and E.

Fresh strawberries were examined on mold every 4 d during storage and seven experiments were performed. In the course of the experiment the evaluation parameters of samples were carried out, including weight loss, decay index, content of ascorbic acid, firmness, respiratory intensity, titratable acidity and the content of total soluble solids.

Evaluation of the strawberry quality: Analysis of weight loss was performed as described by Almenar *et al.* (2006). Weight loss was expressed as percentage loss of the initial total weight.

The decay index was calculated by Eq. (1) (Cao *et al.*, 2007):

$$\text{Decay index \%} = 100\% \frac{\sum AB}{CD} \quad (1)$$

where,

- A = The fruit disease level
- B = The numbers of this level
- C = The highest level of the decay
- D = The total fruit numbers

Firmness of examples was detected by firmness meter (Zhejiang Top Instrument CO. LTD., Hangzhou, China). Trimming both ends of the strawberries and the firmness of which could be examined three times and took the average.

The respiratory intensity was determined based on Luo *et al.* (2007) with certain modifications. Respiratory intensity was measured as CO₂ production. For each treatment, 5 strawberries weighing approximately 0.2 kg were enclosed in a chamber and air was passed through the chamber at room temperature. The effluent air was connected to a GXH-3051H (Shanghai Precision Instruments Co., Ltd, China) infrared CO₂ fruit and vegetable respiratory intensity tester. Respiratory intensity was measured by using following formulas and expressed as mg CO₂/kg/h fresh weight:

$$Q = \frac{F \times 60 \times C}{22.4} \times \frac{44}{W} \times 10^{-6} \times \frac{273}{273 + T} \quad (2)$$

With Q, respiratory intensity; F, flow rate: 500 mL/min; C, CO₂ concentration; W, fruit weight; and T, temperature.

The ascorbic acid (Vc) contents were determined by the Molybdenum blue method and expressed in milligrams of ascorbic acid per 100 g fruit weight (Li, 2000). Each measurement was performed in triplicate.

Titratable acidity of juice was determined using a potentiometric titrator (Metrom 720 SM Tritino, Swiss); 5 mL of juice diluted in 45 mL of distilled water was titrated with 0.1 N NaOH to pH 8.1. The results were calculated as percentage of anhydrous citric acid. The percentage of total Total Soluble Solids (TSS) was measured by a digital refractometer (PR-101, Atago, Japan).

The samples were concentrated and the refractive index of the juice obtained was measured on a refractometer (Shanghai Renhe Instrument CO. LTD., Shanghai, China), with the content of total total soluble solids expressed as degrees Brix. All determinations were performed with three replicates and results are given as the average.

RESULTS AND ANALYSIS

Weight loss of strawberries covered with different composite solutions: During the storage the water content is an important symbol of whether the fruit is fresh or not, therefore it is an important figure to evaluate the fruit preservation. Figure 1 showed weight loss of strawberries covered with different composite solutions through 20 days storage at room temperature.

As shown in Fig. 1, with time increasing all the samples underwent a gradual loss of weight. Obviously, the weight loss of the blank group CK₀ increased fastest, the control group CK which added sodium alginate came the second and weight loss of other groups which added polyphenol increased slowly. As shown in Fig. 1, the preservation effects of fruit coating with sodium alginate were remarkable and the results were much better after adding tea polyphenols. This is because tea polyphenols belongs to natural antioxidant which can remove free radical effectively and prolong fruit's senescence. Moreover, tea polyphenols has strong function of antibacterial and can prevent strawberries from pathological water losing. Considering the two factors, there would be a synergistic effect, superior to sodium alginate only. As shown in Fig. 1, with the increase of tea polyphenols, the weight loss of strawberries was suppressed until it reached to its lowest level when the content of tea polyphenols was 0.4%. However, when the content of tea polyphenols was over 0.4%, the weight loss began to increase. This may due to nonuniform coverage resulted from the existence of granule when tea polyphenols is excessively used, which can restrain the

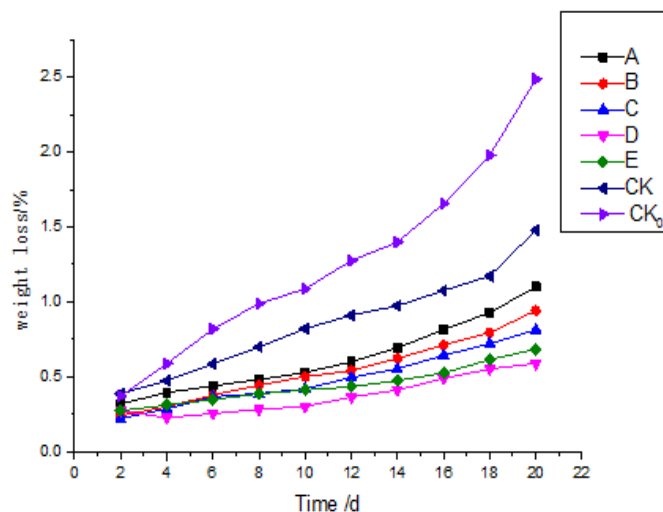


Fig. 1: Weight loss of strawberries covered with different composite solutions

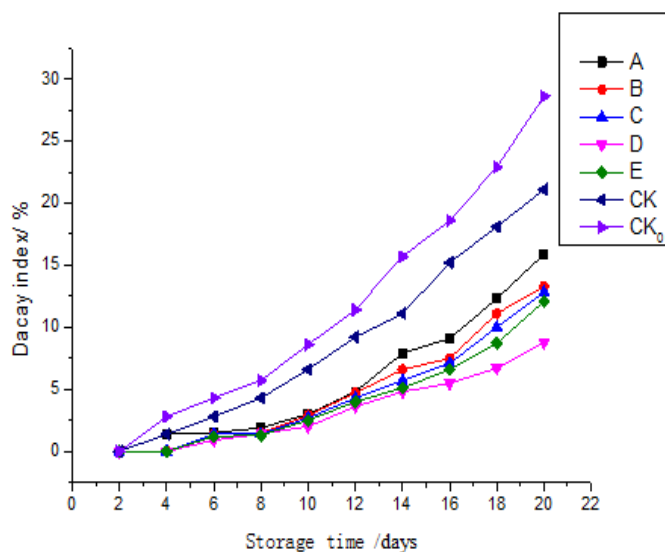


Fig. 2: Decay index of strawberries covered with different composite solutions

strawberries' respiratory. Stored for 20 d with the content of tea polyphenols as 0.4%, the weight loss of D group samples was 0.59%.

Decay index of strawberries covered with different composite solutions: With high water content, strawberries are easily to be rotten and so decay index is an important symbol of strawberries' preservation. Decay index of strawberries covered with different composite solutions were shown in Fig. 2.

From Fig. 2, the decay index of strawberries was rising in the storage period under normal temperature. The decay index of the CK₀ group and CK group were obviously higher compared with other groups which coated by composite solutions. This indicated that tea polyphenols can restrain strawberries' decay to a certain extent. As shown in Fig. 2, strawberries' decay index

decreased with increasing tea polyphenols until decay index reached the lowest level while the content of tea polyphenols was 0.4%. When the content of tea polyphenols exceeded 0.4%, decay index began to increase. After 20d decay index of D group was 8.8%, significantly lower than CK₀ and CK groups. In a word, strawberries were preferably preserved with the best quality when content of tea polyphenols reached 0.4% in the composite solution.

Firmness: Strawberry is a kind of easily to be soft fruit that suffers a rapid loss of firmness during ripening which contributes greatly to its short postharvest life. Fruit softening, one of the most important quality deterioration parameters during postharvest storage is generally caused by the hydrolysis of starch to sugar and mainly the degradation of pectin. Figure 3 showed

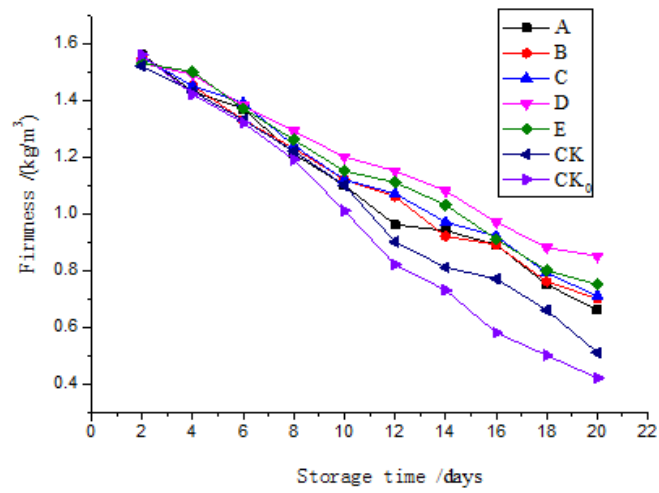


Fig. 3: Firmness of strawberries covered with different composite solutions

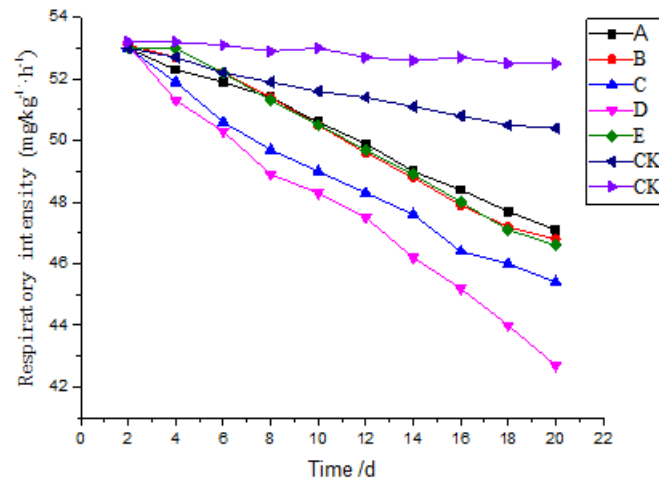


Fig. 4: Respiratory intensity of strawberries covered with different composite solutions

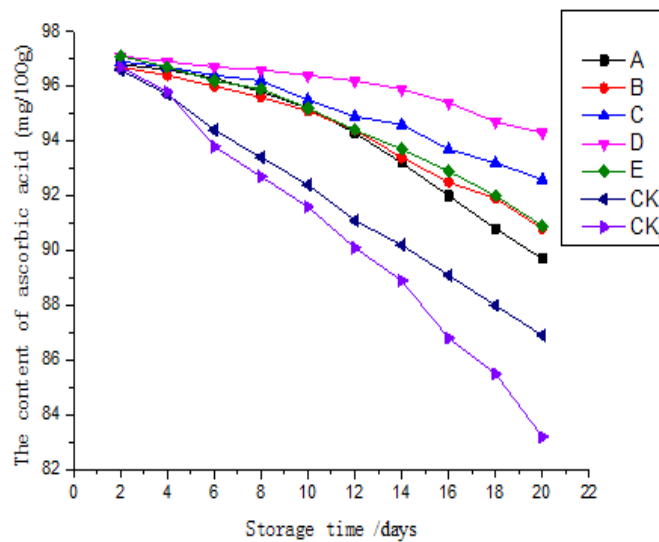


Fig. 5: Content of ascorbic acid of strawberries covered with different composite solutions

the changes in flesh firmness of all group fruit after 20 days of storage. Firmness of strawberries covered with different composite solutions were shown in Fig. 3.

As shown in Fig. 3, the firmness of all groups presented a decline tendency. Stored in room temperature for 8 d, there was not significantly different among all groups. But the firmness of blank group CK₀ and control group CK degraded quickly after 8 d, which indicated adding tea polyphenols would stop the strawberries' firmness declining. As shown in Fig. 3, D group's firmness was higher than other groups. Stored in room temperature for 20 d, the firmness of D group that adding 0.4% tea polyphenols was 0.85 kg/cm² and the appearance of D group was the best. It was 37.0% higher than CK₀ group and 32.1% higher than CK group respectively. In a word, when tea polyphenols content of composite solution was 0.4%, strawberries presented the best quality.

Respiratory intensity: The after-picking strawberries' respiratory intensity is related to carbohydrates consumption and amount of organic acid. Higher respiratory intensity indicates that strawberries' nutrition consumption is vast and their quality deteriorates. Therefore it would be regarded as another important index to evaluate preservation qualities. Respiratory intensity of strawberries covered with different composite solutions was shown in Fig. 4.

From Fig. 4, the respiratory intensity of the blank group CK₀ and the control group CK declines slightly, keeping between the levels of 50~53 mg/kg/h during storage, but other groups which added tea polyphenols decreased quickly, which indicated that tea polyphenols played an important role in inhibiting strawberries' respiratory intensity. As shown in Fig. 4, the strawberries' respiratory intensity could be restrained with increasing application of tea polyphenols and when tea polyphenols content arrived at 0.4% and which reached it's the lowest level after 20 d. Stored for 20 d under room temperature, respiratory intensity of D group dropped to 42.7 mg/kg/h, but the respiratory intensity of blank group CK₀ was 52.6 mg/kg/h. Figure 4 showed also that a coating made of 4% tea polyphenols in 1% sodium alginate solution could delay the ripening of strawberries.

Ascorbic acid: Initially, fruit are rich in ascorbic acid but its level usually decreases during maturation. It's a natural antioxidant and could suppress strawberries' decay effectively. It is well known that ascorbic acid is the most important quality parameter used to evaluate the storage effect of strawberries. Ascorbic acid was one of the most important nutritional components in strawberries and also as an antioxidant to participate in the resistance of senescence (Zhou *et al.*, 2008).

As shown in the Fig. 5, throughout the storage, the ascorbic acid content in the strawberries presented a

decline tendency. The ascorbic acid content of the blank group CK₀ and the control group CK declined faster than other groups using tea polyphenols, which indicated tea polyphenols would decrease strawberries' ascorbic acid consumption effectively. It was found that tea polyphenols had a beneficial effect on restraining ascorbic acid.

Stored under room temperature for 20 d, the ascorbic acid content of the D group adding 4% tea polyphenols was 94.3 mg/100 g, which was higher than the blank group 11% and the control group 7.4%, respectively. When the tea polyphenols content of composite solution was 0.4%, the group was preserved with highest quality. The results may be attributed to low respiration and the growth of spoilage organisms (Jiang and Li, 2001).

Titrateable acidity: Acidity content is a main factor affecting taste of fruit. During storage, organic acid would be consumed during physiological process which also converts organic acids into sugars. Therefore by determining the loss of the organic acids, this can reflect strawberries' preservation conditions.

Acidity content values of all groups decreased with increased storage time to varying degrees (Fig. 6). During the storage period, a significant decline of acidity content observed in control fruits compared to the blank group CK₀ and the control group CK (Fig. 6), which indicated tea polyphenols would decrease acidity consumption effectively. As shown in Fig. 6, strawberries' acidity content began to decrease slowly with adding tea polyphenols. The result showed that the preserving effect of coating with 4% tea polyphenols complex coating reagent was the best. Stored under room temperature for 20 d, the titrateable acidity content of D group with 0.4% tea polyphenols was 0.69%, significantly higher than the CK₀ group and the CK group. In a word, when the tea polyphenols content reached 0.4%, the group could preferably restrain the decline tendency in titrateable acidity. Treatments strawberries with 4% tea polyphenols and 2% sodium alginate composite solution coating could significantly delayed the decrease in acidity content during storage.

Total soluble solids: The total soluble solids content is closely related to the strawberries' taste and could reflect the preservation effect to some extent. Effects on total soluble solids of strawberries dealt with different composite films were shown in Fig. 7.

The total soluble solids content showed an increasing trend during storage (Fig. 7). However, the sodium alginate and tea polyphenols coating significantly delayed the increase in the total soluble solids content, as compared with the blank group CK₀ and the control group CK, particularly from days 8 to 20 postharvest.

Stored under room temperature for 20 d, the total soluble solids of D group were 8.4%, higher than the

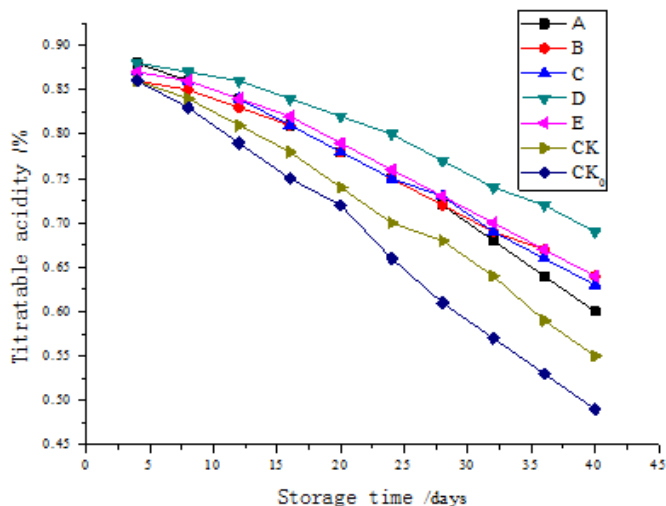


Fig. 6: Titratable acidity of strawberries covered with different composite solutions

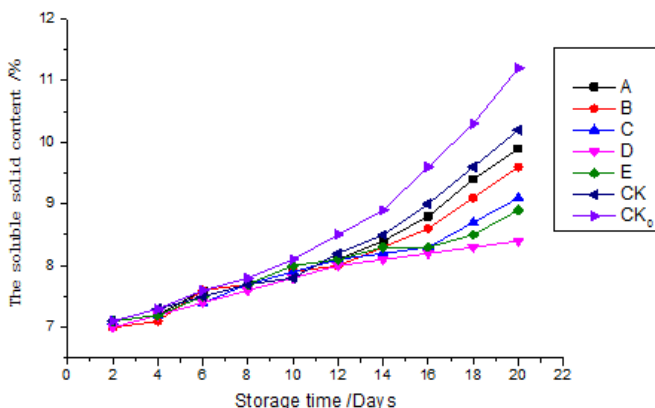


Fig. 7: Total soluble solid of strawberries covered with different composite solutions

CK group and this indicated that tea polyphenols had an effect on restraining the degradation of total soluble solids. But there were no distinctive differences among all the groups coating with sodium and tea polyphenols after 20 d, remaining between the levels of 8.4% and 9.8%, thus it's difficult to make a favorable verdict. Perhaps some organic acids converted into sugar, so the final conclusion is not certain. Maybe it's because the storage time is so short to make a more persuasive result. But in a word, we can also draw the conclusion that when the content of tea polyphenols reached 0.4%, the group could preferably restrain the consumption of the total soluble solids.

CONCLUSION

Strawberry as a sensitive and highly nutritional valuable fruit using the composite solution of sodium alginate and tea polyphenols coated on them, which could improve the strawberries' quality and prolong than the uncoated samples. During the storage, seven

preservation indexes, including weight loss rate, decay index, firmness, total soluble solids, titratable acidity and ascorbic acid, as well as respiratory intensity, were tested every 2 days. Strawberries treated with 1% sodium alginate and 0.4% tea polyphenols showed the best quality.

REFERENCES

- Almenar, E., V. Del-Valle, R. Catala and R. Gavara, 2006. Controlled atmosphere storage of wild strawberry fruit (*Fragaria vesca* L.). *J. Agr. Food Chem.*, 54: 86-91.
- Antunes, M., C. Gago, A. Cavaco and M.G. Miguel, 2012. Edible coatings enriched with essential oils and their compounds for fresh and fresh-cut fruit. *Recent Pat. Food. Nutr. Agric.*, 4: 114-122.
- Azarakhsh, N., A. Osman, H.M. Ghazali, C.P. Tan and N.M. Adzahan, 2014. Lemongrass essential oil incorporated into alginate-based edible coating for shelf-life extension and quality retention of fresh-cut pineapple. *Postharvest Biol. Tec.*, 88: 1-7.

- Cao, J.K., W.B. Jiang and Y.M. Zhao, 2007. Experiment Guidance of Postharvest Physiology and Biochemistry of Fruits and Vegetables. China Light Industry Press, Beijing.
- Dhall, R.K., 2013. Advances in edible coatings for fresh fruits and vegetables: A review. Crit. Rev. Food Sci., 53: 435-450.
- Diaz-Mula, H.M., M. Serrano and D. Valero, 2012. Alginate coatings preserve fruit quality and bioactive compounds during storage of sweet cherry fruit. Food Bioprocess Tech., 5: 2990-2997.
- Fisk, C.L., A.M. Silver, B.C. Strik and Y. Zhao, 2008. Postharvest quality of hardy kiwifruit (*Actinidia arguta* 'Ananasnaya') associated with packaging and storage conditions. Postharvest Biol. Tec., 47: 338-345.
- Gonzalez-Aguilar, G.A., J. Celis, R.R. Sotelo-Mundo, L.A. De La Rosa, J. Rodrigo-Garcia and E. Alvarez-Parrilla, 2008. Physiological and biochemical changes of different fresh-cut strawberries cultivars stored at 5 °C". Int. J. Food Sci. Tech., 43: 91-101.
- Hamzeh, A. and M. Rezaei, 2012. The effects of sodium alginate on quality of rainbow trout (*Oncorhynchus mykiss*) fillets stored at 4 ± 2 °C". J. Aquat. Food Prod. T., 21: 14-21.
- Holcroft, D.M. and A.A. Kader, 1999. Controlled atmosphere-induced changes in pH and organic acid metabolism may affect colour of stored strawberry fruit. Postharvest Biol. Tec., 17: 19-32.
- Jiang, Y.M. and Y.B. Li, 2001. Effects of chitosan coating on postharvest life and quality of longan fruit. Food Chem., 73: 139-143.
- Li, J., 2000. Study on molybdenum blue method of L-VC test by spectrometry. Food Sci., 8: 42-45.
- Luo, Z., X. Xu, Z. Cai and B. Yan, 2007. Effects of ethylene and 1-methylcyclopropene (1-MCP) on lignification of postharvest bamboo shoot. Food Chem., 105: 521-527.
- Park, H.J., 1999. Development of advanced edible coatings for fruits. Trends Food Sci. Tech., 10: 254-260.
- Pavlath, A.E., C. Gossett, W. Camirand and G.H. Robertson, 1999. Ionomeric films of alginic acid. J. Food Sci., 64: 61-63.
- Pérez, A.G. and C. Sanz, 2001. Effect of high oxygen and high carbon dioxide atmospheres on strawberry flavor and other quality traits. J. Agr. Food Chem., 49: 2370-2375.
- Rhim, J.W., 2004. Physical and mechanical properties of water resistant sodium alginate films. LWT-Food Sci. Technol., 37: 323-330.
- Sanz, C., A.G. Pérez, R. Olías and J.M. Olías, 1999. Quality of strawberries packed with perforated polypropylene. J. Food Sci., 64: 748-752.
- Valencia-Chamorro, S.A., L. Palou, M.A. Del Rio and M.B. Pérez-Gago, 2013. Antimicrobial edible films and coatings for fresh and minimally processed fruits and vegetables: A review. Crit. Rev. Food Sci., 51: 872-900.
- Vargas, M., C. Pastor, A. Chiralt, D.J. McClements and C. González-Martínez, 2008. Recent advances in edible coatings for fresh and minimally processed fruit. Crit. Rev. Food Sci., 48: 496-511.
- Zhou, R., Y. Mo, Y.F. Li, Y.Y. Zhao, G.X. Zhang and Y.S. Hu, 2008. Quality and internal characteristics of huanghua pears (*Pyrus pyrifolia nakai* cv. Huanghua) treated with different kinds of coatings during storage. Postharvest Biol. Tec., 49: 171-179.