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A Study of Active Packaging (AP) Technology on Banana Fruit

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Abstract—*Active packaging (AP) treatments (ethylene, moisture, Oxygen and Carbon dioxide scavengers along with an antimicrobial chitosan coating) were formulated in our laboratory and applied on whole banana fruits stored at room (30±2ºC) as well as refrigeration (5±1ºC) temperatures for 9 and 15 days respectively. Fresh and mature banana fruits were packed in LDPE with AP treatments with an objective to reduce the post harvest losses and preserve the storage life of the commodity. The fruits were analyzed for physico chemical parameters such as weight loss (%), moisture content (%), titratable acidity (%), ascorbic acid (mg/100g), O_2 (%), CO_2 (%), C_2H_4 (µl C_2H_4 /h/kg). The results revealed that chitosan coating was found most effective followed by ethylene and moisture scavenging treatments in extending the shelf life of banana under room temperature but at refrigeration storage only chitosan coating treatment showed and proved better in reducing softness and retaining quality parameters. Hence, it can be concluded that active packaging technology has great potential for future development in reducing the postharvest losses and to prolong the shelf life of the horticultural produce.*

Keywords*: Active packaging, chitosan coating, scavengers, physico chemical parameters, treatments.*

1. INTRODUCTION

India has emerged as the second largest producer of fruits and vegetables in the world only next to China, and in terms of total area and production our country is designated as "fruit and vegetable basket" of the world. Presently, India is producing around 88.977 million tonnes of fruits and 162.89 million tonnes of vegetables under a vast area of 7.216 and 9.396 million hectares, respectively [7]. Fruits are perishable and very liable to transport damage that consequently leads to deterioration in quality and wastage. In India, over 30 per cent of the total produce is wasted due to spoilage. Hence, there is an urgent need to develop technologies to overcome post-harvest losses of fruits [19]. In the present study active packaging (AP) technology applied to fresh fruits can provide an alternative way to control and extend quality and shelf-life during storage. Active or smart packaging techniques are proposed for better quality retention and shelf life extension of fruits and vegetables. The term 'active' reflects to perform some role other than providing some inert barrier to external conditions. "Active packaging (AP) is an innovative concept that can be defined as a mode of packaging in which the package, the product and the environment interact to prolong the shelf life or enhance safety or sensory properties, while maintaining nutritional quality of the product" [18]. Five treatments oxygen scavenger, carbon dioxide scavenger, moisture scavenger, ethylene scavenger and chitosan based antimicrobial coating were selected under active packaging concept. This study discusses the effect of AP treatments on the quality of banana fruit stored at 5±1°C refrigeration and 30±2°C ambient temperature.

2. MATERIAL AND METHODS

2.1. Treatments of Fruits

2.1.1. Oxygen scavenger. 100g Iron powder based oxygen scavenger was prepared by selecting the following chemical materials i.e. 40g Iron powder, 30g magnesium sulphate (MgSO4), 20g sodium chloride (NaCl) and 10g silica gel and all the chemical ingredients were mixed well with spatula.

2.1.2. Carbon dioxide scavenger. 100g activated charcoal based carbon dioxide scavenger was prepared by properly mixing of 80g activated charcoal and 20g silica gel with spatula by maintaining the ratio of 8:2.

2.1.3. Moisture scavenger/ absorber. For 100 g of moisture scavenger only silica gel was taken.

2.1.4. Ethylene scavenger. Potassium permanganate based ethylene scavenger was prepared by dipping 96g silica gel powder (AR grade) in 4 per cent $KMnO_4$ (100 ml) solution for the preparation of 100g ethylene scavenger. The homogenous mixture was kept at 28-30°C temperature for 48 hrs. in hot air oven. Dark purple coloured ethylene scavenger powder was prepared and was packed in LDPE pouches for further use.

2.1.1.1. Sachet Preparation. Sachet was prepared by selecting high density woven fabric (100 gauge) which was permeable to gases but impermeable to active packaging ingredients, it was cut into 8 x 4 cm with scissors and 2 sides were sealed by using an electronic form, fill and seal machine. 4 x 4 cm size of each sachet was prepared with one side remained open for incorporating the prepared scavengers and packed in LDPE pouches for further use.

2.1.1.2. Filling of prepared scavengers inside sachet. 5g dried scavenger granules of O_2, CO_2, moisture and ethylene scavengers were weighed and filled in sachet (4 x 4 cm) prepared from gas permeable high density woven fabric but impermeable to sachet ingredients and heat-sealed by using an electronic form, fill and seal machine and packed in LDPE pouches for further use.

2.1.5. Chitosan based antimicrobial coating. Chitosan (Sigma Chemical Co.) coating solution was prepared by dissolving 2g chitosan powder (correspond to 2 per cent) and volume made to 100 ml by 1 per cent acetic acid solution in which 0.4 ml glycerol was added as a plasticizer with continuous hand stirring from glass rod for approximately 30 minutes, until the whole chitosan powder was dissolved. The prepared solution was then de-gassed by using vacuum pump to avoid bubbling in the solution and before application the solution was kept undisturbed at 5±1°C for 24 hours.

2.2. Packaging of fruits

Fresh and mature banana fruits purchased from the local market, after washing and disinfecting the fruits and 150-250 g of samples were taken in LDPE bags. Further, sealing was done after incorporating the prepared sachets of particular scavengers. Chitosan coating solution was applied with brush and left for 5-10 min for surface drying and treated samples were stored at (5±1°C) refrigeration (RT) and (30±2°C) ambient temperature (AT). The fruits were analyzed after every 3^{rd} day at room temperature and every 5^{th} day at refrigeration temperature stored for a period of 9 days and 15 days respectively.

2.3. Physico chemical parameters

Physiological Loss in weight (PLW) was determined by the difference in initial and final weight readings. Moisture content was determined by following the standard method of AOAC [2]. Total acids were estimated by the method of Ranganna [15]. Ascorbic acid was determined by procedure detailed by AOAC [1].

2.3.1. Oxygen and Carbon dioxide concentration. The head space gas concentration was observed using Gas analyzer fitted with chromosorb column and thermal conductivity detector (TCD). The rate was expressed as per cent (%).

2.3.2. Ethylene concentration. Ethylene concentration was determined by the procedure adopted by Banks [3] by using gas chromatograph (Netel) fitted with chromosorb101 column and FID. The flow rate of carrier gas (nitrogen) was 29 ml/min, oven temperature 180°C, injector and detector temperature 200°C. Results were expressed as μl C_2H_4/Kg/hr fruit.

2.4. Statistical Analysis

The data was subjected to statistical analysis of variance using SAS (version 9.1). A significance level of 0.5 was chosen. Factors namely ethylene scavenger, O_2 scavenger, CO_2 scavenger, moisture scavenger, antimicrobial film and storage duration were selected or the study as factorial arrangements in Completely Randomized Design (CRD). Each mean value presented in the tables is the average of three replications.

3. RESULTS AND DISCUSSION

The results regarding changes in physico-chemical parameters are presented in the Figures 1-7.

3.1. Physiological loss in weight (PLW)

Fig. 1.(a,b) express the observations regarding the changes in PLW in banana at refrigeration and ambient temperature, recorded lower PLW (0.69 and 0.83%) for control samples than all the scavengers. Highest PLW value was observed for banana samples treated with moisture scavenger (2.03 and 1.30%) followed by ethylene scavenger (1.94 and 1.30%) and minimum PLW (0.33 and 0.61%) was found in chitosan coated samples at RT and AT on 15th and 9th day of storage respectively.

Highest PLW was observed in intact fruits may be due to high transpirational and respiratory substrate losses at ambient temperature. However the magnitude of losses was lower at low temperature and it may be due to reduced metabolic activities and evapotranspirational losses. Among the treatments of AP, chitosan coated fruits showed minimum weight loss throughout storage period, whereas, fruit samples showed maximum PLW when treated with ethylene scavenger followed by moisture scavenger followed by O_2 and CO_2 scavenger as these scavengers possess the tendency to absorb moisture from the fruit surface and utilized in the chemical reactions, so all the scavengers happened to absorb water during storage. At ambient temperature, among all the treatments minimum reduction in PLW was observed in coated fruits. The results obtained in the present investigation are in accordance with previously reported results by increase in PLW with increasing duration of storage but the PLW was lower in coated samples than the control in mango fruit stored at ambient conditions (20-30°C and 70-90% RH), Giri *et al.* [6]. Further, Lin and Zhao [13] observed that edible coatings provide an effective barrier to oxygen, carbon dioxide and water vapour transmission thus helping to alleviate the problem of moisture loss.

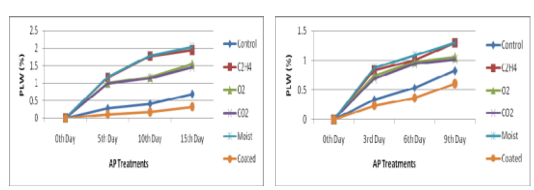

Fig. 1: Effect of Active Packaging on PLW (%) of banana at RT and AT

3.2. Moisture content

Observations regarding the effect of AP on moisture content (%) of banana fruits during storage at refrigeration and ambient temperature are presented in Fig. 2.(a,b) respectively. Initial moisture content for banana was recorded 73.29%. Moisture content of all banana samples was found increasing with advancement of storage period both at RT and AT. Maximum increase i.e. 80.33% and 80% for control samples and minimum increase 77.37% and 77.33% in chitosan coated samples was observed at RT and AT on 15th and 9th day of storage, respectively. Total transfer of moisture from peel to pulp and enzymatic degradation of starch and other molecules might be the possible reason of increase in moisture content in banana fruit. The higher moisture percentage in banana was recorded at refrigerated temperature (RT) as compared with ambient temperature (AT) because low temperature storage is responsible for chilling injury in banana and thereby deterioration of banana fruit and among the AP treatments, chitosan coated fruits showed the best results with respect to chilling injury. It reduced the increase in moisture content in banana and recorded to be 77.4% at RT and 77.3% at AT on the final day of storage and remain acceptable. The highest moisture content in banana fruit was observed in the control samples followed by the samples treated with CO_2 scavenger > O_2 scavenger > moisture scavenger >ethylene scavenger > chitosan coating. AP treatments significantly ($p<0.05$) reduced the movement of moisture from peel to pulp with the advancement of storage. The increase in moisture content with increase in storage duration was reported by Lizada *et al*. [14] who found that water is withdrawn from peel to pulp, consequently, water content decreases in the peel but not in the pulp during ripening. Our results are also in agreement with the findings of Sarode and Tayade, [16] who also reported the similar behaviour of moisture content i.e. movement of moisture from peel to pulp in banana fruit when stored at 32°C.

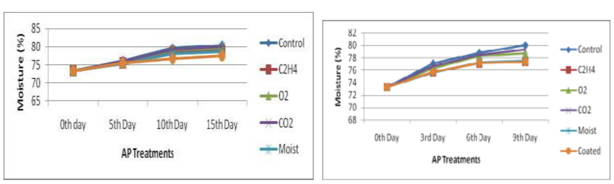

Fig. 2: Effect of Active Packaging on moisture content (%) of banana at RT and AT

3.3. Titratable acidity

Observations regarding the effect of AP on titratable acidity (%) of banana fruits at refrigeration and ambient temperature storage conditions are presented in Fig. 3.(a,b) respectively. Initial titratable acidity for banana was 0.23%. A gradual decline in titratable acidity was observed with the advancement of storage period in all the treatments of AP at refrigeration as well as ambient temperature. Maximum retention (0.163 and 0.161%) was observed in chitosan coated samples followed by samples treated with ethylene scavenger (0.162 and 1.161%), moisture scavenger (0.159 and 0.161%), O_2 scavenger (0.157 and 0.154%), CO_2 scavenger (0.153 and 0.147%) and minimum (0.150 and 0.122%) was observed in control samples at RT and AT on 15th and 9th day of storage respectively. AP treatments except CO_2 significantly retained acidity at RT whereas, at AT all AP treatments significantly retained the acidity ($p<0.05$). The control fruit samples had minimum acidity at the end of the storage at RT and AT. However the magnitude of reduction in acidity was lower at low temperature than AT storage conditions that attributed to lower rate of ripening. The progressive decrease in acidity could be due to conversion of acids into sugars during ripening process. Among AP treatments, chitosan coated samples were found to be effective in maintaining higher acidity i.e. it significantly decreased the reduction in acidity at RT at final day of storage whereas, AP treatments except CO_2 scavenger significantly retained the acidity in all the fruits at AT. This is supported by Castro *et al*. [5] who observed that the rate of reduction in acidity in coated fruits compared to uncoated fruits is low due to restriction of oxygen availability that leads to reduced respiration rate. Further, Jiang *et al*. [10] also reported the effect of chitosan coatings on litchi fruit and found that titratable acidity decreased during storage.

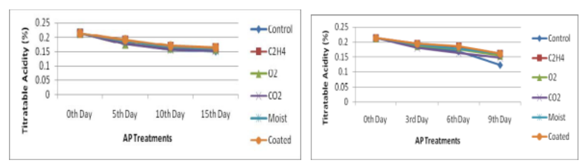

Fig. 3: Effect of Active Packaging on titratable acidity (%) of banana at RT and AT

3.4. Ascorbic acid

The observations regarding the effect of active packaging on ascorbic acid content (mg/100g) of banana fruits are presented in Fig. 4.(a,b) for banana at RT and AT respectively. The initial ascorbic acid content was (10.0 mg/100g) in banana. AP significantly ($p<0.05$) maintained the ascorbic acid content during storage. A gradual reduction in ascorbic acid was observed in all treatments under active packaging for the entire fruit samples and minimum was observed in control fruit samples at RT and AT, however the magnitude was low at RT. The results obtained in the present investigation are in accordance with the previously reported results of Ishaq *et al*. [8] who investigated the physico-chemical characteristics of apricot fruit at 28 to 30ºC and 60-63% RH and observed the decreasing trend of ascorbic acid with passage of time, might be due to the conversion of dehydroascorbic acid to diketogluconic acid by oxidation. However, among AP treatments maximum retention of ascorbic acid was observed in fruits coated with chitosan and treated with ethylene scavenger followed by moisture, O_2 and CO_2 scavengers on the final day of storage under both the storage temperatures. The reason for high ascorbic acid content in chitosan coated fruits can be attributed to slow ripening rate of treated fruits. Srinivasa *et al*. [17] observed that coatings prevent transfer of gases between the fruit and atmosphere and served as a protective layer that control the permeability of O_2 and O_2 and therefore, prevent the oxidation of vitamin C by hindering the fruit's exposure to oxygen, altering enzymatic activity and slowing the respiration process.

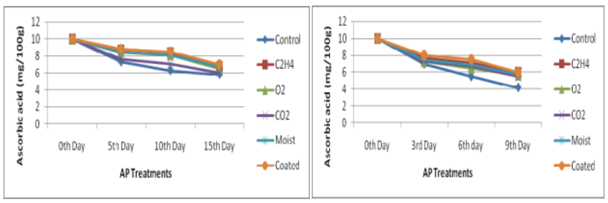

Fig. 4: Effect of Active Packaging on ascorbic acid (mg/100g) of banana at RT and AT

3.5. Oxygen and Carbon dioxide

The headspace O_2 and CO_2 (%) levels in all the fruit packages were analyzed using gas analyzer and the observations regarding O_2 concentration are presented in Fig. 5.(a,b) for banana whereas; the observations regarding CO_2 concentration for are presented in Fig. 6.(a,b) for banana. The initial concentration of O_2 was 21% and CO_2 was 0.03%. Maximum retention of O_2 concentration (12.20 and 7.37%) was observed in chitosan coated banana samples followed by samples treated with ethylene scavenger (10.57 and 6.93%), moisture scavenger (9.23 and 4.60%), O_2 scavenger (9.13 and 4.50%), CO_2 scavenger (9.13 and 4.17%) and lowest (8.47 and 4.03%) in control samples at RT and AT on 15th and 9th day of storage respectively. AP treatments significantly ($p<0.05$) maintained the O_2 concentration at RT whereas; AP treatments except CO_2 and O_2 scavengers significantly maintained the O_2 concentration at AT.

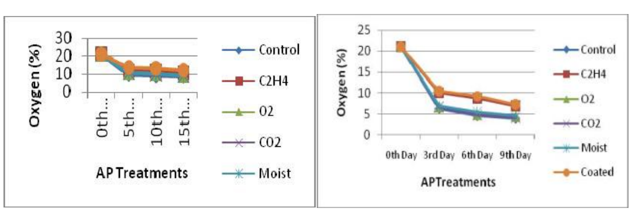

Fig. 5: Effect of Active Packaging on O_2 (%) of banana at RT and AT

Lowest CO_2 concentration (2.43 and 3.07%) in banana samples treated with CO_2 scavenger followed by chitosan coated samples (2.90 and 3.87%), ethylene scavenger (5.40 and 5.80%), moisture scavenger (5.77 and 6.05%), O_2 scavenger (6.07 and 6.78%) and highest (9.7 and 12.97%) was observed in control samples at RT and AT on 15th and 9th day of storage respectively. AP significantly ($p<0.05$) reduce the increase in CO_2 concentration at RT and AT. In general, level of O_2 and CO_2 showed a gradual decrease and increase respectively. From the results it can be concluded that control samples had highest CO_2 concentration than the samples treated with AP treatments. All the AP treatments especially chitosan coated samples followed by ethylene and moisture scavengers delay ripening by the modification of gases and thereby significantly reduce ($p < 0.05$) the rate of respiration at both the storage temperatures. However, the magnitude was low at RT (low temperature). Our results are in accordance with Jiang and Li [11] who studied the effect of chitosan coating on fruits and concluded that chitosan coating may form a protective barrier on the fruit surface which reduces the availability of O_2, and delays ripening in fruits. Furthermore, chitosan coating can also reduce the internal O_2 concentration in treated fruits and so produce low CO_2 and ethylene concentration. Further, Baez-Sanudo *et al*. [4] evaluated the effects of 1-methyl cyclopropene and chitosan based edible coating on banana fruits during storage of 8 days at 22°C, 85% RH and found that treated fruits showed a lower rate of respiration than control fruits.

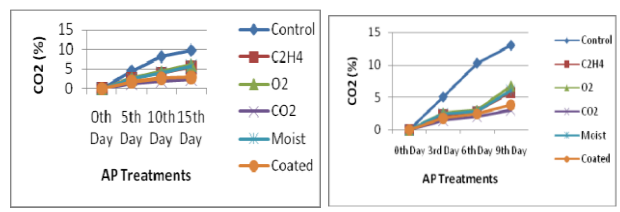

Fig. 6: Effect of Active Packaging on CO_2 (%) of banana at RT and AT

3.6. Ethylene

The observations regarding the effect of AP treatments on ethylene concentration of banana fruit are presented in Fig. 7.(a,b) at RT and AT. At 0 day initial ethylene concentration (57.5 µl C_2H_4/kg/h) was reported. Chitosan coated samples exhibited minimum ethylene concentration (22.91 and 36.77 µl C_2H_4/kg/h) followed by samples treated with ethylene scavenger (25.53 and 37.85 µl C_2H_4/kg/h), moisture scavenger (31.17 and 46.71 µl C_2H_4/kg/h), O_2 scavenger (34.15 and 48.09 µl C_2H_4/kg/h), CO_2 scavenger (35.91 and 46.25 µl C_2H_4/kg/h) and maximum concentration (43.67 and 51.56 µl C_2H_4/kg/h) was observed in control samples at RT and AT on 15th and 9th day of storage respectively. AP significantly ($p<0.05$) reduce the increase in ethylene concentration at RT and AT. The highest ethylene concentration was observed in control of all fruit samples and the lowest was recorded in chitosan coated fruits followed by ethylene and moisture scavenger. AP treatments can delay the ripening process in fruits by slowing down or trapping the ethylene production. Maximum delay in respiration rate as well as ethylene evolution was observed under AP treatments at both the storage conditions so, there was delay in the climacteric rise of CO_2 production in AP treated fruits. Jayaraman and Raju [9] prepared three matrices (based on silica gel, alumina and limestone and cement) impregnated with $KMnO_4$, studied their effects on fresh fruits and vegetables at 10°C and ambient storage and concluded that alumina-limestone based formulation increased the overall extension of shelf-life from 3-8 days. Kudachikar *et al.* [12] found that banana packed with LDPE film in combination of ethylene adsorbent stored under 13°C extended the shelf-life upto 42 days.

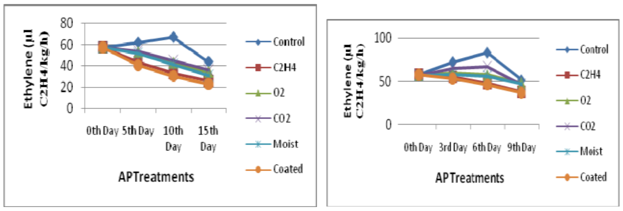

Fig. 7: Effect of Active Packaging on ethylene (µl C_2H_4/kg/h) of banana at RT and AT

4. CONCLUSION

The results reveal that among AP treatments applied on whole banana fruits, chitosan based coating was most effective for all whole fruits in providing improved storage life and quality of the fruits, followed by ethylene, moisture, O_2 and CO_2 scavenging treatments at refrigeration (5±1°C) and ambient temperature (30±2°C). At refrigeration temperature chitosan coated banana samples showed best results and proved better in reducing the softness and chilling injury whereas, other treatments were not found so effective it possibly may be due to chitosan coating is acting as a barrier between the fruit peel and the refrigerated condition due to which the chilling injury may be reduced in the treated samples as compared to control. Chitosan coated fruits followed by samples treated with ethylene, moisture, O_2 and CO_2 scavengers showed lower weight loss (%), retained higher moisture content, TSS, total sugar contents and CO_2 concentration and higher retention of titratable acidity, ascorbic acid, pectin, ethylene and O_2 concentration.

REFERENCES

[1] AOAC., Official methods of analysis: Association of official analytical chemist, Washington, DC, USA, 15, 1990.

[2] AOAC., Official methods of analysis: Association of official analytical chemist, Gaithersburg, MD, USA, 17, 2005.

[3] Banks, N.H., "Some effects of Tal prolong coating on ripeness on bananas", Journal of Experimental Botany, 35, 1984, pp 127-137.

[4] Baez-Sanudo, M., Siller-Cepeda, J., Muy-Rangel, D. and Heredia, B.J., "Extending the shelf-life of bananas with 1-methylcyclopropene and a chitosan-based edible coating, Journal of Food Science and Agriculture, 89, 2008, pp 2343-2349.

[5] Castro, L.R., Vigneault, C., Charles, M.T., and Cortez, L.A.B., "Effect of cooling delay and cold chain breakage on 'Santa Clara' tomato", Journal of Food Agricultural Environment, 3, 2005, pp 49-54.

[6] Giri, S.K., Prasad, N., and Kumar, K.K., "Lac wax based emulsion coating to extend post-harvest life of mango", Indian Food Packer, 3, 2003, pp 62-68.

[7] Indian Horticulture Database., Facts and Figures: National Horticulture Board (NHB), 1, 2014, pp 2-25.

[8] Ishaq, S., Rathore, H.A., Majeed, S., Awan S., and Shah, S.Z.A., "The studies on physico-chemical and Oraganoleptic characteristics of Apricot (Prunus armeniaca L.) produced in Rawalakot, Azad Jammu and Kashmir during storage" Pakistan Journal of Nutrition, 8 6, 2009, pp 856-860.

[9] Jayaraman, K.S., and Raju, P.S., "Development and evaluation of a permanganate based ethylene scrubber for extending the shelf-life of fresh fruits and vegetables" Journal of Food Science and Technology, 29 2, 1992, pp 77-83.

[10] Jiang, Y., Li, J., and Jiang, W., "Effects of chitosan coating on shelf-life of cold-stored litchi fruit at ambient temperature", LWT Food Science and Technology, 38, 2004, pp 757-761.

[11] Jiang, Y.M., and Li, Y.B., "Effect of chitosan coating on the post-harvest life and quality of longan fruit", Journal of Food Chemistry, 73 2, 2001, pp 139-143.

[12] Kudachikar, V.B., Kulkarni, S.G., Vasantha, M.S., Aravinda Prasad, B., and Aradhya, S.M., "Effect of modified atmosphere packaging on shelf-life and fruit quality of banana stored at low temperature" Journal of Food Science and Technology, 44, 2007, pp 74-78.

[13] Lin, D., and Zhao, Y., "Innovations in the development and applications of edible coatings for fresh and minimally processed fruits and vegetables", Comprehensive Reviews in Food Science and Food Safety, 6, 2007, pp 62-63.

[14] Lizada, M.C.C., Pantastico, E.B., Abd. Shukor, A.R. and Sabari, S.D., "Ripening of banana: changes during ripening in banana", Banana: Fruit Development, Postharvest Physiology Handling and Marketing, Abdullah, H. and Pantastico, ASEAN Food Handling Burea, Malaysia, 1990, pp 65-84.

[15] Ranganna, S., Handbook of Analysis and Quality Control for Fruit and Vegetable Products, Tata McGraw Hill Publishing Co. Ltd. New Delhi, 1986.

[16] Sarode, S.C., and Tayade, N.H., "Physio-chemical changes during ripening in 'Williams, 'Zeling' and Grand nain' banana" Journal of Dairying, Foods and Home Sciences, 28 3-4, 2009, pp 220-224.

[17] Srinivasa, P., Revathy, B., Ramesh, M., Prashanth, K.H., and Tharanthan, R., "Storage studies of mango packed using biodegradable chitosan film" European Food Research Technology, 215 6, 2002, pp 504-508.

[18] Suppakul, P., Miltz, J., Sonneveld, K., and Bigger, S.W., "Active packaging technologies with an emphasis on antimicrobial packaging and its applications" Journal of Food Science, 68 2, 2003, pp 408-420.

[19] Surendranathan. K.K., "Post-harvest biotechnology of fruits with special reference to banana-Perspective and scope" Indian Journal of Biotechnology, 4, 2005, pp 39-46.