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Effect of pre cooling and storage conditions on physiological change of mango (*Mangifera Indica* L.) CV. Kesar

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Abstract
The present investigation entitled, Effect of pre cooling and storage conditions on physiological change of mango (*Mangifera indica* L.) Cv. Kesar" was carried out at the Horticulture research farm, Department of Horticulture B.A. College of Agricultural- Anand Agricultural University, during the year 2017. The experiment was laid out on Factorial Completely Randomized Design, with three replications. The influence of precooling treatments viz., Control(P_0), ice cooling for 15 minutes(P_1), ice cooling for 30 minutes(P_2), hydrocooling at 10 °C temperature for 15 minutes(P_3) and hydrocooling at 12 °C temperature for 30 minutes(P_4) and Storage Conditions viz., Ambient Conditions(S_0), Zero energy cool chamber(S_1) and Cold storage 13±2 °C(S_2). After treatment, fruits were kept in CFB boxes at different storage condition. The fruits were analyzed periodically for various physiological changes. It can be conclude that The fruits treated with hydrocooling at 12 °C temperature for 30 minutes, proved to be most effective with respect to longest shelf life (25.04 days), lowest percentage of spoilage (10.65per cent at 9th day) and physiological loss in weight (5.82, 9.55, 13.41and 13.41 per cent, respectively) on 3th, 6th, 9th and 12th day of storage. In cold storage at 13±2 °C reduced physiological loss in weight (5.54, 10.16, 13.91, 12.08, 10.42 per cent and 16.09, 21.7 and 26.16 per cent treatment mean, respectively), enhanced shelf life of fruits (30.35 days), reduced spoilage (5.70, 15.10 and 4.16 per cent and 29.29, 40.40, 49.85 per cent treatment mean respectively) on 3th, 6th, 12th, pooled over periods and 17th, 22^{th,} 27th day of storage.

Keywords: Mango, Kesar, pre-cooling, storage condition, shelf life, physiological change

Introduction
Mango (*Mangifera indica* L.) belongs to the family Anacardiceae and the genus is believed to be originated in the Indo-Burma region. The fruit is having excellent adaptability and regarded as "King of Fruits." Moreover, Mango has been cultivated in Indian subcontinent for well over 4000 years and favorite of the kings and common people as well, Mango fruits have good nutritional value, every 100 g of mango pulp contain 81.7 g water, 16 g carbohydrate, 0.7 g protein, 0. 4 g fat and 0.1 g fibers. It is rich in calcium, phosphorus, iron, magnesium, Vitamin A, B, C and also fair amount of anti-oxidants.

India is the largest producer of mango in the world with 18526.98 thousand MT productions on an area of 2163.47 thousand hectares and productivity of 8.56 MT per hectare (Anon., 2014 - 15a). The major mango growing states are Andhra Pradesh, Bihar, Gujarat, Uttar Pradesh Maharashtra, Karnataka, Kerala, Tamil Nadu, Orissa and West Bengal. The largest area of 315.42 thousand hectares is being covered by Andhra Pradesh, while Uttar Pradesh is largest producer of mango with 4347.50 thousand MT productions and productivity of 17.34 MT per hectare (Anon., 2014 - 15a).

Pre cooling is a rapidly remove of field heat and slower down the respiration of freshly harvested mango crop, which helps in minimizing the susceptibility to microbes and reduce water loss and thereby increase shelf life. Types of pre cooling are room cooling, hydro cooling, ice cooling, vacuum cooling etc. (Sonkar *et al.*, 2002) [114]. In Hydro cooling fruits are dipped in cold water or spray the cold water on the fruits to remove heat of fruits. (Kapse *et al.*, 1997) [38]. In Ice cooling method Packaging icing involves direct placement of slush, crushed ice surrounding the product for definite time.

Zero energy cool chamber known as on farm storage chamber, for fresh fruits to reducing of transpiration, respiration and ripening even after harvest. The spoilage of fruits reducing the storage temperature 10-15 °C cooler than the outside temperature Cold storage, in which the mango fruits are storage at low temperature, for shelf life of fruits. Mango fruits cv. Kesar by applying various precooling treatments and different Storage conditions for tide over glut period and to prevent the pests and diseases infection.

Materials and Methods

The experiment was conducted in at the Horticultural Research Farm, Fruit processing centre Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand during the year 2017. The mango mature fruits of uniform size and shape having specific gravity between 1.0 and 1.04 were selected from Farm, AAU, Anand. Fruits were harvested at tapkaa stage. That fruits were labeled according to treatments and replication. The statistical analysis was done by using method of analysis of variance (ANOVA) for Completely Randomized Desing with Factorial concept by Gomez and Gomez (1976) [115] Hydro-cooling at 10 ˚C temperature for 15 min, Hydro- cooling at 12 ˚C temperature for 30 min. For hydro-cooling treatment, cool water sprayed on fruits. The constant temperature was maintained by continuous adding of ice in cool water for precooling. For ice cooling treatment, fruits placed uniform plastics carats and fruits were covered with ice crystal for 15 and 30 min, treated fruits were kept in CFB boxes and stored at ambient condition, cold storage (13±2 ˚C) and zero energy cool chamber. Analysis was done before application of treatment, and at 3 days interval for fruits stored in all conditions till the end of room temperature storage and then after at 5 days interval for ZECC and in cold storage. Physiological evaluation observations were recorded at fruits ripening stage. During the storage period, the following data observations were recorded at initial, 3th and 6th, 9th,12th, 17th, 22th, 27th days of storage.

Results and Discussion

The result revealed that among different pre cooling and storage conditions on physiological change of mango.

Physiological loss in weight (%)

Data pertaining to the Physiological loss in weight (%) as significant by different treatment of precooling and storage conditions are presented in Table 1

Table 1: Effect of precooling and storage conditions on physiological loss in weight of mango cv. Kesar

Treatments	Treatment details	Physiological loss in weight (%)							
		Storage period (days)							
		0	3	6	9	12	Pooled	17	22	27
A. Precooling										
P_0	Control		7.13	12.08	16.43	17.07	13.18	-	-	-
P_1	Ice cooling for 15 minutes		6.82	11.41	15.68	16.38	12.57	26.87	-	-
P_2	Ice cooling for 30 minutes		6.20	10.37	14.41	14.83	11.45	18.55	23.91	-
P_3	Hydro-cooling at 10˚C temperature for 15 minutes		6.50	10.38	14.92	15.56	11.84	21.11	26.02	-
P_4	Hydro- cooling at 12˚C temperature for 30 minutes		5.82	9.55	13.41	13.89	10.67	17.43	22.43	-
S.Em. ±			0.18	0.18	0.33	0.44	0.28	-	-	-
C.D. at 5%			0.53	0.53	0.94	1.27	0.83	-	-	-
B. Storage Conditions										
S_0	Ambient condition		7.44	11.35	16.02	18.12	13.23	-	-	-
S_1	Zero energy cool chamber		6.50	10.77	14.97	16.44	12.17	24.07	-	-
S_2	Cold storage 13±2˚C		5.54	10.16	13.91	12.08	10.42	16.09	21.7	26.16
S.Em. ±			0.14	0.14	0.25	0.34	0.22	-	-	-
C.D. at 5%			0.41	0.41	0.74	0.98	0.66	-	-	-
C.V. %			8.48	5.11	6.53	8.47	7.15	-	-	-
Interaction			NS	NS	NS	NS	NS	-	-	-

Effect of precooling on Physiological loss in weight (%)

Data found in Table 1 showed that differences among precooling treatments on PLW (%) was found significant during storage periods at 3rd, 6th, 9th, 12th days of storage. Among the different treatment P_4 (hydrocooling at 12 °C temperature for 30 minutes) recorded significantly minimum PLW (%) i.e. 5.82, 9.55, 13.41, 13.71 and 10.67 percent at 3rd, 6th, 9th, 12th and pooled over period days of storage respectively. Where, significantly maximum PLW (%) was recorded with the control (7.13, 12.08, 16.43, 17.07 and 13.18 percent respectively) which was at par with treatment P_1 (ice cooling for 15 minutes) at 3rd, 9th and 12th days of storage. Based on mean data, treatment P_4 (hydrocooling at 12°C temperature for 30 minutes) also recorded minimum PLW (%) i.e. 17.43 and 22.43 percent at 17th and 22nd days of storage respectively. The lowest loss of fruit weight treated with hydrocooling at 12 °C temperature for 30 minutes. In treated fruits reduction rate of transpiration and respiration and delaying in ripening due to restrict ethylene accumulation. The Similar result were also recorded by Mann and Singh (1976) [56], Chauhan *et al*. (1987) [17] and Puttaraju and Reddy (1997) [77]. Who reported that, precooling in easy possible time after harvest had the lowest PLW in mango. While Unde *et al*. (2004) [112] observed that precooling of grapes reduced PLW. The physiological loss in weight could be decreased by pre-cooling treatment and Patel (2006) [74] in mango cvs. Amrapali and Neelphanso mango fruits.

Effect of storage conditions on Physiological loss in weight (%)

Data found in Table 1 showed the differences storage conditions on PLW (%) was found significant during storage periods at 3rd, 6th, 9th, 12th and pooled over periods days of storage. Among the different storage conditions, treatment S_2 (cold storage at 13±2 °C) recorded minimum PLW (%) i.e. 5.54, 10.16, 13.91, 12.08 and 10.42 percent at 3rd, 6th, 9th, 12th and pooled over period days of storage

respectively. Whereas, significantly maximum PLW (%) was recorded with the control (7.13, 12.08, 16.43, 17.07 and 13.18 percent at 3rd, 6th, 9th, 12th and pooled over days period of storage respectively.) That was at par with treatment S_0 (ambient condition) at pooled over periods. Based on mean data, treatment S_2 (cold storage at 13±2 °C) was recorded minimum PLW (%) i.e. 16.09, 21.70 and 26.16 percent at 17th, 22nd and 27th days of storage respectively) and treatment S_1 (zero energy cool chamber) recorded 24.07 percent of PLW at 17th days of storage conditions whereas were ambient conditions fruits rottener and not suitable for marketing. Cold storage at 13±2 °C was also effective in minimizing PLW compared to control. That due high rate of transpiration in ambient condition as compare to cold storage. Similar findings were obtained by Dhemre and Waskar (2004) [24] and Mann and singh (1976) [56] and Galathia (2004) [28] in Dashehar mango and Unde *et al.* (2004) [112] in grapes cv. Thompson seedless.

Interaction effect

The interaction between precooling and storage methods on PLW of mango fruits remained non-significant. It can be concluded that physiological loss in weight was significantly reduced with the treatment hydro cooling at 12 °C temperature for 30 minutes. Whereas, cold storage at 13±2 °C has also profound effect in minimizing loss in weight.

Spoilage fruit (%)

According to data percent spoilage as effect by precooling treatments and storage conditions are presented in Table 2

Table 2: Effect of precooling and storage conditions on spoilage of mango cv. Kesar

Treatments	Treatment details	Spoilage (%)								
		Storage period (days)								
		0	3	6	9	12	Pooled	17	22	27
A. Precooling										
P_0	Control	0	0	0	22.01	50.21	14.44	-	-	-
P_1	Ice cooling for 15 minutes	0	0	0	17.11	34.48	10.32	51.73	-	-
P_2	Ice cooling for 30 minutes	0	0	0	12.72	27.52	8.05	46.67	53.39	-
P_3	Hydro-cooling at 10°C temperature for 15 minutes	0	0	0	14.49	31.04	9.11	45.36	50.38	-
P_4	Hydro- cooling at 12°C temperature for 30 minutes	0	0	0	10.65	23.89	6.91	41.25	49.45	-
S.Em. ±		-	-	-	0.57	1.44	0.40	-	-	-
C.D. at 5%		-	-	-	1.66	4.25	1.16	-	-	-
B. Storage Conditions										
S_0	Ambient condition	0	0	0	23.19	51.09	14.86	-	-	-
S_1	Zero energy cool chamber	0	0	0	17.30	34.09	10.28	48.95	-	-
S_2	Cold storage 13±2°C	0	0	0	5.70	15.10	4.16	29.29	40.40	49.85
S.Em. ±		-	-	-	0.44	1.11	0.31	-	-	-
C.D. at 5%		-	-	-	1.28	3.22	0.92	-	-	-
C.V. %		-	-	-	11.17	12.88	4.81	-	-	-
Interaction		-	-	-	NS	NS	NS	-	-	-

Effect of precooling on Spoilage fruits (%)

Data found in Table 2 showed that differences among precooling treatments on Spoilage (%) was found significant during storage periods at 9th, 12th and pooled over period days of storage. Among the different treatment P_4 (hydrocooling at 12 °C temperature for 30 minutes) recorded significantly minimum spoilage fruits (%) i.e. 10.65, 23.89 and 6.91 percent at 9th, 12th and pooled over period days of storage respectively. Where, significantly maximum spoilage fruits (%) was recorded with the control (22.01, 50.21 and 14.44 respectively) at par with treatment P_1 (ice cooling for 15 minutes) at 9th and 12th days of storage.

Based on mean data, treatment P_4 (hydrocooling at 12 °C temperature for 30 minutes) also recorded minimum spoilage fruits (%) i.e. 41.25 and 49.45 percent at 17th and 22nd days of storage respectively and due to rotting of fruit in treatment P_0 (control) marketable fruits (%) was not recorded at 17th days of storage. Hydrocooling at 12 °C temperaturefor 30 minutes treated fruits have comparatively less spoilage than control, and it proved storage longer period of time with better fruit qualities, because these treatments significantly control of pest and disease infection to fruits, and so reduce decay losses. The similar results were reported by Mann and Singh (1976) [56], Roy and Pal (1991) [87], Oosthugse *et al.* (1995) [67], Kapse and Katrodia (1997) [38] and Vala (2002) [109] in mango fruit, and Trivedi and Desai (2006) in guava fruit.

Effect of storage conditions on Spoilage fruits (%)

Data found in Table 2 showed that differences storage conditions on Spoilage fruits (%) was found significant during storage periods at 9th, 12th and pooled over period days of storage. Among the different storage conditions, treatment S_2 (cold storage at 13±2 °C) recorded minimum spoilage fruits (%) i.e. 5.70, 15.10 and 4.16 percent at 9th, 12th and pooled over period days of storage respectively. Whereas, significantly maximum spoilage fruits (%) was recorded with the control (23.19, 51.09 and 14.86 percent at 9th, 12th and pooled over period days of storage respectively.) Based on mean data, treatment S_2 (cold storage at 13±2 °C) was recorded minimum spoilage fruits (%) i.e. 29.29, 51.09 and 14.86 percent at 17th, 22nd and 27th days of storage respectively) and treatment S_1 (zero energy cool chamber) recorded 48.95 percent of spoilage fruits (%) at 17th days of storage conditions whereas were ambient conditions fruits rottener and not suitable for marketing**.**

Among storage conditions in the present experiment, the cold storage has proved effective in minimizing the spoilage than the ambient condition. The results were reported by Kapse and Katrodia (1997) [38], Padhye (1997) [68] and Puttaraju and Reddy (1997) [77] in mango fruit.

Interaction Effect

The interaction effect of precooling and storage was shows non-significant at various intervals of storage. The results, spoilage in mango fruit increase continuously during storage time. However, the rate of increase was comparatively slower in fruits treated than control. Among storage Condition fruit stored in cold storage at 13±2°C was promising for slower increase in spoilage.

Shelf life in days

The data on days of fruits shelf life as affected by various precooling treatments and storage methods are presented in Table 3

Table 3: Effect of precooling and storage conditions on shelf life of fruits of mango cv. Kesar

Treatment	Treatment Detail	Shelf life (days)
A. Precooling		
P_0	Control	14.30
P_1	Ice cooling for 15 minutes	21.57
P_2	Ice cooling for 30 minutes	23.79
P_3	Hydro-cooling at 10°C temperature for 15 minutes	23.02
P_4	Hydro- cooling at 12°C temperature for 30 minutes	25.04
S.Em. ±		0.61
C.D. at 5%		1.77
B. Storage Conditions		
S_0	Ambient condition	14.26
S_1	Zero energy cool chamber	20.03
S_2	Cold storage 13±2°C	30.35
S.Em. ±		0.48
C.D. at 5%		1.37
C.V. %		8.54
Interaction		NS

Effect of precooling on shelf life in days

The date from the table 3. The different precooling treatments significantly extend the shelf life of fruit over control. Significantly, maximum (25.04 days) shelf life was recorded in P_4 (hydrocooling at 12 °C temperature for 30 minutes) which was at par with treatment P_2 (ice cooling for 30 minutes), Where as minimum shelf life of fruit was recorded (14.30 days) in treatment P_0 (control).

The shelf life of fruits determines their keeping quality. Maximum shelf life observed in hydrocooling at 12 °C temperature for 30 minutes. The pre-cooling extended shelf-life of mango fruits over to control. The extension of shelf-life of mango fruits might be due to the reduction in field heat in shortest possible time, lower moisture loss, restricted metabolic and respiratory activities and inhibition in water loss and low in ethylene production in fruits. These results are in agreement with the results of Singh (1990) [96], Joshi *et al*., (1993) [33], Kapse and Katrodia (1997) [38], Dhemre (2001) [23], Sondkar and Nikam (2002) [101], Galathia (2004) [28], as well as Raut and Pillai (2002) [86] was also seen similar trend in sapota, respectively.

Effect of storage conditions

The methods of storage of fruits for increasing more shelf life were found significant. The treatment S_2 (cold storage at 13±2 °C) achieved significantly maximum (30.35 days) shelf life of fruit, which was followed by treatment S_2 (zero energy cool chamber as 20.03 days). While, S_0 (ambient condition) fruits resulted significantly minimum (14.26 days) shelf life. Among storage conditions, the cold storage 13±2 °C results in to maximum shelf life. The low temperature coupled with high humidity in cold storage and cool chamber, which was more effective in improving the shelf life of mango fruit as compared to ambient temperature storage. Similar results were reported by Dhemre (2001) [23], Joshi (1993) [33], Kaspe (1985), Padhye (1997) [68], Dhemre and Waskar (2004) [24] in mango, and Ransing and Desai (2004) [82] in guava.

Interaction effect

The interaction effect between precooling and storage for extending shelf life of fruit had non-significant effect.From the above results, it can be observed that, fruits treated with hydrocooling at 12 °C temperature for 30 minutes had maximum days of shelf life of fruits. Whereas, among storage method maximum days of shelf life of fruit was achieved in cold storage at 13±2 °C.

Conclusion

From Experiment, it is concluded that, mango fruits treated with precooling treatment of hydrocooling at 12 °C temperature for 30 minutes up to 24.05 days of the storage, found to be the best with respect to extension of shelf life of fruits. It reduced physiological loss in weight and decreased spoilage percentage of fruits, the fruits stored in cold storage at 13±2 °C, exhibited more shelf life, minimum physiological loss in weight and spoilage.

References

1. Anonymous. Report of Indian delegation on viticulture to USSR from 16th September to 15th October, 1971. New Delhi: Government of India; 1971. p. 26-40.
2. Anonymous. Efficient operational method of pre-cooling of mango. In: Mid-term review of post-harvest technology of fruits and vegetables. New Delhi: IARI; 1978. p. 11-12.
3. Anonymous. Mango cultivation. Bangalore: Indian Institute of Horticultural Research, ICAR; 1983. p. 25.
4. Anonymous. Efficient and operational methods of pre-cooling of mangoes cv. Bombay Green. Annual report. New Delhi: Division of Fruit and Horticultural Technology, IARI; 1989. p. 41-42.
5. Anonymous. Mango and cashew: maturity indices of mango fruits. Research Bulletin. Dapoli: Konkan Krishi Vidyapeeth; 1991. p. 8.
6. Anonymous. Efficient and operational methods of pre-cooling mango fruits. In: Proceedings of group meeting of AICRP on post-harvest technology of horticultural crops. New Delhi: ICAR; 1992. p. 19-22.

7. Akmine EK, Goo T. Respiration and ethylene production during ontogeny of fruit. Journal of the American Society for Horticultural Science. 1973;98:381-384.
8. Arora JS, Pal RN, Jawanda JS. Effect of Ethrel on degreening of Valencia sweet orange (*Citrus sinensis* Osbeck). Punjab Horticultural Journal. 1973;13(1):13-17.
9. Arumugam T, Pal PK, Maini SB, Khurdiya DS. Studies on extension of shelf life in banana (*Musa* spp.) cv. Robusta. South Indian Horticulture. 2002;50(4-6):496-499.
10. Kumar A, Dhawan SS. Effect of hydrocooling and Bavistin dip on the shelf life and quality of mango during storage under various environments. Haryana Journal of Horticultural Sciences. 1995;24(2):109-115.
11. Bandyopadhyay A, Sen SK. Studies on physico-chemical changes associated with ripening of sapota cv. Cricket Ball. South Indian Horticulture. 1994;42(6):369-370.
12. Bangerth F. Investigations and reflections on the prediction of bitter pit incidence. Erwerbsobstbau. 1974;16(11):169-172.
13. Beyars E. Drop berry and desiccation of stalk in Waltham Cross grapes. Pretoria: Union of South Africa Department of Agriculture; 1938.
14. Biswas B, Ghosh SK, Ghosh B, Mitra SK. Effect of growth substances on fruit weight, size and quality of guava cv. L-49. Indian Agriculture. 1988;32(4):245-248.
15. Chadda KL. Proceedings of national seminar on post-harvest technology of fruits. Bangalore; 1995 Aug 7-9.
16. Chaplin GR, McBride RL, Aminah A, Nuevo PN. Sensory and physico-chemical quality of Kensington mangoes after storage at low temperature. ASEAN Food Journal. 1991;6(3):109-113.
17. Chauhan HS, Kumar J, Sharma RK, Singh R. Effect of some chemicals and cooling on shelf life of mango. Haryana Journal of Horticultural Sciences. 1987;16(3-4):218-222.
18. Chen KR, Wen FD, Hu QY. Changes in the distribution of polyphenol oxidase activity and content of phenolic compounds during after-ripening of banana. Plant Physiology Communications. 1987;2:31-33.
19. Chikkasubbana V, Huddar AG. Ripening of Alphonso mangoes for processing. Indian Food Packer. 1982;36(3):38-42.
20. Chitale SS, Mann. Studies on forced air pre-cooling and storage of guava fruits. Rahuri: Mahatma Phule Krishi Vidyapeeth; 2004. BTech Thesis.
21. Chundawat BS, Gupta OP, Singh JP. Effect of 2-chloroethylphosphonic acid (Ethrel) on ripening of mango (*Mangifera indica* L.) fruits. Haryana Journal of Horticultural Sciences. 1973;2(3-4):11-16.
22. Das RC, Mahapatra SK. Effect of growth substances and fungicidal wax emulsion on ripening of sapota (*Achras zapota*). Progressive Horticulture. 1976;8(3):75-80.
23. Dhemre JK. Studies on extending the shelf life of mango (*Mangifera indica* L.) cv. Kesar. Rahuri: Mahatma Phule Krishi Vidyapeeth; 2001. PhD Thesis.
24. Dhemre JK, Waskar DP. Effect of post-harvest treatments on shelf life and quality of Kesar mango fruits during storage. Journal of the Maharashtra Agricultural Universities. 2004;29(2):159-163.
25. El-Din Gafar K, Gergis NN, Hassan NB, Eissawy MT, Salem EA, Rizk SS. Cluster-pack for packing and ripening banana and the use of fungicides. Agricultural Research Review. 1977;55(2):93-101.
26. El-Hammady AAM, Montasser AS, Khalifa AS. Effect of some post-harvest treatments on improving quality of banana fruits of 'Sindihi' cultivar. Annals of Agricultural Science, Ain Shams University. 1985;30(2):1449-1469.
27. El-Rayes DA. Enhancement of color development and fruit ripening of 'Washington Navel' and 'Amoon' oranges by Ethrel pre-harvest application. Assiut Journal of Agricultural Sciences. 2000;31(2):71-87.
28. Galathia MB. Study of various post-harvest treatments on shelf life of mango (*Mangifera indica* L.) cv. Dasheri. Navsari: Navsari Agricultural University; 2004. MSc Thesis.
29. Gole RS. Study on fruit development and some aspects of post-harvest handling of mango (*Mangifera indica* L.) fruits. Dapoli: Konkan Krishi Vidyapeeth; 1986. MSc Thesis.
30. Hardenburg RE, Watada AF, Wang CY. The commercial storage of fruits, vegetables, and florist and nursery stocks. Washington (DC): US Department of Agriculture; 1990. Handbook No. 66. p. 3.
31. Hussein AM, Ibrahim AMF, Attia MM. New aspects in delaying post-harvest ripening of banana. Annals of Agricultural Science, Ain Shams University. 1985;30(1):553-568.
32. Illangantileke S, Salunkhe DK. Post-harvest biotechnology to increase storage life of mango. In: ASEAN Science and Technology Week Proceedings. Vol 2. Metro Manila (Philippines); 1990. p. 215-230.
33. Joshi GD, Khan AIA, Relekar PP, Magdum MB. Effect of pre-cooling on shelf life and incidence of spongy tissue in Alphonso mango. In: Proceedings of GJ Symposium; 1993; Bangalore. Abstracts. p. 343-344.
34. Kader AA. Postharvest technology of horticultural crops. Division of Agriculture and Natural Resources, University of California. Special Publication No. 3311; 1982. p. 56-66.
35. Kalra SK, Tandon DK. Regulation of ripening of mango cv. Mallika. Indian Journal of Horticulture. 1983;40(3-4):155-159.
36. Kalra SK, Tandon DK, Singh BP. Mango. In: Salunkhe DK, Kadam SS, editors. Handbook of fruit science and technology: production, composition, storage and processing. New York: Marcel Dekker; 1995. p. 123.
37. Kapse BM. An integrated approach to post-harvest handling of mango (*Mangifera indica* L.) cv. Kesar. Unpublished PhD Thesis. S.K. Nagar: Gujarat Agricultural University; 1993.
38. Kapse BM, Katrodia JS. Studies on hydrocooling in Kesar mango (*Mangifera indica* L.). Acta Horticulturae. 1997;455:707-717.
39. Karacali I. The effect on apples of post-harvest treatment with Ethrel. Yalova Bahce Kulturleri Arastirma ve Egitim Merkezi Dergisi. 1974;7(1-2):19-39.
40. Karacali I, Roemer K. Trials with Ethrel to accelerate the ripening of apple fruits on the tree. Gartenbauwissenschaft. 1972;37(4):251-261.
41. Krishnamurthy S. Studies on storage of mango fruits. Annual report. Bangalore: Indian Institute of Horticultural Research; 1985. p. 52.
42. Krishnamurthy S. Postharvest handling of fruits and vegetables. Annual report. Bangalore: Indian Institute of Horticultural Research; 1986. p. 47.

43. Krishnamurthy S. Studies on storage of mango. Annual report. Bangalore: Indian Institute of Horticultural Research; 1986. p. 49.
44. Krishnamurthy S. Studies on storage of mango. In: Abstracts of IV International Mango Symposium; 1993. p. 101.
45. Krishnamurthy S, Joshi SS. Studies on low temperature storage of Alphonso mangoes. Journal of Food Science and Technology. 1989;26(4):177-180.
46. Krishnamurthy S, Patwardhan MV, Subramanyam H. Biochemical changes during ripening of mango fruit. Phytochemistry. 1971;10:2577-2581.
47. Krishnamurthy S, Rao DVS. Status of postharvest management of fruits. Indian Journal of Horticulture. 2001;58(1-2):152.
48. Krishnamurthy S, Rao GKP. Regulation of ripening by chemicals in Alphonso mango. Scientia Horticulturae. 1982;16:179-183.
49. Krishnamurthy S, Subramanyam H. Respiratory climacteric and chemical changes in the mango fruit. Journal of the American Society for Horticultural Science. 1970;95:333-337.
50. Kumar S, Das DK, Singh AK, Prasad VS. Sucrose metabolism during maturation and ripening of mango cultivars. Plant Physiology and Biochemistry. 1994;21:27-32.
51. Kuramae Lakshmana, Umesh K, Kumar MD. Effect of postharvest treatments on ripening behaviour and quality aspects of banana fruit grown under hill zone. Karnataka Journal of Agricultural Sciences. 2001;14(3):862-865.
52. Lakshminarayana S. Respiration and ripening pattern in the life cycle of mango fruit. Journal of Horticultural Science. 1973;48:227-233.
53. Lizada MCC, Novenario V. Effect of Prolong on physico-chemical and physiological changes during ripening of banana. Annual report. Los Baños (Philippines): Postharvest Horticultural Training and Research Center, University of the Philippines; 1983. p. 2.
54. Lutchmeah RS, Santchurn D. Common postharvest deterioration of banana cv. 'Naine' in Mauritius. Revue Agricole et Sucriere de l'Ile Maurice. 1991;70(1-2):28-36.
55. Madhavi M, Srihari D, Babu JD. Effect of postharvest Ethrel treatment on ripening and quality of sapota cv. Pala fruits. Indian Journal of Horticulture. 2005;62(2):187-189.
56. Mann SS, Singh RN. The cold storage life of Dashehari mangoes. Scientia Horticulturae. 1976;5(3):249-253.
57. Martinez-Bustamante E. Preservation of mango Azucar variety (*Mangifera indica* L.) at different storage stages. Acta Horticulturae. 1997;455:747-754.
58. Mattoo AK. Some aspects of metabolic changes in ripening mangoes. PhD Thesis. Baroda (India): M.S. University; 1969.
59. Mattoo AK, Modi VV. Ethylene and ripening of mangoes. Plant Physiology. 1969;44:308-331.
60. Medlicott AP, Thompson AK. Analysis of sugars and organic acids in ripening mango fruit (*Mangifera indica* L. var. Keitt) by high-performance liquid chromatography. Journal of the Science of Food and Agriculture. 1985;36:561-566.
61. Medlicott AP, Bhogal M, Reynolds SB. Changes in peel pigmentation during ripening of mango fruit (*Mangifera indica* var. Tommy Atkins). Annals of Applied Biology. 1986;109:651-656.
62. Naik SR. Study on physico-chemical changes in Alphonso and Ratna mango (*Mangifera indica* L.) fruit during growth, development and storage. MSc Thesis. Dapoli: Konkan Krishi Vidyapeeth; 1985.
63. Nelson KE. High picking temperature and rough handling can reduce consumer acceptability of California fresh table grapes. Blue Anchor. 1955;32:6-10.
64. Noomhorm A, Illangantileke SG, Guzman JD. Pre-cooling studies of tropical fruits and vegetables. American Society of Agricultural Engineers Paper No. 88-6588; 1988. p. 1-7.
65. Nyanjage MO, Wainwright H, Bishop CFH, Cullum FJ. A comparative study on the ripening and mineral content of organically and conventionally grown Cavendish bananas. Biological Agriculture and Horticulture. 2000;18(3):221-234.
66. Oberbacher MF. Fruit colour, its changes and significance. In: Long WG, editor. Better handling of Florida fruits. Florida Agricultural Experiment Station Bulletin No. 681; 1964.
67. Oosthuyse SA, Mabila MS, Van Straten B, Winter AJ. Yearbook. South Africa: Mango Growers Association; 1995;15:54-57.
68. Padhye PB. Studies on some aspects of post-harvest handling of mango (*Mangifera indica* L.) fruits cv. Alphonso. MSc (Agri.) Thesis. Dapoli (MS): Konkan Krishi Vidyapeeth; 1997.
69. Pal RK. Influence of ethrel and calcium carbide on respiration rate, ethylene evolution, electrolyte leakage and firmness of 'Dashehari' mango (*Mangifera indica* L.). Indian Journal of Agricultural Sciences. 1998;68(4):201-203.
70. Pal RK. Ripening and physiological properties of mango as influenced by ethrel and calcium carbide. Journal of Food Science and Technology. 1998;35(4):358-360.
71. Pandey IC, Tripathi BM, Upadhyay NP. Effect of plant regulators on fruit ripening and quality of mango. Punjab Horticultural Journal. 1980;20(1-2):24-27.
72. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. New Delhi: ICAR; 1985.
73. Panwar JS. Post-harvest physiology and storage behaviour of ber fruit (*Ziziphus mauritiana* Lamk.) in relation to temperature and various treatments (cv. Umran and Kaithli). Thesis Abstracts. 1981;7(1):64-65.
74. Patel UA. Effect of post-harvest treatments on storage behaviour of hybrid mango (*Mangifera indica* L.) cv. Amrapali and Neelphonso. MSc (Agri.) Thesis. Navsari: Navsari Agricultural University; 2006.
75. Pradhan SK, Bandyopadhyay A, Mitra SK, Sen SK. Effect of growth substances on fruit size, yield and quality of banana var. Giant Governor. Progressive Horticulture. 1988;20(3-4):326-330.
76. Prasad A, Kalinj K. Investigation on post-harvest physiological changes and quality parameters in mango varieties. Indian Journal of Horticulture. 1988;45(3-4):235-240.
77. Puttaraju TB, Reddy TV. Effect of pre-cooling on the quality of mango (cv. Mallika). Journal of Food Science and Technology. 1997;34(1):24-25.
78. Purandare ND, Khedkar DM, Sontakke MB. Physico-chemical changes during degreening in sweet orange (*Citrus sinensis* Osbeck L.). South Indian Horticulture. 1992;40(3):128-132.
79. Ram HB, Singh SK, Singh RV, Singh S. Effect of ethrel and smoking treatment on ripening and storage

behaviour of banana cv. Harichhal. Progressive Horticulture. 1979;11(3):69-75.
80. Rana RS, Chauhan KS. Effect of post-harvest ethrel treatment on degreening of fruits of Kagzi lime. Punjab Horticultural Journal. 1976;16(1-2):30-32.
81. Ranganna S. Handbook of analysis and quality control for fruit and vegetable products. New Delhi: Tata McGraw Hill; 2000. p. 9-16, 105-108.
82. Ransing PB, Desai. Studies on forced hydro pre-cooling and storage of guava fruits. BTech Thesis. Rahuri: Mahatma Phule Krishi Vidyapeeth; 2004.
83. Rao DV, Kulkarni V, Rameshwar A, Rao SN. On the quality of off-season mango fruits and its improvement. Science and Culture. 1980;46(7):267-268.
84. Rao VNM, Shanmugavelu KG, Srinivasan C, Iya DRP. Studies on the effect of ethrel (2-chloroethyl phosphoric acid) on the ripening of fruits. South Indian Horticulture. 1971;19:1-8.
85. Rao VNM, Shanmugavelu KG, Srinivasan C, Iya DRP. New methods of ripening fruits. Indian Horticulture. 1971;16(2):7-8.
86. Raut AA, Pillai. Study on forced hydro pre-cooling and storage of sapota fruits. BTech Thesis. Rahuri: Mahatma Phule Krishi Vidyapeeth; 2002.
87. Roy SK, Pal RK. Multilocational studies to reduce post-harvest losses during harvesting, handling, packing, transportation and marketing of mango in India. Acta Horticulturae. 1991;291:499-502.
88. Ruiz M, Guadarrama A. Post-harvest behaviour of mango (*Mangifera indica* L.) type Bocado during controlled ripening. Revista de la Facultad de Agronomía, Universidad Central de Venezuela. 1992;18(1):79-93.
89. Salunkhe DK, Desai BB. Mango. In: Post-harvest biotechnology of fruits. Boca Raton (FL): CRC Press; 1984. p. 77-94.
90. Sandhu SS. Post-harvest handling of grapes. Maharashtra Journal of Horticulture. 1987;4:43-77.
91. Sarkar S, Munshi AA. A study on the content and interconversions of organic acids of mango (*Mangifera indica* L.) at various stages of fruit development. Bangladesh Journal of Agricultural Sciences. 1981;8:69-75.
92. Selvaraj V, Kumar R. Respiratory climacteric and chemical changes in the mango fruits. Journal of the American Society for Horticultural Science. 1994;95:333-337.
93. Selvaraj Y, Kumar R, Pal DK. Changes in sugars, organic acids, amino acids, lipid constituents and aroma characteristics of ripening mango (*Mangifera indica* L.) fruit. Journal of Food Science and Technology. 1989;26:306-311.
94. Shashirekha MS, Patwardhan MV. Changes in amino acids, sugars and non-volatile organic acids in ripening mango fruit (*Mangifera indica* L., Badami variety). Lebensmittel-Wissenschaft und Technologie. 1976;9:369-370.
95. Singh R, Sharma RK, Kumar J, Goyal RK. Effect of oil emulsions and pre-cooling on shelf life of mango cv. Amrapali. Haryana Journal of Horticultural Sciences. 2003;32(1-2):54-55.
96. Singh BP. Studies on storage of mango, guava and other crops. Annual report. Lucknow: Central Institute of Horticulture for Northern Plains; 1990. p. 15-16.
97. Singh K, Chauhan KS. Effect of Waxol and $KMnO_4$ with pre-cooling on storage life of guava cv. L-49. Haryana Journal of Horticultural Sciences. 1982;11(3-4):192-198.
98. Singh UR, Pandey IC, Tripathi BM, Upadhyay NP. Artificial fruit ripening in mango. Punjab Horticultural Journal. 1979;19(3-4):139-141.
99. Singh UR, Singh G, Khan A. Studies on the artificial ripening of banana cultivar Basrai Dwarf. Progressive Horticulture. 1977;9(1):53-59.
100. Singh S, Kumar P, Brahmachari VS, Singh DN. Effect of pre-harvest spray of GA_3 and Ethrel on storage life of mango cv. Amrapalli. Orissa Journal of Horticulture. 1995;23(1-2):112-118.
101. Sondkar SA. Studies on effect of pre-cooling and storage on shelf life of mango. BTech Thesis. Rahuri: Mahatma Phule Krishi Vidyapeeth; 2002.
102. Soule MJ, Haltton TJ. Determination of maturity of hard green Haden and Zill mangoes. Proceedings of Florida Mango Forum; 1955. p. 16.
103. Snedecor CV, Cochran WG. Statistical methods. Calcutta: Oxford and IBH Publishing Co.; 1968. p. 327.
104. Suresh N, Singh Z. Pre-storage Ethrel dip reduces chilling injury, enhances respiration rate, ethylene production and improves fruit quality of 'Kensington' mango. Journal of Food, Agriculture and Environment. 2003;1(2):93-97.
105. Suryanarayana V, Goud PV, Goud PV. Effect of post-harvest Ethrel treatment on ripening of sapota fruits. Andhra Agricultural Journal. 1984;31(4):308-311.
106. Tandon DK, Kalra SK, Singh BP. Ripening pattern of specific gravity graded 'Dashehari' mangoes. Indian Journal of Horticulture. 1988;45(4-5):219-224.
107. Thomas P. Effect of post-harvest temperature on quality, carotenoid and ascorbic acid content of Alphonso mangoes during ripening. Journal of Food Science. 1975;40(4):704-706.
108. Trivedi YV, Desai MM. Effect of different storage techniques and conditions on quality and shelf life of guava fruits. Crop Protection and Production. 2006;2(2):75-78.
109. Vala KV. Post-harvest investigations in mango (cv. Kesar). MSc (Agri.) Thesis. S.K. Nagar (Gujarat): Gujarat Agricultural University; 2002.
110. Vazquez Salinas C, Lakshminarayana S. Composition changes in mango fruit during ripening at different storage temperature. Journal of Food Science. 1985;50:1646-1648.
111. Vijayalakshmi D, Bangarusamy U, Vijayakumar RM. Post-harvest treatments to extend the shelf life of sapota fruit cultivars CO-1 and CO-2. Crop Research, Hisar. 2004;27(2-3):219-226.
112. Unde PA, More HG, Gawande VN, Munde AV. Effect of pre-cooling on field heat removal and shelf life of grapes. Journal of the Maharashtra Agricultural Universities. 2004;28(3):341-342.
113. Waskar DP, Roy SK. Post-harvest ripening changes in banana: a review. Agricultural Reviews, Karnal. 1992;13(1):36-42.
114. Sonkar RK, Huchche AD, Ram L, Singh S. Citrus rootstocks scenario with special reference to India-A Review. Agricultural Reviews. 2002;23(2):93-109.
115. Gomez MX, Polin D. The use of bile salts to improve absorption of tallow in chicks, one to three weeks of age. Poultry Science. 1976 Nov 1;55(6):2189-95.