Effect of "Oxygen and Carbon-dioxide" on the Post-Harvest Management in Tree-Ripe Mango Storage

[1]HAMEED ULLAH, [2]SAEED AHMAD*, [3]ANTHONY KEITH THOMPSON, [2]RAHEEL ANWAR, [2]NOOR-UN-NISA MEMON AND [2]MUHAMMAD NAFEES

[1]*Citrus Research Station, Sahiwal, Pakistan.*

[2]*Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan.*

[3]*Postharvest Technology, Cranfield University, Silsoe, UK.*

(Received on 2nd December 2008, accepted in revised form 27th March 2010)

Summary: There is an increasing niche market demand for tree-ripe mango fruit due to their pleasant level of sweetness and flavour than artificially ripened fruits. However, tree-ripe mango fruits normally have a short storage life therefore, some time these fruits can not be reached to the ultimate consumers and heavy losses occurred. To avoid this problem growers try to harvest the mangoes at early stage of maturity which directly affect the physico-chemical constituents of fruit. Research was carried out to investigate the Controlled atmosphere (CA) storage feasibility and optimum storage conditions for tree-ripe cv. Chaunsa mangoes in order to extend their shelf life without compromising their quality. Tree ripe mangoes were stored in 1, 3, or 5% O_2 combined with 3, 6, and 9 % CO_2 at 10°C for two weeks and compared with those stored in 21% O_2 and 0% CO_2 as control. It was found that the rate of fruit weight loss decreased with an increase of CO_2 in the storage atmosphere. Higher acidity was found in the fruit which were stored at lower concentration of O_2 and higher concentration of CO_2 which might be due to the accumulation of higher concentration of CO_2 in the fruit tissues. CA storage showed better retention of Ascorbic acid but did not show any systematic trend regarding citric acid, tartaric acid and malic acid. Fruits stored under controlled atmosphere showed better retention of freshness, colour, firmness, total soluble solids and flavour in comparison with the fruit stored in air (control). Mangoes stored in 3% O_2 with 6% CO_2 were highly acceptable by the panellists due to their better sweetness, flavour as compared to others.

Introduction

Mango is the most important fruit of Pakistan and also has great export potential. The Chaunsa cultivar is especially preferred for export. Lack of proper handling systems after harvest not only results in huge losses of quantity and quality of mangoes, but also affects both the internal and export trade [1].

Maintenance of fruit quality for an specific period of time before its consumption is important factor in the post harvest life of fruit. It is not possible to improve the quality of fruit after harvest, but it is possible to slow down the rate of undesirable changes. These changes occur in harvested fruit due to unfavourable conditions (temperature and humidity) and atmospheric compositions. Fresh mango fruits have a short storage life of 10 to 12 days at room temperature and they can also suffer low temperature injury (chilling injury) during refrigerated storage [2]. It has also been reported that shipment of mangoes by sea can take 2-3 weeks [3]. Therefore, it is necessary to develop improved methods of storage of mangoes in fresh state to extend their shelf life without detrimentally affecting their quality. Various methods of extending the storage life of mangoes have been tested but little research has been conducted on Controlled Atmosphere (CA) techniques. Controlled Atmosphere (CA) storage has been shown to be beneficial in reducing the rate of physiological and biochemical changes, ethylene sensitivity and incidence of decay development of perishable fruit products [4]. As a result the onset of senescence is delayed. CA storage has proved very successful in commercial use with apples, pears, and now is increasingly being used commercially with other commodities. Mango cultivars show different response to CA condition. In early experiments with 'Alphonso' mangoes, CO_2 levels of 10-15% in a closed system (Modified Storage) caused CO_2 injury in the form of greyish patches and softening after one week of storage and poor flavour after three weeks [5]. It is also reported that CA storage having 5-10% CO_2 is effective to suppress the respiration rate of ripe mango [6]. Earlier investigations [7], found that CA comprised of 2% O_2 and 2% CO_2 is better for

*To whom all correspondence should be addressed.

maintaining the aroma compounds for ripe fruit. It has also been stated that low temperature, hypobaric, and CA storage can keep the mango fruit for about two weeks but further research in this area was suggested [3]. During initial study of the author [8] one concentration of O_2 with different concentrations of CO_2 was evaluated showed that conditions of 3% O_2 with 6% CO_2 emerged as optimal atmospheric conditions for the storage of eating ripe mangoes of Alphonso variety. Mango verities showed different response to different combinations of O_2 and CO_2 [9]. It is also recently observed that CA inhibited the change of fresh colour and the visible appearance of anthracnose during ripening of the mango fruit [10]. Moreover no work has been done on tree ripe mangoes. Therefore, it is essential to formulate different combinations of O_2 and CO_2 to evaluate the response of tree ripe mangoes "Chaunsa" variety before implementation of CA techniques.

Results and Discussion

Weight Loss (%)

Fruit stored in air (21% O_2 with 0% O_2), and 5% O_2 with 3 or 6% CO_2 showed higher weight losses. Fruit held in 1% O_2 with 3 to 9% CO_2, and 3% O_2 with 6 or 9% CO_2 were statistically alike and showed minimal weight losses than other storage conditions (Table-1). Fruit held in open air at 20°C after CA storage showed the same trend of weight loss as in CA storage but it was higher than CA storage (Table-2). The higher weight loss in the control fruit kept in air on the open bench compared to those kept in air in closed CA boxes was due to higher transpiration rates probably due to the lower humidity surrounding fruits and lower metabolic activity [5].

Decreased rate of weight loss with a decrease in O_2 or increase in CO_2 concentration was possibly due to the reduced respiration rate of CA stored fruits which confirms the findings showing that the weight loss in the CA stored mangoes was significantly lower than those kept in air as a control [11].

Table-1: Effect of CA storage on the Chaunsa mangoes stored for two weeks at 10 °C.

Treatments (O_2% + CO_2%)	Weight loss (%)	Peel Colour Green (a)	Peel Colour Yellow (b)	Firmness (N)	TSS (%)
1 + 3	1.03	2.1	51.77	2.13	19.8
1 + 6	1.15	1.11	54.88	2.4	22.0
1 + 9	1.00	0.85	46.33	2.71	22.2
3 + 3	1.30	2.24	44.73	1.91	21.0
3 + 6	1.24	1.62	47.97	2.04	23.1
3 + 9	1.20	1.41	50.72	2.34	22.8
5 + 3	1.57	2.75	48.92	1.72	22.6
5 + 6	1.50	2.02	48.37	1.81	22.1
5 + 9	1.32	1.89	49.06	2.01	20.9
21 + 0	1.74	3.03	43.15	1.77	20.3
LSD (P = 0.05)	0.25	1.03	6.55	0.54	1.88
CV (%)	13	35	9	18	6

Peel Colour

The peel colour of fruit held in 1% O_2 with 9% CO_2 showed highest greenness values while lowest value of greenness was found in control (Table-1). Concerning yellowness (b*) of peel colour, control fruit held in air showed minimal yellowness and were statistically similar to those held in 1% O_2 with 9% CO_2, and 3% O_2 with 3 or 6% CO_2. Fruit held in 1% O_2 with 3 or 6% CO_2 and 3% O_2 with 9% CO_2 showed statistically higher yellowness. Fruit held at 20 °C after the CA storage revealed the same picture (Table-3). Fruit held in air and in 5% O_2 with 3% CO_2 showed lower yellowness than fruit held in the other treatments. Fruit held in 3% O_2 with 6 or 9% CO_2 showed higher yellowness than others. One of the advantages of CA storage of fruit and vegetables is the reduced rate of loss of chlorophyll [12]. The yellow colour of mangoes is due to the chlorophyll breakdown and carotenoid synthesis and both their breakdown and synthesis is gradually inhibited with an increase in CO_2 concentrations [5]. It appears from the current investigations that mangoes could be stored at relatively low temperature in CA compared with

Table-2: Sensory evaluation of CA storage of mangoes CV. Chaunsa stored for two weeks at 10 °C.

O_2 (%)	Flavour CO_2 (%)			Sweetness CO_2 (%)			Acidity CO_2 (%)			Acceptability CO_2 (%)		
	3	6	9	3	6	9	3	6	9	3	6	9
1	1.88	1.43	1.13	2.38	2.55	2.80	2.08	1.98	2.05	1.73	1.78	1.5
3	3.28	3.40	3.13	3.50	3.38	3.68	1.33	1.75	1.20	2.78	3.5	3.33
5	2.20	2.48	2.48	2.70	3.48	3.25	2.15	1.75	1.70	2.73	2.73	2.73
21+ 0% CO_2		1.80			2.73			2.33			1.58	
LSD P=0.05		0.37			0.37			0.41			0.29	
CV(%)		11			9			16			8	

Table-3: Effect of CA Storage of mangoes CV. Chausna on shelf life of three days at 20 °C after storage for two weeks at 10 °C.

Treatments ($O_2 + CO_2$)	Weight loss (%)	Peel colour		Firmness (N)	TSS (%)
		Green (a)	Yellow (b)		
1 + 3	0.29	2.82	41.96	1.9	21.9
1 + 6	0.27	2.46	46.33	2.1	20.8
1 + 9	0.26	2.10	46.92	2.0	21.7
3 + 3	0.36	2.83	43.57	2.0	20.0
3 + 6	0.35	2.59	48.16	2.1	21.3
3 + 9	0.35	2.82	48.47	2.4	21.8
5 + 3	0.45	4.22	40.59	1.7	20.7
5 + 6	0.40	3.17	42.65	2.0	21.4
5 + 9	0.39	3.51	43.62	1.9	21.9
21 + 0	0.57	4.39	40.18	1.2	
LSD (P = 0.05)	0.08	0.91	5.65	0.35	
CV (%)	14	21	8	12	

those held in air. It is well documented that storage of fruit in an atmosphere containing higher CO_2 concentration has been shown to alleviate or eliminate the chilling injury symptoms [13-16].

Fruit Firmness (N)

Fruit held in 1% O_2 with 6 or 9% CO_2, and 3% O_2 with 9% CO_2 were statistically similar to each other and were firmer than those held in control and other CA conditions (Table-1). Chaunsa mangoes retained their firmness during CA storage better than fruit stored in air. The current investigations confirm the view that CA conditions delay fruit ripening and softening [17]. The rate of firmness retention was increased with an increase in CO_2 concentration or to some extent with an increase in O_2 concentration.

Total Soluble Solids (%, TSS)

Fruit held in 3% O_2 with 6% CO_2 exhibited maximal TSS contents and were statistically at par with those held in 3% O_2 with 9% CO_2, 5% O_2 with 6 or 9% CO_2 and 1% O_2 with 9% CO_2. Fruit held in air, 1 or 3% O_2 with 3% CO_2 were statistically similar to each other but showed lower TSS contents than others (Table-1). The lower TSS contents in mangoes held in an atmosphere containing 1% O_2 could be attributed to fermentative decarboxylation of the fruit. These findings are in line with the previous researchers [5]. It has been found that CA condition slowed down the losses in sugars and organic acids in tomatoes during storage at 12.5 °C for up to 2 months [18]. In the current work, the lower TSS for control fruit held in air and for those held in higher O_2 (5%) with lower CO_2 concentration suggests the onset of senescence.

Citric Acid (%)

Statistical analysis revealed significant differences of citric acid contents among fruits kept to observe their shelf life. Fruit held in 3% O_2 with 3% or 6% CO_2 had 0.18% to 0.21% citric acid which was lower than other treatments. Fruit held in air and 5% O_2 with 6 to 9% CO_2 showed higher citric acid contents, having 0.36% to 0.31 % (Fig. 1). The predominant acid is citric acid which decrease as the fruit ripens [3]. Current investigation did not show clear pictures about the increasing or decreasing trend of citric acid with the increase or decrease of CO_2 and O_2 respectively. Further research is needed to give the answer.

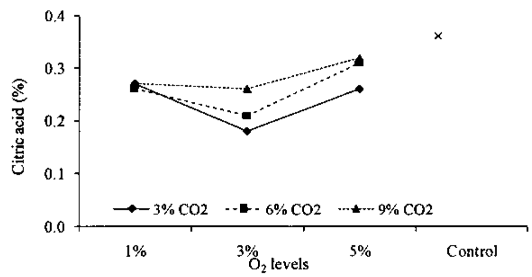

Fig. 1: Effect of different concentrations of O_2 and CO_2 on **citric acid** (%) contents of Chaunsa mangoes during storage at 10 °C.

Ascorbic Acid (mg $100g^{-1}$)

Higher ascorbic acid contents were observed for fruits held in 5% O_2 with 9% CO_2 closely followed by those held in 1 or 3% O_2 with 3% CO_2 and 3 or 5% O_2 with 6% O_2. Control fruit held in air occupied an intermediate position. Fruit held in 1% O_2 with 6 or 9% CO_2, 3% O_2 with 9% CO_2, and 5% O_2 with 3% CO_2 showed poorest performance regarding ascorbic acid contents (Fig. 2). The current investigation support the view that some CA storage treatments results in better retention of ascorbic acid in fruits compared with those stored in air, which had been previously mentioned [19].

Tartaric Acid and Malic Acid (mg 100 g^{-1})

Fruit held in 1% O_2 with 9% CO_2 and in 3% O_2 with 6% CO_2 showed significantly higher tartaric acid than the fruit held in other CA treatments

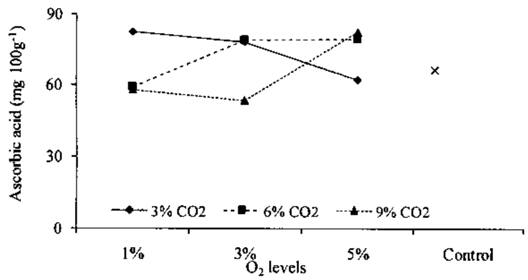

Fig. 2: Effect of different concentrations of O_2 and CO_2 on **ascorbic acid** (mg 100 g^{-1}) contents of Chaunsa mangoes during storage at 10 °C.

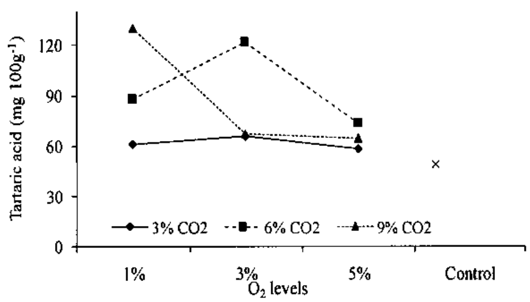

Fig. 3: Effect of different concentrations of O_2 and CO_2 on **tartaric acid** (mg 100 g^{-1}) contents of Chaunsa mangoes during storage at 10 °C.

including control (Fig. 3). Control fruit held in air showed lower tartaric acid contents (Table-4). Fruit held in 3% O_2 with 3% CO_2 showed lower malic acid followed by those held in 5% O_2 with 9% CO_2 (Fig. 4). Fruit held in 5% O_2 with 6% CO_2 showed higher malic acid followed by those held in 1% O_2 with 9% CO_2. Results regarding all organic acid in fruit stored at 20 °C for three days are presented in Table-4. It has also been indicated that the effects of CA storage on organic acids, tartaric acid, malic acid were too completed to draw a general conclusion [20]. Results of current investigation are also inconsistent and show no trend but no reason could be found to interpret these findings.

Sensory Evaluations

The fruit which was held at 20 °C after CA storage for three days were in poor condition and considered to be not worth eating therefore these were not evaluated by sensory evaluations. Results regarding effect of CA storage on the sensory

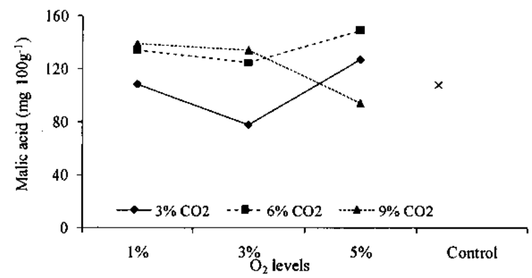

Fig. 4: Effect of different concentrations of O_2 and CO_2 on **malic acid** (mg 100 g^{-1}) contents of Chaunsa mangoes during storage at 10 °C.

Table-4: Effect of CA Storage on organic acid contents of Chaunsa mangoes after two weeks at 10 °C plus 3 days at 20 °C.

Organic Acids	Citric acid			Ascorbic acid			Tartaric acid		
O_2 (%)	CO_2 (%)			CO_2 (%)			CO_2 (%)		
	3	6	9	3	6	9	3	6	9
1	267.1	251.6	234.1	33.1	58.7	41.7	107.1	109.0	64..5
3	337.5	243.1	245.7	40.3	76.2	49.9	112.0	125.8	63.4
5	357.2	320.7	292.5	51.9	53.5	63.4	65.5	68.9	66.04
21+ 0% CO_2	409.0			51.3			66.5		
LSD P=0.05	88.32			20.94			25.34		
CV (%)	21.0			28.0			20.0		

evaluations are given in Table-2. Fruit held in 3% O_2 with 3 to 9% CO_2 showed higher flavour ratings and were statistically similar to each other. Fruit held in air and those held in 1% O_2 with 3 to 9% CO_2 showed poorest performance regarding the falour((Table-2). Fruit held in 3% O_2 with 9% CO_2 showed higher sweetness followed by those held in 3% O_2 with 3 or 6% CO_2, and 5% O_2 with 6 or 9% CO_2. Fruit which were held in 1% O_2 with 3% CO_2 showed minimal sweetness values and occupied the lowest position. Fruit held in air showed higher acidity ratings, and those held in 3% O_2 with 3 and 9% CO_2 had the lowest ratings for acidity. Fruit held in 1% O_2 with 3 to 9% CO_2 received highest off-odour ratings (Fig. 5). Fruit held in 3% O_2 with 6 or 9% CO_2 showed minimal off-odours. Fruit held in 3% O_2 with 6% CO_2 were highly acceptable to the taste panellists followed by those held in 3% O_2 with 9% CO_2. Bananas held in air as a control and in 1% O_2 with 3 to 9% CO_2 were highly unacceptable.

The current investigations produced substantial evidence regarding the sensory evaluation that mangoes held in optimal CA conditions result in better retention of flavour and sweetness. These observations are in line with those reported earlier

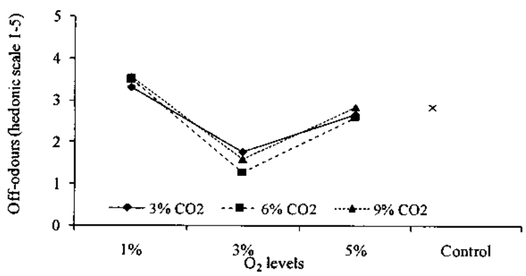

Fig. 5: Effect of different concentrations of O_2 and CO_2 on **off-odours** of Chaunsa mangoes during storage at 10 °C (Sensory evaluation).

[11, 12]. Development of off-odours in mangoes kept in the lower O_2 (1%) level confirmed earlier findings [21]. It has previously been shown that storage of mangoes under low O_2 (1%) [21] or higher CO_2 atmospheres [5] could result in fermentative decarboxylation and accumulation of acetaldehyde and alcohol in the fruits. These end products could increase with an increase in CO_2 concentration in the storage atmosphere. These evidences support the findings of the current investigations. The mangoes held in air and CA conditions were in very poor eating condition at the end of the three days shelf life at the termination of the experiment. However, the rate of deterioration of CA stored mangoes was clearly slower than those held in the air. The fruit used in this experiment was tree-ripe (maturely ripened) but when reached at London it was fully ripe and CA, treatment kept them in good condition for two to weeks. All other CA work reported on mangoes has been done on less mature fruit. Since, there is a marketing advantage for "tree ripe" fruit, this successful technique has clear advantages.

Experimental

The tree-ripe Chaunsa mangoes were harvested at Mango Research Station Shujabad, South Punjab Pakistan and these mangoes were carefully packed in boxes and carried as cabin baggage on scheduled flight from Lahore to London, UK. These mangoes were arrived at Silsoe College, Cranfield University UK by Reefer Container where they were placed in storage at 10 °C. The mangoes of uniform sizes were selected and experiment was started on the same day. These mangoes were stored 1, 3 or 5% O_2 combined with 3, 6 and 9% CO_2 concentrations and with a control treatment of 21% O_2 and 0% CO_2 at 10 °C. After two weeks mangoes were removed from the CA storage and different quality parameters were measured by physico-chemical analysis and sensory evaluations. Some mangoes were kept at 20 °C for three days to test their shelf life after CA storage.

The inlet gases were monitored on a daily basis. These gases were measured using the David Bishop instrument. The controlled atmosphere system consisted of gas tight plastic containers (Model C217, Mailbox International Ltd, Cheshire, UK) each of 75 liters capacity. Each container had one inlet and one outlet tube. The tips of the outlets were immersed in water to prevent hack flow into the container. The inlets tubes were separately connected to a gas distributor (Mercury, UK) by PVC tubing of 6.5 mm internal diameter. The gas distributor was connected to a computer programmed gas blender (Singal Instrument Co. Ltd. Surrey, UK 850 series) which was connected to cylinders of compressed O_2 and CO_2 and a nitrogen generator (Bolton 75-72). The gas output from the gas blender and controlled atmosphere storage containers was analyzed daily using an Oxystate 2.0, Fruit Store Analyzer fitted with an Infra Red Gas Analyzer and a paramagnetic Oxygen Analyzer (David Bishop Instrument Sussex, UK type 770). After three weeks of storage at 10°C mangoes were removed from the boxes and half of them were evaluated for different physicochemical and sensory parameters. The remainder were kept at 20 °C for three days to test their shelf life after CA storage.

The set gas mixture values and the actual gas levels passing through the CA channels were as follows:

Set gas mixture values (O_2% + CO_2%)	Actual gas mixture values (O_2% + CO_2%)	Actual O_2 and CO_2 range (O_2% + CO_2%)
1 + 3	1.2 + 3.4	0.8-1. + 3.1-3.5
1 + 6	1.0 + 8.9	0.8-1.2 + 8.6-9.2
1 + 9	3.1 + 6.0	2.8-3.3 + 5.9-6.2
3 + 3	3.2 + 8.9	3.0-3.4 + 8.7-9.1
3 + 6	5.3 + 5.9	5.1-5.5 + 5.7-6.2
3 + 9	5.4 + 9.0	4.9-5.6 + 8.9-9.2
5 + 3	3.2 + 8.9	3.0-3.4 + 8.7-9.1
5 + 6	5.3 + 5.9	5.1-5.5 + 5.7-6.2
5 + 9	5.4 + 9.0	4.9-5.6 + 8.9-9.2
21 + 0	21.4 + 0.1	21.2-21.5 + 0.0-0.2

This experiment was conducted with four replications. Samples of mangoes were also analysed at the start of the experiment. The peel colour was measured by colorimeter (Minolta Modal CR-200/CR-200b), where a* values corresponded to the degree of greenness and a positive b* value corresponded to the degree of yellowness. Peel and pulp firmness was measured using an Instron Universal Testing Machine (Model 2211) with an 8 mm cylindrical probe. Total soluble solids percentage was measured using a refractometer (Atago Co. Ltd Model PR-1). Titratable acidity was measured by titration against 0.1 N sodium hydroxide. High Performance Liquid Chromatograhpy (HPLC) technique was used to estimate the organic acid contents such as ascorbic acid, citric acid, tartaric acid and malic acid. For the sensory evaluation tests, a panel of eight assessors was selected from the Silsoe College, Cranfield University UK and the tests involved individuals in isolated tasting conditions under a standard light source. Judges were asked to assess pulp flavour, sweetness, off flavour, astringency and overall acceptability each on a five-point scale where: 1 = very low or none; 2 = low to moderate; 3 = medium to high; 4 = high and 5= very high. The scores marked by panellists were collected and an average was calculated for each parameter. All results were analyzed as a randomized blocks 3 x 3 + 1 with 4 replications. Where there was statistical significance at $p = 0.05$ or above in the 'f test' a 't test' at $p = 0.05$ was carried out.

Conclusion

It is concluded that gasses environment in storage clearly beneficial for increasing the shelf life of tree ripe mangoes. Successful controlled atmosphere techniques can eliminate the necessity of harvesting mangoes at an early stage of maturity for shipment to distinct market. CA conditions of 3% O_2 with 6 to 9% CO_2 emerged as optimal atmospheric conditions for the storage of tree ripe mangoes CV. Chaunsa, CA stored fruits showed better retention of freshness, colour, firmness, TSS, and flavour than fruit stored in air. CA works well on extending the storage life of fully ripe fruit but after CA storage.

Acknowledgements

The authors are grateful to the ARP-II project for providing the funds for this project. We also thank Mr. Allan Hilton and Mr. Steve of Cranfield University, Silsoe College, UK for technical assistance

References

1. S. K. Roy, and G. D. Joshi, *Acta Horticulturae*, **231**, 649 (1989).
2. S. Lakshminarayana, *Journal of Horticultural Science*, **48**, 227 (1973).
3. S. Mitra, and E. A. Baldwin, Mango. In: Post harvest Physiology and Storage of Tropical and Sub Tropical Fruit. Ed. S.K. Mitra.CABI, West Bangal, India. p.85 (2005).
4. A. P. Medlicott, and M. J. Jeger, The development and application of postharvest treatments to manipulate ripening of mangoes. In *Mangoes - a review*. Edited by RT Prinsley and G Tucker Commonwealth Science Council, p. 56 (1987).
5. S. Lakshminarayana, and H Subramanyam, *Journal of Food Science and Technology* 7, 148 (1970).
6. N. Nakamura, D. V. S. Rao, T. Shina, and Y. Nawa, *Japan Agricultural Research Quarterly* **38**, 221 (2004).
7. H. J. D. Lalel, Z. Singh, and S. C. Tan, Elevated levels of CO_2 in Controlled atmosphere storage affects shelf life, fruit quality and aroma volatiles of Mango. Proceeding XXVI International Horticultural Congress: Issues and Advances in Postharvest Horticulture, Toronto, Canada. 09 May (2005).
8. Ullah, Ph.D thesis, Cranfield, Uni. UK, 1999.
9. W.G. Burton, *Annals of Applied Biology*, **78**, 149 (1974).
10. K. Youngmok, J. K. Brecht, and S. T. Talcoit, *Food Chemistry*, **105**, 1327 (2007).
11. A. Noomhorm, and N. Tiasuwan, *Journal of Food Processing and Preservation* **19**, 271 (1995).
12. P. E. Brecht, *Food Technology* March, 45-50 (1980).
13. G. R. Chaplin, K. J. Scott, and B. I. Brown, *Singapore Journal of Primary Industries*, **10**, 84 (1982).
14. D. H. Spalding, and W. F. Reeder, *Proceedings of the Florida State Horticultural Soceity* **85**, 337 (1972).
15. D. H. Spalding, and W. F. Reeder, *Phytopathology*, **65**, 458 (1975).
16. V. Vakis, W. Grierson, and J. Soule, *Proceeding of Tropical Region of American Society for Horticultural Sciences*, **14**, 89 (1970).
17. A. A. Kader, *Food Technology March*, p. 51-54 (1980).

18. P.W. Goodenough, and T. H. Thomas, *Annals of Applied Biology,* **94**, 445 (1980).
19. A. A. Kader, *Food Technology,* **40**, 99 (1986).
20. W. G. Burton, Postharvest Physiology of Food Crops. Longman, London, (1982).
21. T. T. Hatton, and W. F. Reeder, *Proceedings of the Caribbean Region of the American Society for Horticulture Science*, **10**, 114 (1967).