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Mitigation of Post-harvest Losses through Pre and Post Harvest Handling under Coastal Region

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Abstract

Coastal region of Maharashtra is rightly known as fruit bowl. Various fruit crops viz mango, *Kokum*, jackfruit, *Karonda*, jamun, cashewnut, etc are grown in the region as commercial crop as well as in house backyards. The maturity of most of the fruits coincide with hot and humid summer days which aggravates the post harvest losses in the form of physiological loss in weight, diseases, damage in external appearance etc. The fluctuations in the climate conditions namely sudden rise in temperature, unseasonal rains, and cloudy weather during fruit development further aggravate the post harvest losses owing to sun scorching, occurrence of pre and post harvest diseases. Various pre and post harvest treatments like preharvest bagging, preharvest nutrient sprays, harvesting at appropriate maturity, grading and appropriate packaging of the fruit help in minimizing post harvest losses of various fruits grown under coastal climatic conditions.

Key words: Fruits, pre-harvest treatments, post-harvest handling, physico-chemical composition.

Introduction

West coast of Maharashtra identified as "Konkan" is a renowned horticultural belt with abundant biodiversity.

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The perennial fruit crops namely mango, banana, jackfruit, kokum, karonda, cashew, sapota etc. are grown commercially which are the base of livelihood for major section of native population. Among these, mango and cashew are grown on massive scale with 1.85 lakh and 1.83 lakh hectare area with 2.47 and 2.37 lakh t production respectively (Haldankar *et al.* 2013, Salvi *et al.* 2016). All these fruit crops mature during summer month and due to fluctuating hot and humid climate, the appearance, size, weight as well as chemical composition of fruits is adversely affected. The occurrence of pre-seasonal rains, sudden rise in temperature beyond 40 ºC, appearance of cloudy weather aggravates the situation by increasing incidence of diseases like powdery mildew, anthracnose which affects the external appearance of the fruit fetching lower prices in the market (Shinde 2011). Harvesting of fruit at particular stage carries prime importance as it is the major factor deciding the quality of fruit after harvest. In fruits like mango, harvesting of fruit at particular maturity affects the flavour and aroma after ripening. Besides the physiological disorder named spongy tissue also aggravates due to harvesting of over mature fruits and improper post harvest handling (Anonymous 2003). The appropriate grading, precooling, storage as well as packaging also contribute in post harvest life as well as quality (Ahmed *et al.* 2014). The pre and post harvest management possess immense importance in mitigating the issues pertaining to maintenance as well as enhancement of quality, declining post harvest losses enhancing maturity as well as stabilizing market rate

Table 1. Influence of plant growth regulators, polyamine and nutrients on quality parameters of fruits of Alphonso mango.

Treatments	T.S.S. (°Brix)	Acidity (%)	Ascorbic acid (mg $100g^{-1}$)	Reducing sugars (%)	Total sugars (%)
NAA (20 ppm)	17.6	0.27	48.26	6.37	14.50
CPPU (15 ppm)	18.1	0.28	47.96	6.91	14.68
Paclobutrazol (10 ppm)	19.0	0.28	44.17	6.67	16.07
Paclobutrazol (25 ppm)	18.6	0.25	43.18	6.52	16.31
Putrescine (50 ppm)	19.3	0.27	44.55	6.59	15.35
KNO_3 (1%)	19.9	0.26	48.37	7.92	16.85
K_2SO_4 (1%)	19.7	0.27	46.32	7.59	17.04
Ca-EDTA (0.1%)	18.7	0.31	49.68	7.08	15.82
Paclobutrazol soil (750 mg m^{-1})	19.0	0.23	46.19	6.71	16.15
Irrigation	17.5	0.28	41.08	6.48	14.77
Control	16.8	0.25	32.14	6.11	14.94
Mean	18.6	0.27	44.72	6.81	15.67
SEm$\pm$	0.31	0.03	1.22	0.33	0.19
CD at 5%	0.86	N.S.	3.38	0.94	0.53

NAA- Naphthalene acetic acid; CPPU - N-(2-chloro-4-pyridyl) phenyl urea; (Source: Burondkar *et al*. 2009)

even under varying climatic fluctuations.

Pre-harvest treatments for quality improvement

Mango response to post flowering application of nutrients. Foliar sprays of urea, KNO_3, MPP (Mono potassium phosphate), Sujala NPK (19:19:19), K_2SO_4, NAA at various concentrations at three different fruit growth stages such as pea, marble and egg stage indicated that 2 per cent urea at pea stage, 0.5 per cent MPP at marble and egg stage significantly increased fruit retention, number of fruits and yield per plant (Bansode *et al.* 2014).

Pre-harvest bagging of fruits at marble stage (30 days from fruit set) with newspaper bag and brown paper bag, improved fruit retention, increased weight of fruit, diameter of fruit, pulp weight, total soluble solids and reducing sugars at ripe stage as compared to unbagged fruits in mango cv. Alphonso. Pre-harvest bagging helped to produce spongy tissue free fruits. The butter paper bag, muslin cloth bag and scurting bag improved the fruit retention, reduced incidence of mealy bug. However pre harvest bagging with different types of bags did not change the sensory qualities of ripe mango fruits cv. Alphonso (Haldankar *et al.* 2015). The sources of potassium (KNO_3 and K_2SO_4) resulted in significant enhancement of fruit size in terms of fruit weight (274.34 and 277.78g) which was 11.8 per cent and 11.4 per cent higher than control (248.40g), respectively (Table 1). The physiological loss in weight was reduced by foliar spray of paclobutrazol (25 ppm) (19.7%), soil

Table 2. Influence of plant growth regulators, polyamine and nutrients on fruit size and physiological loss in weight (PLW) at harvest in Alphonso mango fruits

Treatments	Fruit size (g $fruit^{-1}$)	PLW (%)
NAA (20 ppm)	247.18	22.8
CPPU (15 ppm)	245.27	24.6
Paclobutrazol (10 ppm)	253.68	22.3
Paclobutrazol (25 ppm)	249.70	19.7
Putrescine (50 ppm)	250.60	22.9
KNO_3 (1%)	274.34	21.9
K_2SO_4 (1%)	277.78	19.8
Ca-EDTA (0.1%)	257.50	21.2
Paclobutrazol soil (750 mg m^{-1})	244.95	19.8
Irrigation	256.22	25.5
Control	248.40	23.9
Mean	255.06	22.2
SE m	4.87	1.4
CD at 5%	13.49	3.8

NAA - Naphthalene acetic acid; CPPU - N-(2-chloro-4-pyridyl) phenyl urea; Per cubic meter of tree canopy volume. (Source**:** Burondkar *et al*. 2009)

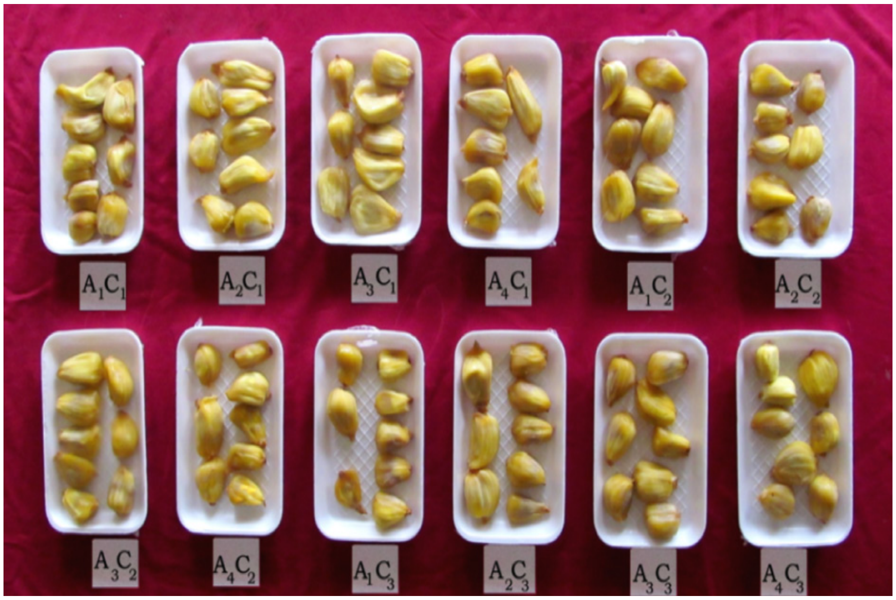

Fig. 1. Jackfruit bulbs at sixth day of storage

Figure 2. Storage of aonla fruits (At the end of shelf life)

application of paclobutrazol (19.8%) and K_2SO_4 (19.8%) as compared to control (23.9%) (Table 2). Ca – EDTA improved the ascorbic acid content (49.68 mg $100g^{-1}$) followed by KNO_3 (48.37mg $100g^{-1}$). The total sugars got better with K_2SO_4 (17.04%) followed by KNO_3 (16.85%), which were 14.1 and 12.8 per cent higher over control (14.94%), respectively (Burondkar *et al.* 2009). The bagged fruits enhanced market acceptances as these were free from blemishes.

The foliar grade fertilizer (19:19:19) @ 1.5 per cent at an interval of 30 days improved the yield (65.44 fruits $tree^{-1}$), length of fruit (4.82 cm), diameter of the fruit (5.37cm) and number of seeds (1.18) and total soluble solids (23.11 ^{0}B) of sapota cv. Kalipatti. The maximum weight of fruit (87.22 g), reducing sugars (10.45 %) and total sugars content (17.91 %) were detected when 0.5

per cent foliar grade fertilizer used at 30 days interval (Khambekar and Pukari 2013).

The post flowering exogenous application of KNO_3 @ 1.5 per cent recorded earlier harvesting (95 days) and improved bunch weight (27.83 kg plant^{-1}), fruit length (29.67 cm), breadth (4.82 cm) and circumference (15.15 cm) in banana. All foliar treatments could improve the fruit weight, pulp weight and pulp: peel ratio. Among all the treatments, the tree receiving KNO_3 @ 1.5 per cent had maximum TSS (4.35 ^{0}B), reducing sugar (0.26%), non reducing sugar (0.27%), total sugar (0.47%) and maximum shelf life (9.5 days).The foliar application on bunch was found to be beneficial than bunch feeding (Haldankar *et al.* 2012).

Harvesting

Mango and sapota are both climacteric fruits and need to be appropriately harvested at proper maturity before ripening of fruits. The mango harvester was designed and developed with harvesting capaciyt of 138 fruits per hour as compared to 72 fruits per hour by traditional harvester. Besides the improved mango harvester helped to harvest fruits with its stalk which help for better ripening and shelflife (Powar and Joshi 1984).

Pre-cooling of mango fruits cv. Ratna, immediately after harvest and storage at low temperature delayed ripening without any deterioration in fruit quality. The method of hydro cooling extended greater shelf life of fruits without affecting the quality of fruits as compared to air cooling. Low temperature storage helped for increasing the availability of fruits (Kulkarni *et al.* 2009a).

The post harvest treatment of mango fruits with $KMnO_4$ @ 1 g improved T.S.S. (17.83 ^{0}Brix), acidity (0.90%), reducing sugars (3.72 %), total sugars (11.26 %), B-carotene (9461 ug 100g^{-1} pulp) and taste of fruits with better organoleptic score (7.96) (Patankar *et al.* 2013).

Jackfruit is one of the delicious fruits but its bulbs are excessively perishable and spoil within 24 hours. The firm flesh jackfruit bulbs could be stored in best condition up to 6 days by keeping them in refrigerated condition after sterilization with chlorine water (30 ppm) and treatment with 1.5 per cent ascorbic acid, 0.5 per cent calcium chloride (A_4C_2) along with100 ppm KMS and 0.5 per cent citric acid (Figure 1) (Chulaki 2015).

Aonla is exclusively used for value added products. The harvested fruits need greater shelf life. The chemical composition, PLW (Physiological Loss in Weight), shelf life, shrivelling and spoilage were improved when the fruits of Aonla variety Krishna were treated with 0.1 per cent carbendazim under cool chamber conditions. The shelf life was extended upto 16 days (Figure 2) (Bhujabal 2012).

The physiological loss in weight of banana fruits cv. Safed Velchi was enhanced by exposure of fruits to ethylene gas for 36 hrs. The prolong exposure period to ethylene gas, intensified the ripening process. All ethylene gas treated banana fruits except 6 hours exposure period recorded significantly highest sensory score for colour, flavour, texture, taste and overall acceptability than the untreated banana fruits (Table 3) (Hirave *et al.* 2013).

Physical and chemical composition of fruits

Physical and chemical parameters play an important role to assess the quality of fruit. Different postharvest handling operations act on physical and chemical parameters of fruits.

The chemical components viz., moisture, acidity, ascorbic acid and tannins decreased with the increase in specific gravity of fruits at the time of harvest. These components showed further decline during ripening, transportation and storage. However, the T.S.S., sugars, carotenoid pigments and pH were directly proportional to specific gravity of fruit, both at harvest and during ripening. The starch content enhanced with an increase in specific gravity of the hard green fruits and exhausted when fruits were ripened (Joshi and Roy 1985, Joshi and Roy 1989).

Total volatile blends of 22 Indian and 5 non–Indian cultivars were investigated using solvent extraction

Table 3. Effect of ethylene treatment on organoleptic quality of banana cv. Safed Velchi

Treatment*	Organoleptic score for				
	Colour	Flavour	Taste	Texture	Avg.
T_1 6 hrs	5.25	4.12	3.75	3.87	4.27
T_2 12 hrs	7.00	7.25	7.50	7.62	7.34
T_3 18 hrs	6.87	7.00	7.37	7.37	7.17
T_4 24 hrs	7.37	7.37	7.62	7.50	7.46
T_5 30 hrs	7.25	7.25	7.37	7.37	7.31
T_6 36 hrs	6.87	7.00	6.57	7.00	6.92
T_7 Control	5.00	4.00	3.38	3.75	4.17
SE ±	0.30	0.521	0.62	0.636	0.48
CD at 5%	0.882	1.534	1.85	1.871	1.43

Source: Hirave *et al.* 2013 (*period of exposure to ethylene gas in ripening chamber; Control i.e. without exposure of ethylene gas) and gas chromatography. Total 84 volatiles belonging to various chemical classes were detected. From the study, it was observed that mango flavour is dominated qualitatively as well as quantitatively by terpene–hydrocarbons (Pandit *et al.* 2009a).

In another study, total of 55 volatiles belonging to various chemical classes such as aldehydes, alcohols, mono and sesquiterpenes hydrocarbons, lactones and furanones were identified for influencing ripening of 'Alphonso' mango. In all Alphonso tissues mono terpenes quantitatively dominated (57 to 99 per cent) in particular, (z)-ocimin was found in the highest amount. Ripeness was characterised by the *de–novo* appearance of lactones and furanones in the blend of monoterpenes (Chidley *et al.* 2013).

Twenty six volatiles were tracked through six ripening stages of pulp and peels after giving ethylene treatment (100 ppm ethylene gas) for studying spatial and temporal changes. Accelerated ripening in terms of early appearance of ripening–specific compounds, lactones and mesifuran, upon ethylene treatment were observed as ethylene plays an important role in ripening of mango. While the levels of lactones remain unaffected, the mesifuron level vastly increased upon ethylene treatment. Peel showed high terpene content and pulp had higher amount of lactones compared to peel. It indicated involvement of ethylene as a natural hormone in the biosynthesis of lactones and furanones in naturally ripened fruits; whereas, an increase in the terpene level during ripening appears to be independent of ethylene (Pandit *et al.* 2009b).

Two furanonnes, furaneol (4–hydroxy–2, 5–dimethyl–3(2h)–furanol) and mesifuran (2, 5–dimethyl–4 methoxy–3(2h)-furanol) are important constituents of flavour of the Alphonso cultivar of mango. To get insights into biosynthesis of these furanones, an

Table 4. Effect of different stages of ripening on physical parameters of sapota fruits

Ripening Stage	Wt. of fruit (g)	Wt. of pulp (g)	Wt. of skin (g)	Wt. of seed (g)	Volume of fruit (ml)	Specific gravity	Length of fruit (cm)	Diameter of fruit (cm)	Colour	Recovery of juice (%)	Pulp:Seed ratio
R_1	94.22	85.42	7.16	1.64	90.50	1.04	6.52	5.52	Light brown	50.87	52.09
R_2	91.87	81.84	8.34	1.69	87.58	1.05	5.58	5.38		49.56	48.43
R_3	84.61	74.33	8.64	1.64	79.08	1.07	5.53	5.33	Brown	45.90	45.32
R_4	60.66	54.22	4.95	1.49	59.30	1.02	4.88	4.76	Dark brown	41.38	36.39
S.Em±	1.64	2.16	0.38	0.11	1.40	0.01	0.25	0.18	-	1.81	2.61
C.D. at 1%	6.78	8.93	1.56	N. S.	5.77	0.03	1.05	N. S.	-	7.47	10.78

Source: Pawar *et al*. 2011 R_1 - Mature (harvesting stage), R_2 - Half Ripe, R_3 – Ripe, R_4 - Over ripe

Table 5. Effect of different stages of ripening on chemical composition of sapota fruits

Ripening Stage	T.S.S. (^{0}Brix)	Total sugars (%)	Reducing sugars (%)	Titratable Acidity (%)	P^H	Ascorbic acid	Tannins (%)	Moisture (%)
R_1	19.00	14.40	8.90	0.23	5.30	20.60	0.45	75.80
R_2	21.50	16.76	9.89	0.20	5.60	15.22	0.29	74.10
R_3	23.60	19.12	11.08	0.13	6.20	11.95	0.18	72.50
R_4	22.60	18.20	10.11	0.10	6.30	7.99	0.15	69.80
S.Em ±	0.41	0.23	0.06	0.01	0.07	0.17	0.02	2.21
C.D. at 1%	1.68	0.94	0.25	0.04	0.30	0.69	0.08	NS

R_1 - Mature (harvesting stage) R_2 - Half Ripe R_3 - Ripe R_4 - Over ripe. (Source**:** Pawar *et al.* 2011) enoneoxidreductase gene from the Alphonso mango was isolated. Expression profiling in various ripening stages of Alphonso fruits depicted and expression maxima at 10 days after harvest stage, shortly before the appearance of the maximum amount of furanones (completely ripe stage, 15 days after harvest). Although no furanones were detected immediately after harvest stage, significant expression of this gene was detected in the fruits at later stage. Overall results indicated that oxido–reductase plays important roles in Alphonso mango fruits (Kulkarni *et al.* 2013).

Cashew apple is a rich source of Vitamin-C (250 to 270 mg 100g^{-1}) and it also contains about 12.3g carbohydrates and 0.9 g crude fibre per 100 g. The physical and chemical composition indicates remarkable variability among the improved varieties (Vengurle-1to Vengurle-5). Vengurle-5 had the maximum TSS (13.5 ^{0}Brix), acidity (0.34 %), juice (82.11 %) but smallest apple weight (30 g), fruit length (4.05 cm) and apple: juice (1.21) and had maximum fruit weight (75.55 g) (Haldankar *et al.* 1986).

The kokum genotypes KK-87, KK-76 were highly promising for yield (48.56 and 45.53 kg tree^{-1}, respectively) and number of fruits (2818 and 3304 fruit tree^{-1}, respectively). The highest fruit weight was recorded for KK-201 (26.79 g). There was positive correlation between fruit yield and number of fruits. Fruit length exhibited significant negative correlation with yield. The characters viz. fruit breadth, fresh weight of rind and number of seeds, weight of pulp showed very poor association with yield. The genotypes KK-87 and KK-155 were promising (Khanvilkar *et al.* 1986).

The weight of fruit and pulp, volume of fruit, length and diameter of fruit, juice recovery, pulp to seed ratio showed decreasing trend and specific gravity showed increasing trend from maturity stage to over ripe stage in sapota (Table 4). The TSS, total sugars, reducing sugars and pH content of sapota fruits differed significantly at different stages of ripening (Table 5) and significantly increased from mature (19 ^{0}Brix, 14.40 %, 8.90 % and 5.30, respectively) to ripe stage (23.60 ^{0}Brix, 19.12 %, 11.08 % and 6.30 %respectively). The escalation in TSS and sugars during ripening process was due to accumulation of more sugars in the fruit due to hydrolysis of starch. Decrease in acidity from mature stage (0.23 %) to over ripe stage (0.10 %) and augmentation in pH during ripening was attributed to oxidation of organic acids. Ascorbic acid content of sapota fruits declined throughout the ripening process from 20.60 mg 100g^{-1} (mature stage) to 7.99 mg 100g^{-1} (overripe stage) due to oxidative destruction of ascorbic acid by ascorbic acid oxidase (Pawar *et al.* 2011).

The physical and chemical composition of three karonda genotypes (K-1, K-2, K-3) were studied. The mean ripe karonda fruits were 1.88 cm, 1.85 cm and 3.75 g in length, girth and weight, respectively. The average number of seeds (2.77), weight of seeds (0.44 g), skin (0.38 g), pulp (2.93 g), volume (3.62 ml), specific gravity (1.036) and juice percentage (62.33 %) per berry were also determined. The average drying ratio and berry to pulp ratio was 3.83:1 and 1.30:1, respectively. On an average the ripe karonda fruits of 3 genotypes were characterised with 73.89 per cent moisture, 20.17 per cent T.S.S., 11.48 per cent total sugars, 0.341 per cent acidity, 62.31 ^{0}Brix: acidity and 1.75 mg 100g^{-1} ascorbic acid. The genotype K-3 was superior to K-1 and K-2 (Joshi *et al.* 1986).

Konkan bold is an improved variety released for coastal region which bears bold fruits (16.26 g) with high yield (3.508 kg plant^{-1}). The maturity of fruit commences from 2nd fortnight of April to 2nd fortnight of May in the Konkan region. It contains good pulp (14.97 g), TSS (30 ^{0}Brix), acidity (0.21 %) and Vitamin-C (361 mg 100g^{-1}) (Figure 3) (Anonymous 2004b).

The improved variety of jackfruit viz. Konkan prolific possess 5.78 kg average fruit weight,126 number of bulbs fruit^{-1}, 1.629 kg bulb weight fruit^{-1}, 677 g seed weight fruit^{-1}, 39.90 per cent edible portion (bulbs and seeds), 25 ^{0}B T.S.S. with greenish to yellowish brown fruit colour (Figure 4) (Anonymous 2004c).

'Konkan bahadoli' variety of jamun developed by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli bear fruits of average weight 23.4 g, 87 per cent pulp, 6.7 pulp: seed ratio, 17.6 ^{0}Brix TSS, 0.45 per cent acidity, oblong fruit shape and dark purple with luster fruit colour. The fruiting season commence in third week of April and last till fourth week of May (Figure 5) (Anonymous 2004a).

Sensory evaluation

The sensory attributes viz., colour, flavour, texture of fruit helps in judging the quality of fruit. The different postharvest handling operations effect on sensory quality of fruits. As specific gravity of fruit increases palatability with a fruit gravity range of 1.02 to 1.04 are most palatable (Joshi and Roy 1985) (Table 6). The preharvest bagging at marble stage (30 days after fruit set) with different types of bag did not change the sensory qualities of ripe fruits of mango cv. Alphonso

Figure 3. Karonda variety-'Konkan bold'

Fig. 4. Jackfruit variety-'Konkan prolific'

Fig. 5. Jamun variety-'Konkan bahadoli'

Table 6. Organoleptic evaluation of ripe Alphonso fruits

Organoleptic Qualities	Organoleptic score*			
	Group I Sp. gr. < 1.00	Group II Sp. gr. 1.00-1.02	Group III Sp. gr. 1.02-1.04	Group IV Sp. gr. > 1.04
Colour	6.13	6.71	8.29	8.43
Flavour	6.00	7.00	8.29	7.71
Texture	6.13	7.71	7.86	6.57
Mean	6.09	7.14	8.15	7.57

Sp. gr. = Specific gravity, * The score of 5.50 and above indicates acceptability. Source**:** Joshi and Roy 1989.

(Haldankar *et al.* 2015).

Spongy tissue

The spongy tissue is a serious disorder in Alphonso mango accounts for 30 per cent loss in fruit production annually. This disorder is characterised by appearance of pale yellow flesh colour, soft or spongy in nature, with or without air pockets, having off flavour. The incidence is more in large size fruits and is directly associated with delayed harvest. The occurrence and intensity of spongy tissue amplified with advance in maturity (Table 7). The fruits harvested at four stages viz. A 12 anna (75 % maturity), B 14 anna (85 % maturity), C 16 anna (100 %) and D (tree ripe fruits). The least percentage of affected fruits (10 %) was observed at 'A' stage twelve anna (75 % maturity) and the maximum percentage (86.67 %) was in the fruits harvested at 'D' stage. The stage of harvest of fruits has greatest influence on the occurrence of spongy tissue. The fruits harvested at 'B' stage (85 % maturity) had remarkably reduced occurrence of spongy tissue with appropriate quality whereas, the fruits harvested at 'A' stage (75 % maturity) had minimum spongy tissue but with least quality (Limaye *et al.* 1976).

The pre harvest dip with calcium significantly reduced the occurrence of spongy tissue in ripe Alphonso fruits. It elevated the calcium content in ripe fruits. There was no significant increase by post harvest calcium dips (Table 8). Calcium chloride was more effective in reducing occurrence of spongy tissue than calcium nitrate (Gunjate *et al.* 1979).

The incidence of spongy tissue was maximum at the beak end followed by middle portion and stem end of the fruit under ambient and cold storage conditions. The spongy tissue affected portion of the fruit contained lowest T.S.S. (10.50 ^{0}Brix), non-reducing sugar (4.54 %), total sugars (9.86 %), total carotenoid pigment (5207 µg 100 g^{-1}), pH (3.75) and highest acidity (0.65 %), ascorbic acid (65.60 mg 100g^{-1}) and tannins (123.50 mg 100g^{-1}), as compared to unaffected part of the fruit which is free from spongy tissue (Table 9). Starch (8.45 %) was present exclusively in spongy tissue affected fruits (Joshi and Roy 1986).

Traditionally, mango fruits are harvested when partially ripe one or two fruits naturally fall from tree. The traditionally harvested fruits were categorized into 4 specific gravity groups, viz., specific gravity <1.00, 1.00 to 1.02, 1.02 to 1.04 and > 1.04. About 80 per cent fruits had specific gravity more than 1. The incidence and intensity of spongy tissue increased with increase in specific gravity above 1.00. The immature Alphonso fruits (sp. gravity less than 1) were completely free from spongy tissue. On the basis of best organoleptic qualities, resistance to chilling injury and less incidence of spongy tissue, the fruits harvested at specific gravity 1.02 to 1.04 were the best for subsequent marketing and storage (Roy and Joshi 1989).

The enzymes such as amylase, glutamate dehydrogenase, glutamate oxaloacetate transaminase, peroxidase and

Table 7. Occurrence and intensity of spongy tissue in Alphonso mango fruits at different stages of maturity

Stage of maturity of fruits	No. of fruits studied	No. of fruits affected	Affected fruits (%)	Percentage of affected fruits in intensities		
				a	b	c
A stage	30	3	10.00	Nil	3.33	6.67
B stage	30	7	23.33	Nil	6.67	16.66
C stage	30	16	53.33	13.33	26.67	13.33
D stage	30	26	86.67	20.00	46.67	20.00

Source: Limaye *et al.* 1976

Table 8. Effect of pre-harvest calcium treatment on occurrence of spongy tissue and calcium content in ripe Alphonso mango fruits.

Treatments	Total No. of fruits	Affected fruits	Average √x+1	Percent spongy tissue	Ca content mg $100g^{-1}$ dry wt.
$CaCl_2$ 0.5% -1 dip	30	0	1.00	0	91.73
$CaCl_2$0.5%-2 dips	30	1	1.14	3.3	92.60
$CaCl_2$ 2.0%-1dip	30	2	1.27	6.6	103.33
$CaCl_2$ 2.0%-2 dips	30	0	1.00	0	113.93
$Ca(NO_3)_2$ 0.5% -1 dip	30	2	1.27	6.6	85.66
$Ca(NO_3)_2$ 0.5% -2 dips	30	4	1.52	13.2	91.46
$Ca(NO_3)_2$2.0% -1 dip	30	3	1.38	9.9	96.33
$Ca(NO_3)_2$2.0% -2 dips	30	1	1.14	3.3	100.60
Control (Absolute)	30	7	1.82	23.0	80.80
SEm±			0.1225		5.364
CD at 5%			0.318		16.073

Source**:** Gunjate *et al.* 1979

Table 9. Chemical composition of healthy and spongy tissue affected ripe Alphonso mango fruits

Fruit Part	Chemical composition										
	Moisture %	Total soluble solids %	Starch %	Reducing Sugar %	Non-Reducing Sugar %	Total Sugar %	Carotenoids μg $100g^{-1}$	Acidity %	pH	Ascorbic acid mg $100g^{-1}$	Tannins mg $100g^{-1}$
Healthy fruit	81.98	19.25	Nil	4.20	12.00	16.20	11428	0.37	4.50	56.50	60.00
Affected fruit											
i)Unaffected part	81.97	18.60	Nil	3.98	11.70	15.68	11280	0.11	4.40	58.21	66.18
ii) Spongy tissue	82.00	10.50	8.45	4.32	4.54	9.86	5207	0.66	3.75	65.60	123.50

Source**:** Joshi and Roy 1987

catalase were low in content in spongy tissue, and invertase and ascorbic acid oxidase were high (Gupta *et al.* 1985). Greater levels of polyphenols and starch and smaller quantity of ascorbic acid and soluble proteins were detected in spongy tissue (Gupta *et al.* 1985; Patkar *et al.* 1983).

Calcium deficiency in spongy tissue affected fruits is detected. The affected portion contains less calcium than unaffected tissue in same fruit. The calcium content was less near to the beak end of the fruit as well near the stone, where this internal breakdown most readily occurs (Gunjate *et al.* 1979).

The fruits of the second flowering flush of Alphonso were more vulnerable to spongy tissue disorder (53.33 %) than those of first flush (43.33%) (Joshi and Limaye 1984). The foliar application of paclobutrazol (10 and 25 ppm) at full bloom, marble and egg stages as well as soil application (750 mg m.c.d^{-1}) four months prior to full bloom registered remarkable reduced occurrence of spongy tissue at 'B' (2.28-6.78 %), 'C' (3.22-8.21 %) and 'D' (41.71-41.78 %) stages of fruit maturity (Burondkar *et al.* 2009).

A collaborative research project conducted between Central Electronics Engineering Research Institute, Chennai and Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli resulted in development of a prototype based on the soft X-Ray imaging system for spongy tissue detection. The machine could best detect and sort the spongy tissue affected fruit from four days after harvest followed by five days after harvest and three days after harvest, but was less successful for two days after harvest. The machine could also detect fruits with air pockets (Mehta *et al.* 2013).

A post-harvest treatment of 'Alphonso' mangoes with ethephon reduced the level of spongy tissue disorder as well as hastened the commencement of ripening (Lad *et* *al.* 1985).

Packaging

The existing huge postharvest losses of fruits can be considerably reduced by adopting improved packaging, handling and efficient system of transport. The package must be capable of protecting the produce from the hazards of transport, preventing microbial and insect damage and minimizing physiological and biochemical changes.

In an investigation the Alphonso mango fruits were packed in four different packages viz., CFB (Corrugated Fiber Board) box with partitions, CFB Box with trays, CFB Box with straw (dry grass and newspaper) and conventional wooden crates with straw (dry grass and newspaper). After packing fruits were transported from Dapoli to New Delhi by road and rail. The fruits packed in CFB Box with partitions exhibited less bruising during transport as compared to those packed in wooden crates with straw and newspaper as cushioning material. The CFB Box with partition exhibited slow rate of ripening, spoilage and shrivelling of the fruits during storage. The fruits in cold storage (10$\pm$1 ^{0}C, 85-90 % R.H.) did not shrivel and had less physiological loss in weight than those at ambient temperature. The fruits packed in CFB Box with partition or trays reduced PLW (Physiological Loss in Weight) than other packaging. The CFB Box with partition exhibited higher moisture, starch (till ripening), acidity, ascorbic acid and tannins in the fruits during transport but had moderately low T.S.S., sugars, total carotenoid pigments and pH during storage than any other packaging material (Joshi and Roy 1986).

Karonda fruits packed in punnet box and stored under cold storage had the lowest magnitudes for physiological loss in weight and shrivelling of karonda fruits. The fruits without packaging and stored under ambient temperature had the highest values for TSS, total sugars and reducing sugars during storage. The shelf life of karonda fruits was extended upto 8.88 days and 13 days when packed in punnet box and stored at ambient and cold storage conditions, respectively (Sanas *et al.* 2015).

Storage

The fruit storage affects the rate of respiration, thermal decomposition, and microbial spoilage and also aids in retention of quality and freshness for longer period. The cold storage (10 $\pm$1 ^{0}C and 85 to 90 % RH) had better retention of chemical constitutions in the fruits for a longer period as compared to ambient temperature storage (26.4 to 32.4 ^{0}C and 36 to 64 % RH), but had adverse effect on biosynthesis of carotenoid pigments. The fruits at cold storage had better shelf life but slightly less palatability as compared to those at ambient temperature storage. The shelf life the Alphonso mango fruits with specific gravity 1.00 to 1.04 could be the best for storage (Joshi and Roy 1989).

In an another investigation the mango fruits stored at cool storage (10 ^{0}C) exhibited maximum storage life but reduced TSS, sugars and total carotenoid pigments and higher moisture, acidity, ascorbic acid and tannins compared to those ripened at room temperature (Roy and Joshi 1989). Colour was affected (reduced total carotenoid pigments) as compared room temperature storage.

The Cell-fresh (0.18 % Tablet (1-MCP) = 1 Tablet 1 m^{-3}) significantly delayed ripening of mango fruits by 6 days with maximum TSS (19.70 ^{0}Brix), acidity (0.35 %), total sugars (14.32 %), ß – carotene (10192.2 µg 100 g^{-1} of pulp) as compared to control (T-4) at ripe stage. Further, it resulted in the lowest per cent of spoilage (11.4 % stem end rot and 11.05 % anthracnose), to control (8.62 %) in cold storage at ripe stage (Table 10) (Jadhav *et al.* 2013).

Mango fruits of cv. Ratna stored at ambient temperature attended ripening peak after eight days, which delayed in cool chamber (16 days) and cold storage (32 days). The disease incidence was also greater in cool chamber followed by cold storage and ambient temperature (Kulkarni *et al.* 2009b).

The physiological loss in weight of cashew apple enhanced right from first day till the end of storage period irrespective of storage conditions and varieties. The shelf life of all varieties was only two days. Under cold storage condition it was 7 days (Vengurle-1, Vengurle-2 and Vengurle-5) and 12 days (Vengurle-3

Table 10. Effect of 1-methylcyclopropene on shelf life of Alphonso mango fruits under cold storage

Treatment	Shelf life (days)	Spoilage (%)	Physiological loss in weight (%)
T_1	30.53	22.45	6.57
T_2	29.99	23.60	7.97
T_3	30.46	25.40	7.24
T_4	24.73	29.97	8.62
Mean	28.93	25.35	7.60
SEm$\pm$	0.34	1.42	0.83
CD at 1%	1.39	5.88	N.S.

Source**:** Jadhav *et al*. 2013

and Vengurle-4). The moisture content, total soluble solids, reducing and total sugars, acidity, ascorbic acid and tannins decreased during storage irrespective of varieties and storage conditions. However, pH increased at the end of storage (Antarkar *et al.* 1991).

The kokum fruits stored at ambient temperature had maximum PLW. The shelf life of the fruits at ambient temperature, cool chamber + waxol 12 per cent and cold storage + waxol 12 per cent was 5, 15 and 28 days, respectively. The shrivelling and spoilage of kokum fruits commenced from 3rd day at ambient temperature, 5th day at cool chamber and 7th day at cold storage. The shrivelling was observed maximum in the fruit stored at ambient temperature followed by cool chamber whereas cold storage did not show any shrivelling. Microbial spoilage was also observed maximum at ambient temperature as compared to other storage conditions viz. cool chamber and cold storage. The total soluble solids and total sugars elevated at the end of storage period irrespective of storage conditions. The fruits stored at ambient temperature exhibited maximum TSS, reducing sugar and total sugars followed by cool chamber and cold storage. The titratable acidity and ascorbic acid of the kokum fruits declined throughout the storage period under all storage conditions. The maximum retention of ascorbic acid was detected in fruits stored in cold storage and kept in perforated polythene bag (5.34 mg 100gm^{-1}) (Raorane *et al.* 2012).

Post- harvest disease management

The post harvest treatment with bavistin (0.2 %) and Captan (0.2 %) were effective and at par with each other for controlling post-harvest fruit rots of mango by fruit dipping for two minutes (Anonymous 1983). The sooty mould on mango fruits can be controlled by washing of fruits by bleaching solution (0.05 %) followed by fruit dip treatment with Carbendazim (0.05 %) (Anonymous 2002). Fruit dipping of mango cv. Alphonso fruits in 50 ^{0}C hot water solution of potassium metabisulphite (0.05%) for ten minutes effectively control post harvest fruit rot (Anonymous 2012).

In another study, the post- harvest fruit rot (Anthracnose) of Alphonso mango can be avoided by fruit dip treatment in hot water at 52 ^{0}C for ten minutes (Anonymous 2014).

Conclusion

The west coast of Maharashtra is endowed with wide diversity of fruits which mature in during summer season. The aberrant climatic conditions such as pre-seasonal rains, sudden rise in temperature appearance of cloudy weather adversely affect the fruit quality, aggravates the diseases like powdery mildew, anthracnose and physiological disorder spongy tissue. The pre and post harvest treatment viz. Preharvest bagging, spraying of nutrients, proper grading and packaging are developed for various fruit crops. Adoption of these technologies help to control the post harvest loss and elevate the quality and marketability of the fruits.

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