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A COMPARISON OF MODIFIED ATMOSPHERE PACKAGING UNDER AMBIENT CONDITIONS AND LOW TEMPERATURES STORAGE ON QUALITY OF TOMATO FRUIT

COMPARAISON DU CONDITIONNEMENT EN ATMOSPHERE MODIFIEE SOUS CONDITIONS ENVIRONNANTES ET DE LA CONSERVATION A BASSE TEMPERATURE POUR LA QUALITE DU FRUIT DE TOMATE

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ABSTRACT

Low temperature and modified atmosphere packaging (MAP) were evaluated for their effectiveness in extending the postharvest storage life of tomato (*Lycopersicon esculentum Mill*.) fruits. Fruits were harvested at the mature-green stage of ripeness, washed, sorted and treated with a solution of sodium hypochlorite (150 ppm chlorine). The fruits were packaged in low density polyethylene bags (0.044 mm) and kept at ambient conditions of 24±2 ^{0}C and relative humidity (RH) of 65±2% or held in environmental chambers at 15 ^{0}C and RH of 65% for 4 weeks. The fruits were then transferred to ambient conditions of air, temperature and RH for a further one-week to simulate marketing conditions. Samples were evaluated initially and thereafter every week for weight loss, titratable acidity (TA), soluble solids content (SSC), pH, chlorophyll content, ascorbic acid content and visual appearance. MAP reduced weight loss better than low temperature storage. MAP was also superior in delaying ripening in the fruits for the entire four weeks as evidenced by delayed increase in SSC, chlorophyll degradation and increase in ascorbic acid content which are associated with the fruit ripening. After two weeks of storage at 15 ^{0}C most of the fruits had started shriveling, thereby leading to loss of brightness in color and there were signs of mold infection. Under MAP the carbon dioxide and ethylene concentrations in the bags increased to 9% and 31 ppm, respectively. Upon transfer of fruits to ambient conditions, fruits held under MAP ripened normally with no signs of carbon dioxide injury. At the end of five weeks, 50% of fruits held at 15 ^{0}C were spoilt while only 26% of fruits under MAP were spoilt. These results indicate that under tropical conditions the quality and storage life of tomato fruits can be extended and ripening delayed better by MAP than by low temperature storage owing to fruit susceptibility to chilling injury.

Key words: Ascorbic acid, Low temperature storage, Lycopersicon esculentum, Modified atmosphere packaging, Tomato

RESUME

La conservation à basse température et le conditionnement en atmosphère modifiée (modified atmosphere packaging – MAP) ont été évalués pour leur efficacité dans le but de prolonger la durée de conservation après la récolte des fruits de tomate (Lycospersicon esculentum Mill.). Les fruits ont été récoltés à l'état de maturité vert avancé, lavés, triés et traités avec une solution d'hypochlorite de sodium (150 ppm de chlore). Les fruits ont été emballés dans des sacs en polyethylene à basse densité (0,044 mm) et conservés sous conditions environnantes à 24±2 °C avec une humidité relative (HR) de 65±2% ou maintenus dans des pièces tempérées à 158C avec HR de 65% pendant 4 semaines. Les fruits ont ensuite été transférés en conditions environnantes d'aération, de température et de HR pendant encore une semaine pour simuler les conditions de mise sur le marché. Les échantillons ont été évalués au début de l'étude et ensuite chaque semaine pour perte de poids, acidité titrable (AT), teneur en matière solide soluble (TMS), pH, teneur en chlorophylle, teneur en acide ascorbique et apparence visuelle. Le MAP avait un meilleur effet réducteur de poids que la conservation à basse température. Le MAP était aussi supérieur pour retarder la maturation des fruits, pendant toute la période de quatre semaines, ainsi que démontré par une augmentation retardée du TMS, de la dégradation du chlorophylle et de l'augmentation du contenu en acide ascorbique qui sont associés à la maturation du fruit. Après deux semaines de conservation à 158C, la plupart des fruits commençaient à se ratatiner, entraînant une perte du brilliant de la couleur, et il y avait des signes de moisissure. Dans les conditions de MAP, les concentrations de dioxyde de carbone et versène dans les sacs ont augmenté jusqu'à 9% et 31 ppm, respectivement. Lors du transfert des fruits en conditions environnantes, les fruits conservés par MAP ont mûri normalement sans montrer de signes de dommage dû au dioxyde de carbone. Après cinq semaines, 50% des fruits conservés à 15 °C étaient abimés tandis que seulement 26 % des fruits l'étaient avec le système MAP. Ces résultats indiquent que dans des conditions tropicales, la qualité et la durée de conservation des fruits de tomate peuvent être améliorées et la maturation mieux retardée en utilisant le MAP que la conservation à basse température, compte tenu de la susceptibilité des fruits aux dommages causés par le refroidissement.

Mots clés: acide ascorbique; conservation à basse termpérature; Lycopersicon esculentum; conditionnement en atmosphère modifiée; tomate.

INTRODUCTION

The accumulation of carbon dioxide and depletion of oxygen to beneficial levels by the application of modified atmosphere packaging (MAP) is known to extend the postharvest life and quality of many horticultural commodities [1, 2]. Indeed MAP has been used as a supplement or even a substitute for refrigeration to prolong storage life of fresh produce during transportation and retail handling [2, 3]. Kader *et al.* [4] reported that controlled atmosphere (CA) storage could retard quality deterioration in fresh tomato in a manner similar to low temperature. Several other researchers have reported similar results. However, the high degree of atmospheric regulation associated with CA is capital intensive and expensive to operate especially in developing countries, and is, therefore, amenable for long-term storage of commodities such as apple [1, 5]. Alternatively, an inexpensive way of delaying fruit ripening is the use of MAP, where fruits are sealed in semipermeable plastic packages that enable the development of a beneficial gas atmosphere created and maintained by the interaction of fruit respiration and gas diffusion through the packaging film. Few previous reports have evaluated the superiority of MAP to low temperature storage. In Kenya, like in many developing countries, low temperature storage is not commonly used due to lack of refreigeration facilities, and hence the need to evaluate MAP as a suitable alternative.

Tomato fruits are one of the major crops involved in rural-urban trade in Kenya and are among the most perishable during retail marketing. The deterioration of tomato fruits following harvest is influenced by many factors including stage of ripeness, prepackaging treatment and packaging material [6]. Most of the work done on postharvest handling of tomato has been done in the developed countries where emphasis has been laid on low temperature effects (probably due to availability of cooling facilities) on the fruit quality. Although a lot of work has been done on MAP, it has mainly been in combination with low temperature. Information on real rather than simulated tropical conditions seems to be lacking. Moreover, tomato fruit being sensitive to chilling temperature can only be stored safely at above 12 ^{o}C to ensure freedom from chilling injury, good color and flavour profile [7]. Although optimum quality of tomato is attained through vine ripening, ripe tomato fruits are perishable and very labile to transport damage that consequently leads to loss of quality and waste [8]. This is especially so in developing countries due to poor postharvest handling systems and transportation of fruits and vegetables over rough roads and uneven surfaces [9]. For this reason fruits intended for distant markets are usually harvested at mature-green or breaker stages so that the fruits can endure the rigors of handling while maximizing shelf life [10].

Since development of a modified atmosphere within the polymeric film extends the storage life of fruits and vegetables by reduction of ethylene production and respiration [2, 11, 12]. MAP may provide a cheap means for the storage of fruits and vegetables and serve as an alternative to fungicides in extending their shelf life. Most recently, polyethylene packaging of fruits (including tomato) during retail marketing has become a common practice in Kenya [13] and this practice is also extended to the household level. However, the effects of this mode of packaging on deteriorative changes in tomato fruit have not been reported. The viability of MAP as an alternative to low temperature storage and especially under tropical conditions needs to be evaluated. It is against this background that we compared low temperature storage and MAP as means of controlling ripening in tomato fruits. Since the benefits of MAP are lost when the package is opened, we also evaluated the residual effects of MAP on the ripening characteristics. Fruits are a good source of vitamins. However, most of the work done using MAP has been geared towards physiological effect and little has been done on its effect on vitamins as has been done for vegetables. We, therefore, further investigated the effect of MAP on ascorbic acid content in mature-green tomato fruits where maximum level has not been attained.

MATERIALS AND METHODS

Plant material and treatment

Freshly harvested mature-green tomato (*Lycopersicon esculentum Mill. var. Cal J*) fruits were obtained from a commercial supplier in Thika Town, Kenya. The fruits were selected for uniformity in size, color, absence of blemishes and fungal infection, and transported to the laboratory within one hour. Before the experiment, the fruits were washed with a solution of sodium hypochlorite (150 ppm chlorine). The fruits were divided into two lots: one lot was stored in an environmental chamber maintained at 15 ^{o}C and 65% RH. This temperature was chosen since normal ripening does not occur at below 12 ^{o}C [14]. The other lot was packaged in low density polyethylene bags of 18 cm x 24 cm and 0.044 mm in thickness and kept on a laboratory bench to simulate marketing conditions. The temperature in the laboratory ranged from 23 ^{o}C to 27 ^{o}C while the RH ranged from 63% to 67% during the experimental period. Each bag contained six fruits and were replicated three times. The fruits were held at these conditions for four weeks and then transferred to ambient conditions of 23 ^{o}C to 27 ^{o}C and 63% to 67% RH for a further one week to simulate marketing conditions.

The fruits were evaluated before treatment (time 0) and at weekly intervals for weight loss, titratable acidity (TA), soluble solids content (SSC), pH, chlorophyll content, ascorbic acid content and spoilage. Carbon dioxide and ethylene concentrations in the polymeric films were monitored on a weekly basis for six weeks.

Titratable acidity (TA), pH and soluble solids (SSC) content

Three fruits from each treatment were analyzed for TA, SSC and pH. The core was removed and the fruits were pureed in a blender. The pureed samples were filtered to remove fibres. TA was determined by titrating five ml sample with 0.1 N NaOH to pH 8.1. The acidity is expressed as percent citric acid. pH was determined using a pH meter (Toa, Kyoto, Japan). SSC was determined by refractometry using an Atago N1 refractometer and expressed as ^{o}Brix (= %sucrose). This represents not only the reducing sugar content but also organic acids and minor constituents in the sap that contribute to the refractive index [15].

Chlorophyll content

Color change during the experiment was assessed both subjectively and objectively. Since determination of either chlorophyll or lycopene content can be used to indicate tomato color change [16], in the objective assessment, chlorophyll content was used as an index of ripening. Total chlorophyll was extracted according to the method of Arnon [17]. Four grammes of pericarp tissue including the skin was ground in a mortar and pestle with some cold 80% acetone and in the presence of some acid-washed sand. The homogenate was filtered and washed with cold 80% acetone until the filtrate was colorless. The amount of acetone used in each case was noted. Total chlorophyll content in the extract was determined spectrophotometrically by measuring absorbance at 645 nm and 663 nm using a Shimadzu UV-visible spectrophotometer (Model UV-1600, Shimadzu Corporation, Kyoto, Japan). Total chlorophyll content in the extract was calculated according to the Arnon formula [17].

In the subjective evaluation, fruit color change during storage was assessed visually and the fruits classified into three groups: Group I = mature-green fruits only; Group II = breaker and turning fruits only and Group III = pink and red ripe fruits only.

Ascorbic acid content

Ascorbic acid content in the fruit pericarp tissue was determined by visual titration of extract with 2,6-dichlorophenolindophenol solution according to AOAC methods [18].

Gaseous monitoring

In the MAP treatment the concentrations of carbon dioxide and ethylene in the polymeric films were monitored during six-week storage by gas chromatography. Samples of internal gas were withdrawn through a self-sealing septum affixed on the surface of the bag using a 1-ml gas-tight syringe. Carbon dioxide was analyzed by injecting 1 ml of the headspace gas into a Shimadzu GC 8A gas chromatograph (Shimadzu Corporation, Kyoto, Japan) equipped with a thermal conductivity detector and a Porapak Q column. Ethylene concentration was determined by injecting 1 ml of headspace gas into a Shimadzu GC 9A gas chromatograph (Shimadzu Corporation, Kyoto, Japan) equipped with a flame ionization detector and an activated alumina column.

Visual appearance and weight loss

The stage of ripening, appearance and decay of the tomato fruit were evaluated by visual observation noting color development, shriveling and presence of molds on the tomato surface. The results were expressed as percent of the total sample. Weight loss was monitored every week using a weighing balance and expressed as a percentage.

Results, where applicable were analyzed using Duncan`s Multiple Range Test at P = 0.05.

RESULTS

Weight loss

Fruits held under MAP lost less weight compared to those held at 15 ^{o}C (Fig. 1). When the fruits were transferred to ambient conditions to simulate market conditions, the rate of water loss was higher in fruits previously held at low temperature than those under MAP. This weight loss was associated mainly to loss of moisture. In general, weight loss progressively increased with storage time and was linear for fruits under MAP before transfer to normal air.

Titratable acidity (TA), pH, soluble solids (SSC) content and SSC:TA ratio

The effects of low temperature storage and MAP on TA, pH, SSC and SSC:TA ratio in the tomato fruits are shown in Table 1. SSC in fruits under MAP remained fairly constant until transferred to normal air, while in fruits held at 15 ^{o}C there was a general increase in SSC. TA in fruits under MAP decreased slightly and remained fairly constant, whereas in fruits held at 15 ^{o}C, TA increased up to a maximum in the second week and then began to decrease and was similar to that of fruits under MAP upon transfer to normal air. There was a general increase in SSC:TA ratio under both treatments, initially being higher in fruits under MAP than in fruits held at 15 ^{o}C. Fruits held at 15 ^{o}C had low pH values which correlated to the TA values.

Color change and gas composition

Color is the most visible ripening indicator, hence determination of color development appears to be a logical factor in investigating modified atmosphere storage of tomatoes [19]. MAP was more effective in retarding chlorophyll degradation than low temperature storage (Fig. 2).

Although low temperature delayed chlorophyll degradation, it did not prevent it altogether and majority of the fruits had lost most of the green color by the end of the second week. The effect of MAP was reversed upon transfer of fruits to ambient conditions where color developed normally. The carbon dioxide concentration in the polymeric films increased to 9% while ethylene increased to 30 ppm (Fig. 3).

Ascorbic acid content

Ascorbic acid is fairly labile and its retention is often followed when evaluating postharvest storage effects on nutritional quality in fruits and vegetables. In fruits held at 15 ^{o}C, ascorbic acid content increased to a maximum within two weeks and then started to decline (Fig. 4) while MAP delayed the increase in ascorbic acid content that is associated with ripening. Upon transfer of fruits from MAP to normal air, ascorbic acid content increased to the maximum observed for fruits at 15 ^{o}C after two weeks of storage. This increase was in parallel with the increase in other parameters associated with ripening. Therefore, MAP could be an inexpensive way of preserving the nutritional quality of tomato fruits and other fruits and vegetables.

Ripening and spoilage

The effects of low temperature storage and MAP on ripening and spoilage of the fruits is depicted in Table 2. Although storage at 15 ^{o}C delayed ripening process, it did not stop it altogether. By the end of three weeks, most of the fruits were either at the pink or red stages of ripeness. Most of the fruits were shriveled due to excessive water loss and we observed some traces of molds. On the other hand, MAP significantly reduced the rate of ripening. By the end of the fourth week 55% of the fruits were still at the mature-green stage of ripeness. This correlated well with the results of chlorophyll content. However, we observed traces of molds on the fruits and we attributed this to condensation of water on the fruit surface. Upon transfer of fruits to air for one week, 50% of fruits previously held at 15 ^{o}C were spoilt, mainly due to excessive water loss and mold infection whereas only 26% of fruits previously under MAP were spoilt, mainly due to mold infection.

DISCUSSION

The loss of moisture results in a reduction in the fresh weight of harvested product, which when sold on a weight basis is translated into loss in value. Generally, the loss of only 5-10% moisture renders a wide range of products including tomato fruits unsellable [20]. Previous studies have shown that MAP reduces weight loss in various commodities including tomato [8] although none of these reports had assessed its superiority to low temperature storage. Meir *et al*. [21] observed that MAP reduced water loss in bell pepper by 40-50%. Water loss of fresh tomato fruits is primarily due to transpiration and respiration. Transpiration, the greatest contributor to reduction in weight is the mechanism by which water is lost due to differences in vapor pressure of water in the atmosphere and the tomato surface while respiration causes weight reduction because each time a carbon atom is lost a molecule of water is produced [22]. The reduced weight loss by fruits held under MAP is most likely due to the high RH maintained inside the polyethylene bags. Bhowmik and Pan [22] observed that high RH under CA considerably reduced weight loss in tomato fruits. The considerable water loss from fruits held at 15 ^{o}C was associated with shrinkage of the skin leading to impairment of appearance. The fruits were unattractive due to formation of wrinkles on the surface. According to Artes and Escriche [7] and Bhowmik and Pan [22], this leads to loss of brightness in color, results which are consistent with our observation.

It has been proposed that the lower TA in fruits held at high RH as would be encountered under MAP is primarily due to their higher retention of water and, therefore, the concentration effect caused by water loss may be reflected in TA values [22]. Interestingly, we did not observe any change in TA upon transfer of fruits previously under MAP to air. A similar observation has previously been made [8]. The increase in SSC:TA ratio was probably due to the changes observed in SSC and TA under both treatments during the storage period. High quality tomato fruits are characterized by containing more than 3% SSC, 0.32% TA and having a SSC:TA ratio greater than 10 [4]. Our results, therefore, indicate that with respect to these parameters, fruits from both treatments were of good quality. The observation that MAP had little effect on SSC is in good agreement with that of Nakhasi *et al*. [8] and supports the conclusion reached by Goodenough *et al*. [23] that MAP may not equally control all ripening processes. Yang and Chinnan [24] reported that an appropriate MAP delays changes in SSC among other parameters. In tomato fruits held under CA, SSC remained low during storage probably due to suppression of respiration and delay in ripening and then increased upon return to air [22]. The low pH values for fruits held at 15 ^{o}C could be attributed to the low RH in the storage chambers. These results are similar to those reported earlier by other researchers [22]. However, Wright and Kader [25] observed that persimmons stored in air or atmospheres containing 12% carbon dioxide had similar pH.

MAP maintained chlorophyll content in the fruits. This implies that MAP decreased the metabolic processes responsible for both chlorophyll degradation and lycopene synthesis or any process that may facilitate unmasking of preexisting lycopene. Kidd and West [26] observed that the color change in tomato fruits from green to red, indicative of ripening could be retarded by high carbon dioxide, low oxygen or a suitable combination of these gases. The increase in the concentrations of carbon dioxide and ethylene is in agreement with the results reported earlier [8]. The increased carbon dioxide concentration may have prevented accumulation of higher levels of ethylene, and also counteracted the biological activity of ethylene in enhancing chlorophyll degradation. Color development (i.e. loss of chlorophyll) is delayed by storing tomato fruits under CA [22]. MAP has also been shown to delay color change in tomato fruits although these treatments were in combination with low temperature storage [8, 24]. Gong and Corey [10] showed that tomatoes under MAP kept for three weeks at 20^{o} C without reaching the pink stage that is in agreement with our observation. Reduced respiration rates combined with lowered ethylene production and reduced sensitivity to ethylene results in decreased chlorophyll degradation [2]. MAP has also been shown to delay chlorophyll degradation in green vegetables [27].

In tomato fruits ascorbic acid content increases with maturity and stage of ripening [28]. It has been indicated that once fruits reach full ripe stage, ascorbic acid content starts to decline [18]. It seems that MAP suppresses the synthesis of ascorbic acid but does not impair the fruit capability to synthesize the vitamin. MAP may inhibit the activity of L-galactono-ƒ-lactone dehydrogenase, which is required for the synthesis of ascorbic acid, a possibility we are currently investigating. Factors such as high RH and temperature have also been shown to affect ascorbic acid content [28]. Bhowmik and Pan [22] observed that tomato fruits held at 12 ^{o}C started ripening within a short time and over 80% were lost within four weeks of storage. Although the carbon dioxide concentration in the package increased to 9%, we did not observe any carbon dioxide injury, either when fruits were in the package for upto four weeks or when subsequently ripened in air at 25^{o}C. This is in agreement with the observation of Gong and Corey [10]. Consistent with the observation of Shirazi and Cameron [3], the limiting factor in our MAP experiment seemed to be appearance of mold that we associated with the high in-package RH.

In conclusion, water loss seemed to be the overriding factor influencing visual appearance and quality of tomato. Therefore, eliminating water loss through packaging holds greater potential for extending postharvest life of tomato fruits. Further study will, however, be required to optimize packaging conditions especially relative to disease control. To this end we are investigating the effects of modifying in-package RH on tomato fruit ripening. We conclude that MAP of tomato fruits is more superior to low temperature storage with respect to delaying ripening and associated quality changes. This is mainly due to maintenance of high RH and elevated carbon dioxide and/or low oxygen concentrations in the package. Therefore, implementation of MAP for tomato fruits in Kenya and other developing countries where refrigeration facilities are rare will retard ripening processes and extend fruit shelf life, thereby facilitating postharvest handling and reducing waste.

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REFERENCES

1. **Zagory D and AA Kader** Modified Atmosphere Packaging of Fresh Produce. *Food Technol.* 1988; **42**: 70-77.
2. **Kader AA, Zagory D and EL Kerbel Modified** Atmosphere Packaging of Fruits and Vegetables. CRC *Crit. Rev. Food Sci. Nutrit*. 1989; **28**: 1-30.
3. **Shirazi A and AC Cameron** Controlling Relative Humidity in Modified Atmosphere Packages of Tomato Fruit. *Hortscience* 1992; **27**: 336-339.
4. **Kader AA, Morris LL, Stevens MA and M Albright-Holton Composition** and Flavour Quality of Fresh Market Tomatoes as Influenced by Some Postharvest Handling Procedures. *J. Amer. Soc. Hort. Sci*. 1978; **103**: 6-13.
5. **Cheng TS and RL Shewfelt** Effect of Chilling Exposure of Tomatoes during Subsequent Ripening. *J. Food Sci.* 1988; **53**: 1160-1162.
6. **Geeson JD, Browne KM, Maddiso K, Shepher J and F Guradi** Modified Atmosphere Packaging to Extend the Shelf Life of Tomatoes. *J. Food Technol*. 1985; **20**: 339-349.
7. **Artes F and AJ Escriche** Intermittent Warming Reduces Chilling Injury and Decay of Tomato Fruit. *J. Food Sci*. 1994; **59**: 1053-1056.
8. **Nakhasi S, Schlimme D and T Solomos** Storage Potential of Tomatoes Harvested at the Breaker stage using Modified Atmosphere Packaging. *J. Food Sci*. 1991; **56**: 55-59.
9. **Mathooko FM** Studies on the Biochemical and Physiological Responses of Fruits and Vegetables to Treatment with Elevated Levels of Carbon Dioxide. Ph.D. Thesis, Okayama University, Okayama, Japan . 1995.
10. **Gong S and KA Corey** Predicting Steady-state Oxygen Concentrations in Modified Atmosphere Packages of Tomatoes. *J. Amer. Soc. Hort. Sci.* 1994; **119**: 546-550.

11. **Kader AA** Biochemical and Physiological Basis for Effects of Controlled and Modified Atmospheres on Fruits and Vegetables. *Food Technol*. 1986; **40**: 99-100, 102-104.
12. **Mathooko FM, Sotokawa T, Kubo Y, Inaba A and R Nakamura** Retention of Freshness in Fig Fruit by Controlled Atmosphere or Modified Atmosphere Packaging under Ambient Temperature. *J. Jap. Soc. For Hort. Sci*. 1993; **62**: 661-667
13. **Abe K, Mathooko FM, Kiiyukia C, Koaze H, Muigai CW and MW Mwaniki** Surveillance of Postharvest Handling of Perishable Food Crops in Kenya . Technical Report, Department of Food Science and Postharvest Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya . 1996.
14. **Shewfelt RL, Thai CN and JW Davis** Prediction of Changes in Color of Tomatoes during Ripening at Different Constant Temperatures. *J. Food Sci*. 1988; **53**: 1433-1437.
15. **Davies KM and GE Hobson** The Constituents of Tomato Fruit - The Influence of Environment, Nutrition and Genotype. *Critical Review on Food Science and Nutrition* 1981; **15**: 205-280.
16. **Grierson D and AA Kader** Fruit Ripening and Quality. **In:** JG Atherton and J Rudich (Eds). The Tomato Crop - A Scientific Basis for Improvement. Chapman and Hall, New York. 1986: 241-280.
17. **Arnon DI** Copper Enzymes in Chloroplasts. Polyphenol Oxidase in *Beta vulgaricus*. *Plant Physiol*. 1949; **24**: 1-16.
18. **AOAC** Association of Official Analytical Chemists. Official Methods of Analysis, 14th Ed. AOAC, Washington D.C.,1984.
19. **Yang CC and MS Chinnan** Computer Modeling of Gas Composition and Color Development of Tomatoes Stored in Polymeric Film. *J. Food Sci.* 1988; **53**: 869-872.
20. **Kays J** (Ed) Postharvest Physiology of Perishable Plant Products. Van Nostrand Reinhold, New York.1991.
21. **Meir S, Rosenberg I, Aharon Z, Grinberg S and E Fallik** Improvement of the Postharvest Keeping Quality and Color Development of Bell Pepper (cv. 'Maor') by Packaging with Polyethylene Bags at a Reduced Temperature. *Postharvest Biol. Technol.* 1995; **5**: 303-309.
22. **Bhowmik SR and JC Pan** Shelf Life of Mature Green Tomatoes Stored in Controlled Atmosphere and High Humidity. *J. Food Sci.* 1992; **57**: 948-953.
23. **Goodenough PW, Tucker GA, Grierson D and T Thomas** Changes in Color, Polygalacturonase, Momonosaccharides and Organic Acids during Storage of Tomatoes. *Phytochemistry*1982; **21**: 281-284.

24. **Yang CC and MS Chinnan** Computer Modelling of Color Development of Tomatoes in Modified Atmosphere Storage. *Trans. Amer. Soc. Agric. Eng*. 1987; **30**: 548-553.
25. **Wright KP and AA Kader** Effect of Slicing and Controlled-Atmosphere Storage on the Ascorbate Content and Quality of Strawberries and Persimmons. *Postharvest Biol. Technol.*1997;**10**: 39-48.
26. **Kidd F and C West** The Gas Storage of Fruit. II. Optimum Temperatures and Atmospheres. *J. Pomol. Hort. Sci.* 1930; **8**: 67-83.
27. **Barth MM, Kerbel EL, Broussard S and SJ Scmidt** Modified Atmosphere Packaging affects Ascorbic Acid, Enzyme Activity and Market Quality of Broccoli. *J. Food Sci.* 1993; **58**: 140-143.
28. **Watada AE Vitamins**. **In:** J. Weichmann (Ed). Postharvest Physiology of Vegetables. Marcel Dekker, New York. 1987: 455-468.