Effect of Chitosan based Edible Coating on Quality and Shelf Life of Sapota (*Manilkara Zapota*) Fruits during Storage

Anuradha Saha[1], Rajinder K. Gupta[2] and Yogesh K. Tyagi[3*]

[1,3]University School of Basic & Applied Sciences, Guru Gobind Singh Indraprastha University, Sector-16C, Dwarka, Delhi-110078, India
[2]University School of Biotechnology, Guru Gobind Singh Indraprastha University, Sector-16C, Dwarka, Delhi-110078, India
E-mail: [1]anuradha_saha85@yahoo.com, [2]rkg67ap@yahoo.com, [3]drytyagi@ipu.ac.in

Abstract—*Fast ripening of Sapota (Manilkara zapota) fruits during postharvest stage results in their short postharvest life which leads to deterioration of their quality. Polysaccharide such as chitosan which has been known for its excellent film forming and antifungal properties and essential oils which are known for their antimicrobial properties were used as an edible coating to prolong the storage life of sapota fruits, which would be an innovative approach for the fruit preservation and towards sustainable development. Edible coatings are environmentally friendly technology popularly used now-a-days to enhance the shelf life of fruits and vegetables while maintaining its internal and external quality. In our study, chitosan in combination with cinnamic acid and oleic acid were used for coating sapota fruits which were then stored at ambient conditions and their physicochemical properties were measured at the end of each storage period. Shelf life of coated sapota fruits were extended to 9 days while control sapota fruits were deteriorated in 6 days.*

1. INTRODUCTION

Sapota (Manilkara zapota) is a tropical fruit native to Mexico and Central America and belongs to the family *Sapotaceae*. After mango, banana, citrus and grapes, sapota ranks fifth both in production and consumption in India. Sapota is grown mainly in coastal areas such as Maharashtra, Gujarat, Karnataka and Tamilnadu. It is consumed mostly indigenously. Sapota contains various important nutrients which has certain health benefits [1]. It is a climacteric fruit which requires ethylene to ripen [2] due to which it gets ripens within 3-5 days after harvest. These health benefits have resulted in increased demand for these fruits with high quality, freshness and nutritious level with no toxicity. Increased demand of consumers also led to advanced practices for fruit storage, quality management, transport and processing so that it can reach to consumers in best possible way [3]. However, presently, due to lack of proper storage facilities, sensitivity of sapota fruits to cold storage, mishandling and improper transport adds to the post harvest loss (National Horticultural Board, Ministry of Agriculture, Govt. of India). However, being a climacteric fruit, it has a short post harvest life which results in high respiration rate, ethylene production and weight loss leading to deterioration in the quality of the fruit [2]. Postharvest metabolic changes leading to increased respiratory activity and loss of water due to transpiration are the two basic aspects that determine the storage life and quality of fruits [3]. Several studies have been conducted to extend postharvest life of sapota by controlled atmosphere packaging (CAP), modified atmosphere packaging (MAP) [4] and pre-cooling techniques. Edible coatings are a simple technology in which thin layers of edible components are applied to the surface of fruit and act as a physical barrier towards carbon dioxide, oxygen, aroma and moisture movement [5]. Edible coating is an environmentally and eco friendly technique as used for extending the shelf life of fruits. It creates semi-permeable barrier around the food surface and modifies the internal atmosphere within the fruit, thereby preserving its quality and extending shelf life. Edible coatings have many advantages over other techniques [5]. Polysaccharides, proteins, lipids, or a blend of these compounds can be used as coating materials [6]. Chitosan is economical because it is a natural compound obtained by deacetylation of chitin which is produced from shrimp, crab, and crawfish shells waste [7]. A number of functional properties of chitosan have been reported to be useful in nutrition [8, 9]. These include its antimicrobial activity and its ability to form protective films [10, 11], its texturizing [12], and binding action [13]. Thus, we have selected chitosan as an edible coating for sapota along with plasticizers such as glycerol that makes chitosan films more flexible [14]. Essential oils such as cinnamon oil are natural antimicrobials derived from vegetable extracts. Due to their hydrophobicity, it forms a partition in the lipid of the microbial cell membrane and mitochondria, disturbing the pathogen cell structures [15]. Fatty acid such as oleic acid is also bioactive compound which enhance the antifungal capacity of chitosan [16]. Research has been conducted on various films and their applications on whole fruits and vegetables as well as on fresh-cut fruits and vegetables. To the best of our knowledge, no work has been reported on edible coating on whole sapota fruit. The objective of this study was to investigate the chitosan based edible coating and its combination with cinnamon oil and oleic acid on the shelf life and other physicochemical properties of sapota fruits during storage at ambient condition.

2. MATERIALS AND METHODS

Homogenous and uniform size half ripe sapota fruits (var. Kalipatti) free from fungal rots, bruises, wounds or holes were harvested from a local orchard in Gujarat and within two days brought to the laboratory, Delhi for edible coating experiment. They were cleaned, dried, sorted and labeled. The first set was kept as control and other sets were coated.

2.1. Edible coating preparation and application

Chitosan (75%deacetylated) was provided by Hi-media, Mumbai, India. All other chemicals and solvents were of analytical grade and obtained from SRL (Delhi, India) and Hi-media (Mumbai, India). Chitosan (1%) was prepared by dissolving 1 g chitosan in 100ml distilled water containing 0.5% (v/v) glacial acetic acid followed by addition of glycerol (0.2%), Tween 80 (0.1%) and calcium chloride (0.1%). The pH of the solution was adjusted to 6.0 with 1N NaOH [17]. Total three coating treatments (T) were prepared, T1 (chitosan 1%+oleic acid 0.1%), T2 (chitosan 1%+cinnamon oil 0.1%), T3 (chitosan 1%+oleic acid 1%), T3 (cinnamon oil 0.1%+ Calcium chloride 0.1%) while the fourth group that is uncoated was designated as (T0). All the solutions were homogenously agitated over night. The fruits were dipped on the respective coating treatments for 1 minute and residual coating was allowed to drip off. The coated fruits were air dried at room temperature and kept for storage at ambient conditions (25°C) and 50-60% R.H. The coated as well as uncoated sapota fruits were subjected to following physicochemical parameters and difference in visual and physical appearance has been evaluated after every three days of storage interval.

2.2 Physical and chemical parameters

Physiological Weight Loss: Sapota fruits were weighed at the beginning of the experiment and at the end of each storage interval. The difference between the initial & final weight of the fruit was considered as a total weight loss. The results were expressed as the percentage loss of the initial weight as per the standard method of [18].

Decay percentage was measured as the number of decayed fruit due to microbial or fungal infection or rotting of both control and coated was recorded after every two days and it was expressed as percentage. Internal gas for respiration rate was measured by placing the fruits in a hermetically sealed with silicon rubber septum for 1 hour. After 1 hour, the headspace gas was sucked through a hypodermic hollow needle and the respiration rate was measured (Model: Checkmate 9900, PBI Dansensor, Denmark) and the result were expressed as ml CO_2 kg^{-1} h^{-1}. Firmness of fruit sample were analysed using Texture Analyzer (model: TA+Di, Stable micro systems, UK). Fruit firmness is the measurement of the force required for a cylindrical probe (2mm diameter) to penetrate 10mm inside the fruit. This probe was advanced at a speed of 2 mm/s and the results were expressed as Newton (N). The peel colour was determined at the end of storage period using the HunterLab System (EasyMatch software), US. The peel colour determination was expressed as L*, a^* and b^* parameters in triplicate for each fruit. Soluble solid concentration (SSC), Titratable acidiy (TA) & pH: The soluble solid concentration of the fresh juice was determined using hand refractometer (Atago, Japan) which was calibrated with distilled water prior to taking readings. A drop of filtered juice was placed on the prism glass of the refractometer to obtain the reading in (°Brix). The titratable acidity (TA) of the juice was analyzed according to the method of [19] by titration of 1ml of juice with 0.1% NaOH using phenolphthalein as an indicator and the results were expressed as percent of citric acid per 100g of fresh juice. The pH of the juice samples was obtained using digital pH meter according to the standard method of [17]. Ascorbic acid content of both control and coated fruit samples were measured according to the Dye method of [19]. The juice samples were homogenized and extracted with 3% meta-phosphoric acid using a blender. The extract was filtered through a standard dye solution (2, 6-dichlorophenol-indophenol) to a pink colour that persisted for at least 15 seconds. The ascorbic acid content was expressed as mg/100g.

2.3. Statistical analysis

The experiment was conducted in completely randomized design. ANOVA was used to determine the treatment effects and LSD was determined at 5%.

3. RESULTS AND DISCUSSION

3.1 Weight loss (%)

The weight loss of both coated and control fruits has been increased significantly ($p<0.5$) with storage period (Fig. 1) and as sapota fruits are perishable, so weight loss is high. However, maximum weight loss was found on uncoated (controlled) fruits. Higher percentage of weight loss was found in control sapota fruits due to high rate of transpiration, increased gaseous exchange, increased respiration rate, membrane permeability, toughening of tissue as well as softening of tissues in some cases result in loss of consumer acceptability compared to treated ones [20]. Comparatively lower weight loss found in coated ones. Our results also supported the view of [21] who found minimum weight loss in 1.5% chitosan coated papaya fruits. Similar results were also reported by [21] and [22] who observed that chitosan coated carambola and sapota fruits, respectively showed lower weight loss at the end of storage period.

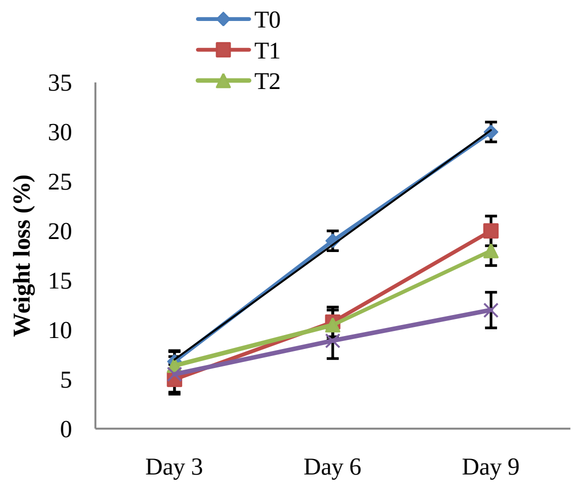

Fig. 1: Effect of Different Coatings on Weight loss (%) of Sapota fruits during storage where T0=control (uncoated), T1= (chitosan 1%+oleic acid 0.1%), T2= (chitosan 1% + cinnamon oil 0.1%), T3=(chitosan 1%+oleic acid 1%, cinnamon oil 0.1%+ Calcium chloride 0.1%). [The vertical bar represents standard error of the means].

3.2. Decay percentage and shelf life of fruits

Decay percentage of coated and uncoated fruit increases with storage time. All the coating solutions were tested in this study reduces the decay percentage as compared to control fruits. In first 3 days, no decay has been observed in control as well as coated ones. After 6 days, T1, T2 and T3 sets showed similar decay percentage of 12.95%, 10%, 9.95% while control showed more than 30% decay. However, after 9 days of storage, T1, T2 and T3 showed 14.9, 16.6% and 13% decay due to shrivelling and excessive browning while uncoated ones shows 50% fungal decay which was absent in coated ones. The storage life of sapota fruits treated with chitosan, oleic acid, cinnamon oil, calcium chloride (T3) was extended to 9 days as compared to that of other treatments whereas fruit treated with T1, T2 both showed 8 days of shelf life whereas control fruits completely deteriorated in 6 days. Baldwin [5] suggested that edible coatings are a simple, environmentally friendly and relatively inexpensive technology that has the potential to extend the shelf life of tropical fruits. Ghaouth *et al*. [17] reported that chitosan induces chitinase, an enzyme which catalyzes the hydrolysis of chitin, which is a component found in the cell walls of fungi that prevents the growth of fungi on the fruit and vegetables. The presence of oleic acid and cinnamon oil enhances the antifungal activity of chitosan [16]. In this study, it was found that the decay control of T3 was better than that of T1 and T2 and showed efficacy against decay incidence of sapota fruit.

3.3 Respiration Rate

Respiration rate of sapota is very high as its climacteric fruit [23]. However, application of edible coating on sapota fruits showed relatively low CO_2 evolution as compared to uncoated fruits. Respiration rate of the uncoated fruits increased from 40 to 82.5% at the end of storage period (Fig. 2). Respiration is catabolic process which breaks down the sugars & starch present in the matrix of the vegetable [19, 24]. There was no significant differences found in respiration rate among the treatments, however, relatively low respiration rate in coated ones was due to reduced gas exchange, low oxygen availability to the tuber tissues, reduced loss of vitamins & mineral [25].

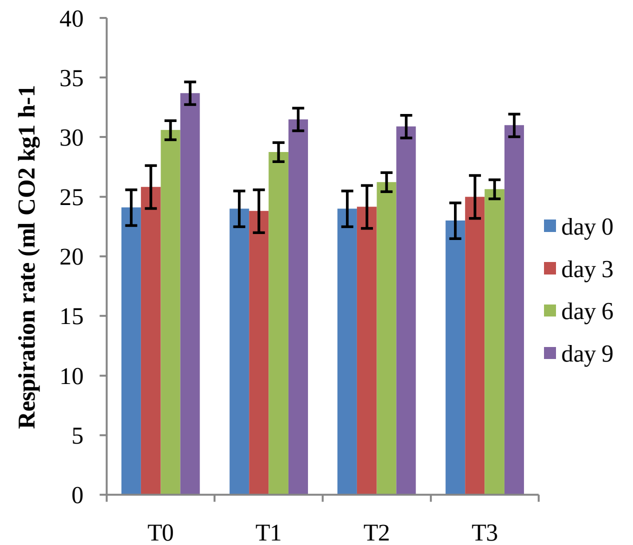

Fig. 2: Effect of Different coatings on Respiration rate (ml CO_2 kg^{-1} h^{-1}) of sapota fruits during storage where T0= control (uncoated), T1= (chitosan 1%+oleic acid 0.1%), T2= (chitosan 1% + cinnamon oil 0.1%), T3=(chitosan 1%+oleic acid 1%, cinnamon oil 0.1%+ calcium chloride 0.1%) [The vertical bar represents standard error of the means].

3.4 Total soluble solids, pH and Titratable acidity

It was reported that soluble solids content increased with fruit and vegetable maturity through biosynthesis process or degradation of polysaccharides [24]. Total average TSS values of the control ones are less than coated ones (Fig. 3). Lower level in uncoated fruits could be due to higher respiration rate and water loss of control (uncoated) than coated fruit. Not much change in pH and acidity observed during storage (Fig. 3) but slight decrease may be attributed to the oxidation of organic acids [26]. Results of the present study were supported by [27] in sapota fruits.

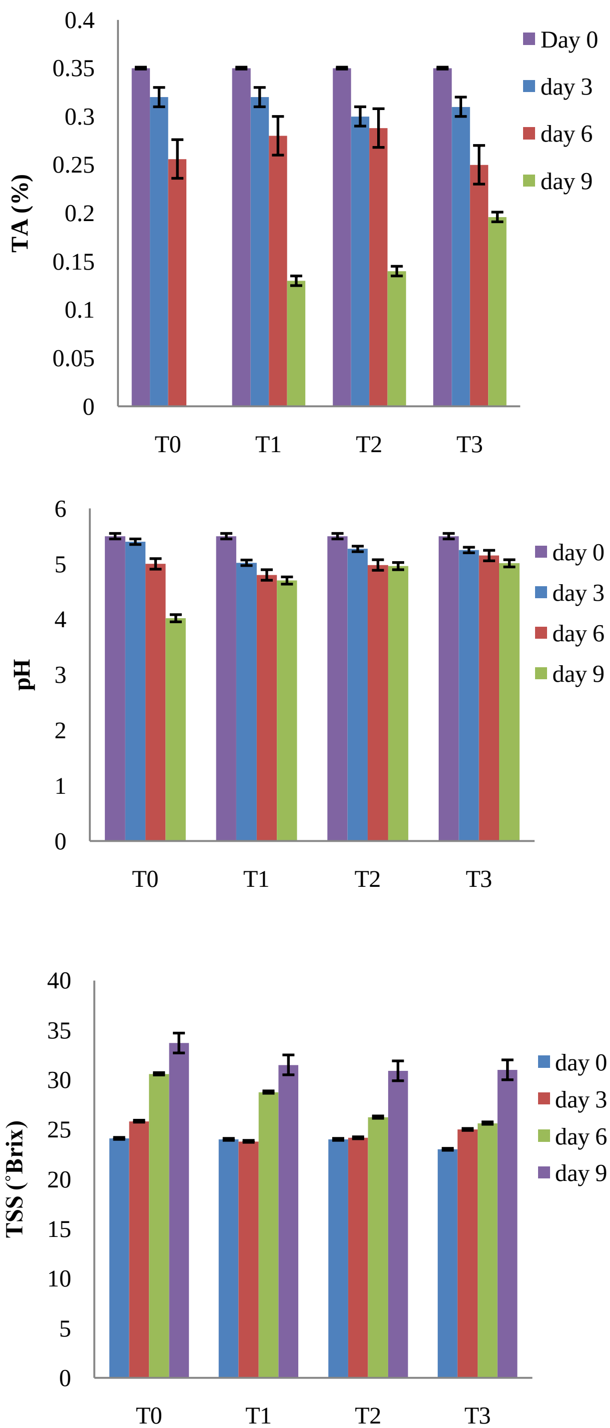

Fig. 3: Effect of different edible coatings on Titratable acidity (TA), pH and TSS of sapota fruits during storage where T0=control (uncoated), T1= (chitosan 1%+oleic acid 0.1%), T2= (chitosan 1% + cinnamon oil 0.1%), T3=(chitosan 1%+oleic acid 1%, cinnamon oil 0.1%+ calcium chloride 0.1%) [The vertical bar represents standard error of the means].

3.5 Effect on Fruit firmness

There was decrease in firmness leading to fruit softening during the storage period. Fig. 4 showed that firmness change in coated fruits were relatively lower than uncoated fruits. Maximum fruit firmness was recorded in T3 coated fruits whereas minimum firmness was recorded in control ones. Softening was largely due to breakdown of starch and other pectic polysaccharides in the pulp, thereby reducing cellular rigidity [28]. Reduction in respiration rates of coated sapota fruits could be responsible for delayed ripening which resulted in retention of firmness during storage.

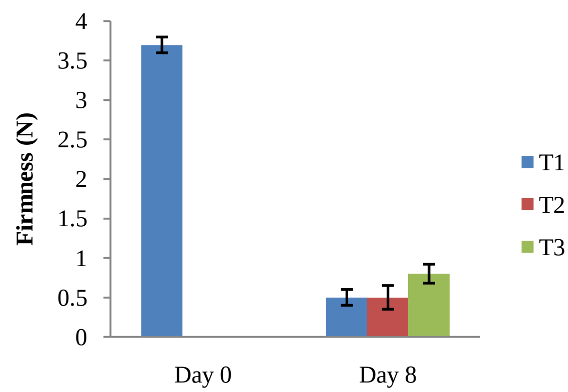

Fig. 4: Effect of different Edible coatings on Fruit Firmness during storage where T0=control (uncoated), T1= (chitosan 1%+oleic acid 0.1%), T2=(chitosan 1% + cinnamon oil 0.1%), T3=(chitosan 1%+oleic acid 1%, cinnamon oil 0.1%+ calcium chloride 0.1%) [The vertical bar represents standard error of the means].

3.6 Colour difference

Colour is one of the major visual attributes of fruits. The change in colour from light brown to dark brown continued over the storage period due to which there is decrease in values (Table 1). Control fruits showed faster colour change than coated ones. Lower rate of decrease in values found in coated fruits indicated that edible coating has relatively delayed the browning and colour development of the peel which leads to slower changes in colour development. The slow colour development can be attributed to modified internal atmosphere created within the fruit [21].

Table 1: Effect of Different Coatings on Colour Changes (L*, a*, b*) of sapota fruits during storage where T0=control (uncoated), T1=(chitosan 1%+oleic acid 0.1%), T2= (chitosan 1% + cinnamon oil 0.1%), T3=(chitosan 1%+oleic acid 1%, cinnamon oil 0.1%+ calcium chloride 0.1%) [The vertical bar represents standard error of the means].

	L*		**a***		**b***	
	0 day	**Day 9**	**0 day**	**Day 9**	**0 day**	**Day 9**
T0	56.34±0.32	Decayed	10.22±0.5	Decayed	33.52±0.67	Decayed

T1	56.34±0.32	38.46±0.52	10.22±0.5	9.28±0.88	33.52±0.67	13.51±0.52
T2	56.34±0.32	39.89±0.22	10.22±0.5	8.416±0.12	33.52±0.67	15.01±0.25
T3	56.34±0.32	40.42±0.45	10.42±0.5	9.92±0.38	33.52±0.67	16.08±0.63

3.7 Ascorbic acid content

Ascorbic acid content of fruit decreases with storage due to oxidative destruction of ascorbic acids by enzyme [26]. However, delay in decrease was found in coated ones than uncoated. Fig. 5 showed that the lowest average value was shown by T0 (control ones) followed by coated ones with treatment T1, T2 and T3. Throughout the storage period, there were significant differences between coated and uncoated fruits. Ascorbic acid was in higher level in coated fruits (T3) than in uncoated fruits, similar to that reported by [29].

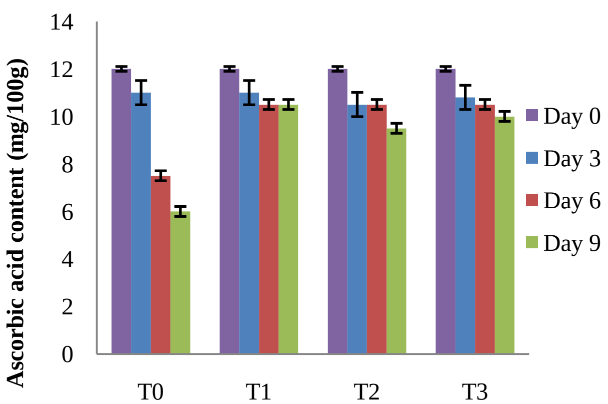

Fig. 5: Effect of different Edible coatings on ascorbic acid content of sapota fruits during storage where T0=control (uncoated), T1=(chitosan 1%+oleic acid 0.1%), T2= (chitosan 1% + cinnamon oil 0.1%), T3=(chitosan 1%+oleic acid 1%, cinnamon oil 0.1%+ calcium chloride 0.1%) [The vertical bar represents standard error of the means].

4. CONCLUSIONS

These results demonstrated that polysaccharide coatings in combination with lipids such as cinnamon oil, oleic acid are simple, environmentally friendly and relatively inexpensive technology that can extend the storage life of sapota fruits. The application of these treatments reduces weight loss, respiration rate, loss of ascorbic acid content and acidity as compared to control which implies that edible coating is forming a protective barrier on the fruit surface. Shelf life of sapota fruits increases to 9 days with no foul smell and microbial spoilage. Hence, overall quality and marketability has been enhanced during storage period. Control fruits deteriorated in 6 days.

5. ACKNOWLEDGEMENT

The Authors are thankful to Guru Gobind Singh Indraprastha University, Delhi, India for providing the Indraprastha Research Fellowship and necessary facilities for carrying out this work. The authors would also like to express their appreciation and gratitude to the Dr. V.R. Sagar, Head, Food Science and Post Harvest Technology Division, Indian Agricultural Research Institute, Delhi, India for providing the most sophisticated facilities for this research work.

REFERENCES

[1] Anand, P., Kulkarni, R.S., Policegoudra, and Aradhya, S., "Chemical composition and antioxidant activity of sapota (Achras sapota linn.) fruit", *Journal of Food Biochemistry*, 31, 2007, 399-414.

[2] Lakshminarayana, S., Subramanyam, H., "Physical, chemical and physiological changes in sapota fruit [*Achras sapota* Linn. (Sapotaceae)] during development and ripening", Journal of Food Science and Technology, 3, 1966, 151–154.

[3] Vijay, P., and Rakesh, P., Role of internal atmosphere on fruit ripening and storability-a review. *Journal of Food Science and Technology*, 51(7), 2014, 1223-1250.

[4] Goswami, T.K., Deka S.C., and Dash K.K.,, *Agricultural Engineering International: CIGR Journal*, 2012 14(2), 102-109.

[5] Baldwin, E.A., Burns, J.K., Kazokas, W., Hagenmaier, R.D., Bender R.J., Pesis, E., *Postharvest Biology and Technology.*, 1999, 17(3), 215–226.

[6] Navarro-Tarazaga, M.L., Sothornvit, R., Perez-Gago M.B., *Journal of Agricultural Food Chemistry*, 2008, 56, 9502-9509

[7] Knorr, D., *Journal of Food Technology*, 1994, 44, 114-122.

[8] Shahidi F., Arachchi, J.K.V., Jeon Y.J., *Trends of Food Science and Technology*, 1999, 10, 37–51.

[9] D Gallaher; C Gallaher; G Mhrat; T Carr; C Hollingshead; R Hesslink, *Journal of American College of Nutrition*, **2002**, 21, 428-433.

[10] Cuero, R.G., Antimicrobial Action of Exogenous Chitosan. Chitin and Chitinases, Jolles P and Muzarelli RAA (Eds.). Basel, Birkhauser, Boca Raton, Florida, 1999, 315-33.

[11] Jeon Y.L., Kamil, J.Y.V.A, Shahidi, F., *Journal of Agriculture Food. Chemistry*, 2002, 20, 5167-78.

[12] Benjakul, S., Visessanguan, W., Phatchrat, S., Tanaka, M., *Journal of Food Biochemistry*, 2003, 27, 53-66.

[13] No, H.K., Lee K.S., Meyers S.P., *Journal of Food Science and Technology*, 2000, 65, 1134-1137

[14] Rivero, A., García M.A., Pinotti, A., *Journal of Food Engineeering*, 2009, 90, 531-539.

[15] Ayala Zavala, J., Del Toro Sanchez, L.,, Alvarez Parrilla, E., Gonzalez Aguilar, G., High relative humidity in package of fresh cut fruits and vegetables: advantage or disadvantage considering microbiological problems and antimicrobial delivering systems. *Journal of Food Science*, 73(4), 2008 R41-R47.

[16] Vargas, M., Albors, A., Chiralt A., and Gonz´alez-Martınez, C., Quality of cold-stored strawberries as affected by chitosan–oleic acid edible coatings, Postharvest Biology and Technology, 41, 2006, 164-171.

[17] Ghaouth A.E., Arul J., Ponnampalam R., Boulet M., *Journal of.Food Science*, 56, 1991, 1618-1620.

[18] AOAC (Association of Official Analytical Chemists), *Official Methods of Analysis*. 16th Ed. Virginia, USA, 1994.

[19] Ranganna, S., Handbook of analysis and quality control for fruit and vegetable products. Ranganna, S. (Ed.) Tata McGraw-Hill Publications, New Delhi, 2001, p.88-89.

[20] Gol, N.B., Patel, P.R., and Rao, T.V.R., Improvement of quality and shelf-life of strawberries with edible coatings enriched with chitosan. *Postharvest Biology and Technology*, 85, 2013, 185-195.

[21] Ali, A., Muhammad, M.T.M., Sijam, K., Siddiqui, Y., Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya* L.) fruit during cold storage. *Food Chemistry*, 124(2) 2011, 620-626

[22] Ahlawat, A., Saha, A., Tyagi, Y.K., and Gupta, R.K., Developments of chitosan based edible coatings to study Sapota (*Manilkara zapota*) fruit shelf life. *Journal of Chemical and Pharmaceutical Research* 7(1), 2015, 879-885.

[23] Alia-Tejacal, I., Villanueva-Arce, R., Pelayo-Zaldivar, C., Colinas-Leon, M.T., Lopex-Martinez, V., Bautista Banos, S., Postharvest physiology and technology of sapota mamey fruit. *Postharvest Biology and Technology*, 45, 2007, 285-297.

[24] Rezaee, M., Almassi, M., Saeed, M.F., and Paknejad F., *Journal of Food Science and Technology*, 50(2), 2013 339-345.

[25] Dhall, R.K., *Critical Review of Food Science and Nutriion*, 53(5), 2013, 435–50

[26] Hulme, A.C., The Biochemistry of Fruits and Their Products. Vol. 1, Academic Press, London and New York, 1970**,** 1,107 and 376.

[27] Paralkar P.S., Studies on Physico-Chemical Changes in Sapota (Manilkara achras (mill) Forsberg) Cv. Kalipatti Fruits during Growth, Development and Storage, M.Sc. (Agri.) Thesis, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Ratnagiri, (India). 1985

[28] Salunkhe D.K., Boun H.R., Reddy N.R., Storage Processing and Nutritional Quality of Fruits and Vegetables. CRC Press Inc., Boston, USA, 1991, 156–61.

[29] QF Dang; JQ Yan; Y Li; XJ Cheng; C.S Liu; XG Chen, *Journal Food Sci.*, **2010**, 75, 125-131.