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Novel Techniques in Post Harvest Management of Mango- An Overview

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Abstract

Proper post- harvest operations and handling practices of mango (*Mangifera Indica* L.) fruit is as importance to provide outstanding quality in market as pre-harvest operations for the good quality mangoes production. Pre-cooling, sorting and grading, packaging, storage, transportation, etc practices of mangoes are very important to control the fruit's quality deterioration. The proper post harvest management also maintains the quality parameters of mangoes such as total soluble solids (°Brix), fruit's maturity, colour, size, sweetness, over/under ripe, etc as per consumer demands and for the minimization of the losses. In addition, another cause/factor of deterioration in fruit's quality and market value is defects and disease during pre-and-post harvest operations. Anthracnose (black lesion), Latex burn (staining), Stem end rot, Chilling injury, Alternaria rot, etc. are among them. Thus, to achieve optimum quality of mango fruit before the exporting, various operations and treatments should be applied under the scientific supervision. This paper reports the various novel-techniques applied in post harvest operations of mango fruit and recent work on its quality management.

Keywords: Mango, post-harvest, operations, quality, management, novel-techniques

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Introduction

The king of fruit mango is very rich not only in taste and flavour but also in medicinal values. Most of the mango eater likes mango fruit because of its luscious taste. Southern Asia (mainly eastern India and Burma), the native place mango fruit, was spreaded its cultivation to other countries (Jagtiani *et al.*, 1988; Patel *et al.*, 2019a). Mango is, now, growing in more than 100 countries after spreading outside of India. The production of many countries is greater than 1,000 MT a year (Mitra, 2016). With an estimated output of 18.5 million tonnes in 2017, India ranks first in area (2.31 million ha) and production, and currently accounts for approximately 40 percent of total global production (FAO, 2017). In India about every states are now cultivating mangoes. Production of mangoes from some states of India has been given in the Table 1a. Fruit characteristics of some exporting mango cultivars in India (Anon, 2001) are given in Table 1b.

The high qualities of medicinal and nutritional values and unique taste of mangoes increased its commercial value not only in domestic market but also at international marketing platform. Mango is liked by people for its rich luscious aromatic flavour and a delicious taste with evenly blended sweetness and acidity. Nutritionally, Table 2, it is a rich source of prebiotic dietary fiber, carotenoids, organic acids, polyphenols, provitamins, minerals, etc. (Anon, 2001). Indian mangoes (fresh) exported to several countries including Gulf countries. The effort of Indian Government is to fully utilize the American, Asian and European markets. Besides these, various products of mangoes (raw/ripe) are exported to the Kuwait, Russia and western countries. Mangoes are consumed not only ripe form but also in the form of athanu, chutneys, powder, pickles, side dishes, etc.

prepared from raw mature fruits. Panna or panha, a summer cooling drink, prepared from raw mango is also very popular among the mango eater. Raw mango, in addition, mar also be eaten with salt, chili and or/soya sauce.

In spite of huge production, deliciousness, rich in vitamins, minerals and anti-oxidants, mangoes also have enzyme with stomach soothing properties. More than 25% mangoes are spoiled in India because of lack of proper postharvest management technique. Thus the main goal of this study is to report the recent studies on post-harvest operations and management of mangoes.

Post-harvest management before marketing

Proper handling of agricultural produce to maintain its quality, freshness and to prolong the shelf life after harvest before marketing is termed as postharvest management (GOI, 2013) to enhance market value. Operations such as sorting, grading, pre-cooling / washing, packaging, storage, transportation, marketing, etc. (Fig. 1) are reported very important after postharvest of mangoes (Anon, 2016). Another operation curing, spreading of fruits on paddy straw cushion floor in the orchard's yard far nearly 24 hrs then washing of fruit to remove dirt, has been reported very crucial in extending the shelf life by GOI (2013).

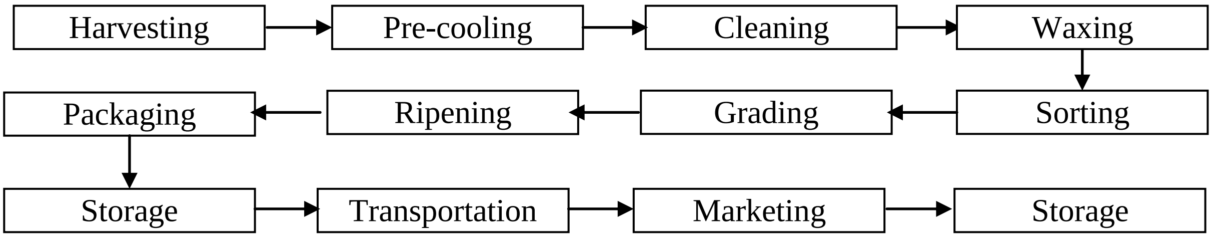

Fig. 1 Steps for post-harvest management of mango

Pre-cooling of mango fruit

Waskar and Dhemre (2005) investigated effect of precooling on shelf-life of Kesar fruits and reported that the shelf life of precooled fruits after harvest was more than the un-precooled. According to Makwana *et al.*, (2014), fruits precooled at 8°C for 8 hr had longer shelf life, lower spoilage, higher percentage of marketable fruits, less physiological loss in weight and had more firmness, and also such treated fruits were taken more time (days) to ripe during storage. As the temperature of fruits after harvest regulates respiration, plays an important role in the deterioration. Atkin and Tjoelker (2003) have reported that the rate of respiration increased 2 or 3 times at every 10°C increment in tissue temperature. The precooling of tropical fruits like mango is, thus, most significant operation to maintain the marketable quality and extending the shelf life of mangoes (Hardenburg *et al.,* 1986)

Consequently, several types of precooling techniques have now been invented for precooling of the agricultural produce. Room cooling, forced air-cooling, hydro cooling, running water, ice coolie, evaporative cooling, etc. are more common for the precooling of mango. Puttaraju and Reddy (1997) have studied effect of some precooling techniques [hydro-cooling (for 15 and 30 min), running water (for 15 and 30 min), room cooling (30 and 60 min), ice cooling (15 and 30 min) and evaporative cooling] on storage of mango (*cv.* Mallika) and reported that immediate precooling after harvest delayed ripening without any decay. Similarly, Ravindra and Goswami (2008) have reported the potential of liquid nitrogen (LN_2) as another cooling medium and stated that it would be practically very useful in controlled atmosphere storage system. Its cooling capacity is very high and has inertness property of vaporized nitrogen encourages to apply with mechanical refrigeration system with the precooling techniques common for mangoes. The chilling injury, however, is a cause of concern because of its intense cold temperature. The precooling of mangoes (cv. Amrapali) using LN_2 system (LN2 flow rate: 20.5 kg/hr; average temperature: -85°C) was recorded with no adverse effect on quality. In addition to above, precooling after harvest provides flexibility for market by making it possible at the optimum time.

Table 1a: Area, production, productivity and varieties of mango in some popular state of India in the year 2010-11 (GOI, 2013) and major harvesting seasons in different states

Name of the state	Area (000'ha)	Product-ion (000' t)	Produc-tivity (t /ha)	Major varieties grown	Month of harvest
Andhra Pradesh	399.3	3194.3	8.00	'Allumpur Baneshan', 'Banganapalli', 'Bangalora', 'Cherukurasam', 'Himayuddin', 'Suvernarekha', 'Neelum', 'Totapuri'	April – May (coastal districts), May (Rayalaseema)
Uttar Pradesh	251.5	2673.3	10.60	'Bombay Green', Chausa', 'Dashehri', 'Fazli' 'Langra', 'Safeda Lucknow', '	June - August
Karnataka	124.5	1236.8	9.90	'Alphonso', 'Bangalora', 'Mulgoa', 'Neelum', 'Pairi', 'Baganapalli', 'Totapuri'	May – July
Bihar	140.2	1222.7	8.70	'Bathua', 'Bombai', 'Himsagar', 'Kishen Bhog', 'Sukul', 'Gulab Khas', 'Zardalu', 'Maldah/Langra', 'Chausa', 'Dashehri', 'Fazli', 'Kalkatia'	June - August
Gujarat	96	772.1	8.00	'Alphonso', 'Kesar', 'Rajapuri', 'Vanraj', 'Jamadar', 'Totapuri', 'Neelum', 'Dashehri', 'Langra'	May – June
Maharashtra	444.5	638.6	1.40	'Alphonso', 'Mankurad', 'Mulgoa', 'Pairi', 'Rajapuri', 'Kesar', 'Gulabi', 'Vanraj'	April – May (Ratnagiri) May – June (other areas)
Tamil Nadu	125.1	537.8	4.30	'Banganapalli', 'Bangalora', 'Neelum', 'Rumani', 'Mulgoa', 'Alphonso, 'Totapuri'	April – May
West Bengal	70.1	513.3	7.30	'Bombai', 'Himsagar', 'Kishen Bhog', 'Langra', 'Fazli', 'Gulabkhas', 'Amrapalli', 'Mallika'	May – August
Kerala	88	511.1	5.80	'Mundappa', 'Olour', 'Pairi'	March - April
Orissa	125.3	428.8	3.40	'Baneshan, 'Langra, 'Neelum, 'Suvarnarekha, 'Amrapalli, 'Mallika'	May to July
Others	156.2	809.1	5.20		
Total	2020.7	12537.9			

Mango Grading

Ripening time for bigger and smaller size fruits is different. Ripening time of fruits of larger size is 2-4 days more than the small fruits. The role of size in uniform ripening is, thus, very important. Consequently, grading of mangoes on the basis of size has its own significant role in packaging and to achieve uniform ripening. In addition to size (Fig. 2), the fruit's shape, weight, colour and maturity are the other important grading parameters of mangoes before exporting. Before exporting, mangoes are graded into three classes (Class-I: 200-250g; Class-II: 251-300g; Class III: 300-350g) as per their weight.

Table 1b: Fruit characteristics of some exporting mango cultivars in India

S. No.	Exporting Varieties	Fruit characteristics	Production area
1	Alphonso	The fruit quality is excellent and keeping quality is good. It has been found good for canning purposes.	Maharashtra, Gujarat, Karnataka Madhya Pradesh.
2	Banganpalli	Fruit size is large, shape is obliquely oval and colour of the fruit is golden yellow. Fruit quality and keeping quality are good. It is a mid season variety and is good for canning.	Andhra Pradesh and Tamil Nadu.
3	Chausa	Fruit is large in size, ovate to oval oblique in shape and light yellow in colour. It is a late variety.	
4	Dashehari	The fruit size is medium, shape is oblong to oblique and fruit colour is yellow. Fruit quality is excellent, keeping quality is good.	Uttar Pradesh, Haryana and Punjab.
5	Kesar	Fruits are medium sized, shape is oblong; flesh is sweet and fibreless. Colour is apricot yellow with red blush on the shoulders, good keeping quality; ideal for pulping and juice concentrates; an early season variety.	Gujrat
6	Langra	Fruit is of medium size, ovate shape and lettuce green in colour. The lemon-yellow flesh is juicy and flavourful. It is scarcely fibrous, a mid season variety.	Uttar Pradesh, Bihar, Haryana, Madhya Pradesh, Orissa, West Bengal and Punjab.
7	Malda	Variety is alternate bearer; fruit medium, ovate and yellow in colour; keeping quality medium.	Bihar, West Bengal and Madhya Pradesh.
8	Neelum	Fruit is medium ovate-oblique in shape and saffron yellow in colour; good keeping quality; high yielding and regular bearing; ideal variety for transporting to distant places.	Tamil Nadu, Karnataka and Orissa

The post-harvest grading is, thus, very much important task among the steps cleaning, sorting, packing, transport, storage, waxing, etc. of mango fruit. Grading of mangoes is usually done on the basis of physical parameters such as size, shape, weight, colour, maturity, firmness, etc. However, the fruits with immaturity, over ripen, any disease and damage if found during grading are discarded (Pradeepkumar, 2008). Manual sorting and grading of mangoes is carried out in India which needed lot of man power to complete this task. Labours required sitting close to heaped mango and separating the damaged, diseased and rotten fruits by hand on the basis of tradition visual inspection norms. Sometimes fruits conveyed mechanically through the belt conveyor and visual inspection is done for picking up the undesirable produce by the labours standing both sides of the conveyor. But, in this type of visual inspection (Fig.3) is very expensive, labour intensive, and prone to human error, leading to variability in the final product. Non destructive methods can be used to do so without any biasness.

Table 2: Nutritional Value of 100 g fresh mango pulp (Anon, 2001)

Constituent	Amount in 100 g fresh pulp	Constituent	Amount in 100 g fresh pulp
Water	81.7 g	Vitamin A, RE	389 mcg_RE
Energy	65 kcal (272 kj)	Vitamin E	1.120 mg_ATE
Protein	0.51 g	Tocopherols, alpha	1.12 mg
Fats	0.27 g	*Lipids*	
Carbohydrates	17.00 g	Total saturated fatty acids	0.066 g
Total dietary fiber	1.8 g	Total monounsaturated fatty acids	0.101 g
Ash	0.50	Total poly unsaturated fatty acids	0.051 g
Mineral		Cholesterol	0.00 mg
Calcium	10 mg	*Amino acids*	
Iron	0.13 mg	Tryptophan	0.008 g
Magnisium	9.0 mg	Threonine	0.019 g
Phosphorus	11 mg	Isoleucine	0.018 g
Potassium	156 mg	Leucine	0.031 g
Sodium	2 mg	Lysine	0.041 g
Zinc	0.04 mg	Methionine	0.005 g
Copper	0.11 mg	Phenylalanine	0.017 g
Mangnese	0.027 mg	Tyrosine	0.01 g
Selenium	0.6 mcg	Valine	0.026 g
Vitamins		Arginine	0.019 g
Vitamin C (total ascorbic acid)	27.2 mg	Histidine	0.012 g
Thiamine	0.056 mg	Alanine	0.051 g
Riboflavin	0.57 mg	Aspartic acid	0.042 g
Niacin	0.584 mg	Glutamic acid	0.06 g
Pantothenic acid	0.16 mg	Glycine	0.021 g
Vitamin B_6	0.16 mg	Proline	0.018 g
Total folate	14 mcg	Serine	0.022 g
Vitamin A, IU	3894 IU		

These sophisticated novel technologies have developed for quick, accurate and efficient evaluation of agricultural produce to avoid the chance of human error. Various non-invasive techniques have now been emerged very strongly for the quality assessment of agricultural produce and also for other sectors of agriculture to achieve the above objectives (Patel *et al.*, 2019a). For instance, machine/computer vision system, magnetic resonance imaging/nuclear magnetic resonance, near infrared, ultra sound, electronic nose and eye, X-ray and computed tomography, etc. (Anonymous, 2016; Patel *et al.*, 2012b). Figure 3 shows a glimpse of computer vision vs. human vision.

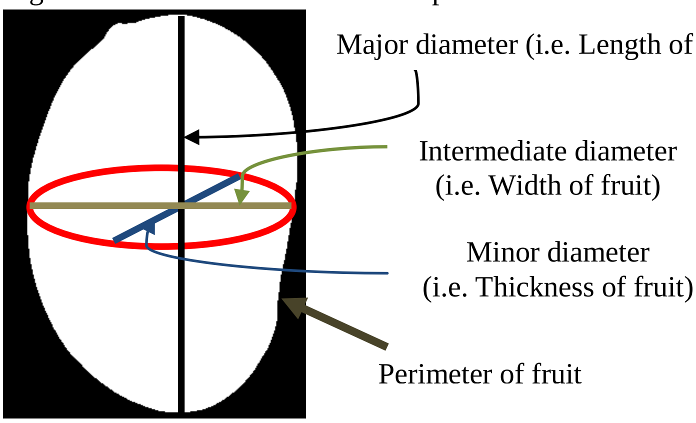

Fig. 2 Some geometrical attributes of mango fruit

Further, the main physical damages, responsible for post harvest losses of mango, the important parameter of grading, are physiological decay, water loss and over ripening (GOI, 2013). These damages may occur at any point of marketing process and during handling and transport. In addition, other serious causes of mangoes are the post-harvest diseases among the growers and the diseases are cause of concern during storage and transportation too. These issues, thus, limit the thriving mango industry. A range of leaf, fruit and soil disease can also be affected the quality of mango fruit or can induce disease after harvesting. Anthracnose, latex stain/sap burn, stem-end-rot, chilling injury, fruit rot, cut wounds, stem end cavity, mealy-bug, hot water injury, mango scab, bacterial black spot, powdery mildew, etc are the unacceptable defects/disease/disorders causing the lowering of prices of fruits. Brief descriptions of some major diseases are given below.

a. computer vision system (Abdullah, 2008)

b. Human vision system

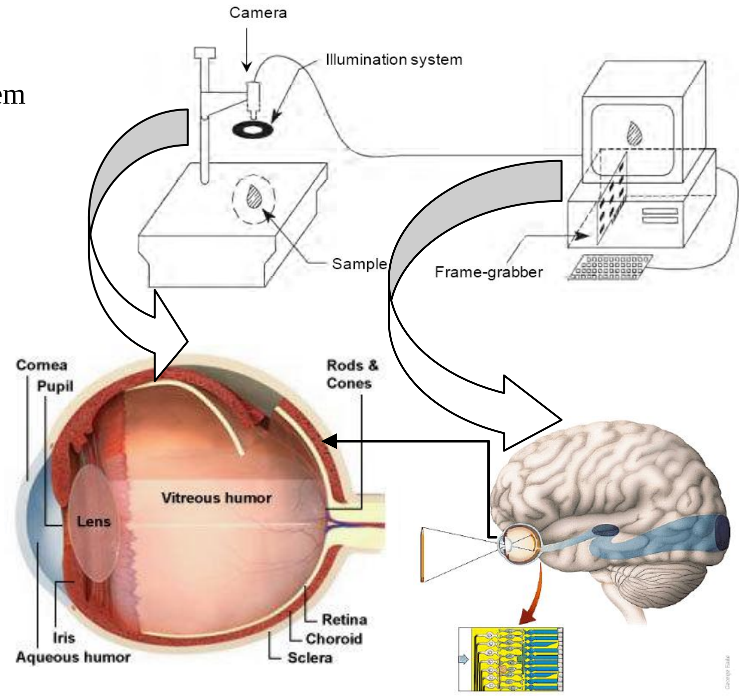

Fig. 3: Computer vision *vs*. human vision system

Post-harvest disease/decay of mangoes

Anthracnose (black lesion): Fungus, *Colletotrichum gloeosporioides* (*teleomorph: Gloeomerello cingulata*) (Arauz, 2000). Fungus (*C. gloeosporiodes*) is responsible for many diseases of mangoes and of many tropical fruits and is referred as anthracnose (Nelson, 2008). Anthracnose causes serious decay during marketing and after sale of fruits. The effect of anthracnose under wet condition of fruits is more serious and produces conspicuous pinkish-orange spore (Corkidi *et al.,* 2006). Anthracnose infected panicle, leaves and fruits from 20° to 30°C temperature and more than 95% RH (Dodd, 1991). In the field, anthracnose infections are favored by wet, humid, warm weather conditions while post-harvest anthracnose development generally favored by warm and humid temperatures (Corkidi *et al.*, 2006). Post harvest anthracnose, similarly, causes black to brown lesions on the surface. These surface spots eventually penetrate and mingle, and cause huge losses. Post harvest anthracnose is actually similar pre-harvest anthracnose when infected young fruits in the field and remains in quiescent stage until ripening (Prusky, 1996). Fruits appear healthy at harvest; thus, can develop rapid considerable anthracnose symptoms during ripening. It has been reported that most of the infected green remains latent and mostly hidden until ripening. Anthracnose infected ripened fruits develop sunken, dark brown to black spots. Mature fruits when infected caused significant losses during storage, transportation and marketing because transfer of fungus into the storage. Sometimes maturity, however, restricted the disease to the peel and becomes evident during storage. However, a serious anthracnose infection invaded into the pulp and further advancement develops acervuli and orange to salmon pink masses of conidia on lesions (Arauz, 2000).

Table 3 Non-destructive technologies for defects detect and quality assessment of mangoes

S. No.	Technique	Target	References
1.	Reflected UV imaging at 400nm	• Detection of anthracnose (black lesion), latex stain, fungal stricken area, shriveled fruit and dried tissues beneath the peel surrounding the defected area. • Detection of Scratch on surface/crack or cut on surface or beneath the peel of fruit.	Patel *et al.*, (2019a)
2.	Colour CVS	• Physical characterization of mangoes	Patel *et al.*, (2019b)
3.	3-D image analysis	• Spot-like lesions on the surface of mango.	Corkidi *et al.*, (2016)
4.	Automatic Multiclass support vector machine (SVM)	• Grading of mangoes.	Agilandeeswari *et al.*, (2017)
5.	Colour camera based CVS and image processing	• Detection of bacterial canker disease	Nadarajan and Thamizharasi (2017)
6.	Colour camera based CVS and image analysis	• Defect identification and maturity detection.	Sahu and Potdar (2017)
7.	Digital X-ray imaging technique	• Stone weevil in mango fruit.	Sambrani *et al.*, (2015)
		• Spongy Tissue in fruit like Alphonso mango.	Musale and Patil (2014)
8.	Colour camera based Computer Vision System (CVS) and image processing	• Determination of surface defects (black spot or scratches).	Nandi *et al.*, (2014)
9.	UV-light using a low-cost webcam	• Anthracnose and latex stain.	Nagle *et al.*, (2012)
10.	NIR Technology	• Determining the starch and dry matter content of immature and mature mangoes.	Slaughter *et al.*, (2009)
11.	MRI Technology	• Heat treatment induced injury to mesocarp tissue.	Joyce *et al.*, (1993)

Latex burn (staining): Sap burn, a serious quality concern (Maqbool and Malik, 2007), is the largest single quality problem with mango. Mango latex is a clear, slightly milky and viscous fluid which is responsible for allergic action on the skin (Loveys *et al.*, 1992) and can inflict serious eye effect (Menezes *et al.*, 1995). Poor harvesting and handlings result in a high incidence of sap burn which downgrades the fruit quality severely (Johnson and Parr, 2006). Sap is caustic in nature and has aroma characteristics of ripe fruit while oozes out instantly from unripe fruit as soon as the fruit is detached from stalk. Sap can be separated into two phase lower (milky and viscous) and upper phase (clear, yellow-brown and oily) by centrifugation at 12000rpm for 5 min (Loveys *et al.*, 1992). Upper phase is more responsible for sap burn than lower phase. When sap comes in contact with the fruit during harvesting and post-harvest handling causes undesirable skin blemish or burn (Anon, 2003). Sap classified as spurt sap and ooze sap (Bagshaw, 1989). Spurt sap released rapidly after skin injuries and stem removal within 5 second while ooze sap released slowly over about one hour. Ooze sap does not harm the skin but spurt sap burn the fruit and leave a blemish which further advanced during storage and transportation and leads huge losses (GOI, 2013).

Further, the amount and composition of sap exuded by a fruit depends on fruit maturity, harvest time of day, cultivar, and harvest season and production region. The less mature fruit generally exuded more sap and the harvesting of fruit early in the morning has greater sap flow than later during the day (Bagshaw, 1989). In order to avoid exudation of latex onto the fruit, the pedicel should be pointed downward at the time of removal, placed on de-sapping bench to drain out sap and then fruit should be washed to avoid the chance of any sap burn (GOI, 2013). Maximum sap burn took place within the first 24 hour of sap contact but the injury continue even after 72 hour of sap contact in *Chausa and Sindhuri* cultivars of mango. Thus extra care must be taken during first 24 hour of harvest. De-stemming under $Ca(OH)_2$, Tween-20 and Tween-80 can be most effective treatments against sap burn in both cultivars (Maqbool and Malik, 2007). Sap burn avoided by using latex/sap dynamics in Ambalavi and Chembaddan mangoes. For Karuthakolumban mangoes, de-stemming and dipping in the 5% NaCl (table salt) is very effective for reducing of sap burn injury. Similarly, the 1 % table salt has been reported effective for Willard mangoes to reduce sap burn without affecting quality (Krishnapillai and Wijeratnam, 2016).

Stem-end-rot: *Different f*ungi, *Dothiorella spp.*, *Lasiodiplodia theobromae* (Johnson and Cooke, 1991; Ploetz *et al.*, 1994) or phomopsis mangiferae (Ploetz *et al.*, 1994; Ko *et al.*, 2009), are responsible for stem-end-rot and for several post harvest mango diseases alongwith anthracnose. Complex pathogens (*Botryosphaeriocaeae* (De Oliveira Costa, 2010), *L. theobromae, N. mangiferae, Neofusicoccum parvum* and *Fusicoccum aesculi)* are found to be associated with stem-end-rot reported several studies. Stem-end-rot in Austrian mangoes, for instance, associated with *N. parvum* and *F. aesculi*, *N. mangiferae* (Slippers *et al.,* 2005) and Stem-end-rot dieback disease of mango in Brazil was associated with *L. theobromae*, *N. parvum* and *F. aesculi* pathogens (De Oliveira Costa, 2010). Amin *et al.,* (2011) reported *A. alternate, P. mangifera, Botryodiplodia spp.* as main pathogens associated with stem-end-rot in agro-ecological conditions of Punjab (Pakistan). Although, the disease started after attacking of fungus on fruit stem prior to harvest or on mechanically injured site. The initial symptom of disease is darkening of skin around the base of pedicel. Infected area enlarges rapidly and forms circular brownish-black lesion area of water soaked tissues which extended to whole fruits as time passed and at last fruits rotten within some days after entering the fungus at stem (Anon, 2003). During ripening, endophytic colonization of inflorescence and pedicel tissues found to be primary route of infection. However, 30°C temperature reported to be in favour of *L. theobromae* pathogen. Infection can be reduced by leaving a pedicel of 1bout 1-2 cm (Yahia, 2005).

Chilling injury: Chilling injury, physiological induced disorder (Yahia, 2005) of mango fruit is occurring at storage temperatures below about 10-13°C (Mann and Singh, 1976) or 10°C (Hulme, 1971) or 11°C (Anonymous, 2003) according to Ji *et al.*, (1994), fruit stored at 8°C developed no chilling injury symptoms. In contrast, Kane and Marcellin (1978) have reported that storage of mango at 4°C and 8°C developed chilling injury after 10 days. Chilling injury is also responsible for pitting, sunken lesion, uneven ski color, internal darkening, decay, and off-flavour and leakage of metabolites (amino acids, mineral salts and sugars) from cell structure. Similarly, Medlicott (1990) reported that chilling injury inhibited ripening when all harvests stored at 8°C and when early season harvests stored at 10°C. The better storage temperature of mangoes, harvested at mid- and late session, to avoid chilling injury is 10°C and 12°C. Temperature and storage period are the main factors responsible for severity of chilling injury. Storage at lower temperature for longer period causes more chill injury (Anon, 2003). Although, it has been reported that some cultivars such as: *Dashehari*, *Langara*, etc. can safely be stored at 7-8°C for 25 days. The enhanced resistance to the chilling injury might be related to the higher the total soluble solids content in fruit (Mukherjee and Srivastava, 1979).

Furthermore, temperature of hydro-cooling water found to be directly responsible for chilling injury and thus it should be maintained at 10° C (DeEll *et al.,* 2000). The hot water treatment of *Dashehari* and *Langara* fruits usually control the chilling injury during storage at low temperature. Exogenous putrescine treatments can also be used to avoid chilling injury. Since, putrescine treatment inhibit ethylene production and maintained superoxide dismutase activity in pericarp at a higher level and retard the malondialdehyde content and membrane permeability. In addition, mango fruit when wrapped in micro-perforated poly ethylene/ or Xtend film and stored in modified/controlled atmosphere of 5% CO_2 and 10% O_2 can also reduce the possibility chilling injury (Pesis *et al.,* 2000). In addition, high temperature (35-38°C) conditioning for few hours before low temperature storage shows better results (Yahia, 2005).

Alternaria rot: In the absent or well controlled of anthracnose and stem-end rot disease, *Alternaria* rot caused by *Alternaria alternate* can cause significant post-harvest decay in mango (Prusky *et al.,* 2009). In other words, *A. alternate* can cause serious/huge losses during storage for three or more weeks (Yahia, 2005) and compromise the storage life of fruits (Prusky *et al.,* 1981; Kobiler *et al.,* 2001). The casual organism of black spot and stem-end-rot disease is *A. alternate.*

Through lenticels of fruits, *A. alternate* penetrates the fruit, darkens the intercellular spaces and collapses the cell. Appearance of disease consists of either black spot (diameter: 0.5-1.0 mm) with dark centre and diffusive border or dark lenticels (Yahia, 2005). Initially spots were noticed to be concentrated around the stem of fruits where high numbers of lenticels are present and later these spots grow, coalesce and become large spot, and cover half of the fruit. .As time passed disease extended into the flesh and darkens and becomes partially soft (Anon, 2003).

Further, Diedhiou *et al.,* (2007) conducted a study to understand better the interaction between fungi involved in the post harvest rotting of mango, local production practices and climate changing conditions during the maturation period. Their study reported that the fruit harvested during humid season were infested more and the cultural practices played important role. Orchard sanitation, particularly cleaning and pruning reduced the infection rates.

Mansour *et al.,* (2006) isolated *A. alternate* alongwith *Botrydiplodia theobromae* and *Botrytis cinerea* from rotten mangoes (Meitt, Kent and Tommy Atkins. They reported that these are highly pathogenic to all these varieties. They further reported that when fruits were treated with hot air (50°C for 4 hr) followed by hot water (40°C for 5 min) in combination were found more effective in retarding of post harvest disease without peel darkening, fruit damage and affecting the uninoculated fruit's qualities (TSS, titratable acidity, vitamins C content, etc) and found to be increased shelf life of inoculated and uninoculated fruits. *Alternaria* rot can also be controlled using combination of physical (15-20s spraying of hot water of 50-55°C temperature and brushing) and chemical (prochloraz, chlorine, etc.) treatments. This new approach enhances the quality of fruits in the same manner as it reduced disease incidence (Prusky *et al.,* 2009).

In addition to above, several researchers such as Patel *et al.,* (2019a) Agilandeeswari *et al.,* (2017), Nadarajan and Thamizharasi (2017), Sahu and Potdar (2017), Sambrani *et al.,* (2015), Musale and Patil (2014), Nandi *et al.,* (2014), Nagle *et al.,* (2012), Slaughter, (2009), Corkidi *et al.,* (2006), Joyce *et al.,* (1993) have reported techniques for quality assessment and defect detection of mangoes (Table 3). For instance, Patel *et al.,* (2019a) have studied the potential of reflected ultra-violet imaging for surface defect (mechanical damage, black lesion, latex stains, and shriveling) detection of mangoes responsible for post harvest losses and lowering of market prices. In their study they detected the exact seriousness of injuries unable to detect by RGB colour camera by reflected UV imaging technique at 400nm band-pass filter (Table 3). In addition, computer vision system (CVS) can also be used for evaluation of size attributes (length, width, thickness), various morphological features (area, perimeter, Max Feret diameter, hydraulic radius, Waddel disk diameter, elongation factor, compactness, factor, Heywood circularity factor and type factor) of mangoes (*Chausa and Dashehari*) (Patel *et al.,* 2020).

Packaging

Packaging means all those activities related to designing, evaluating and producing the container for a product. Packaging protects every fruits from rub, contact and any type of compression and damage. In addition, it avoids fruits from dirt, dust, pests, contaminants, etc. Wooden boxes, CFB (corrugated fibre boxes), polythene (low density), crates, etc are used for packaging of graded fruits (Gill *et al.,* 2005). For mango fruit, wooden boxes are more common for packaging and transportation in the domestic market. However, CFB is now need of an hour because of lack of wood and more worry about the environment condition. The CISH (Central Institute for Subtropical Hrticulture), Lucknow has designed CFBs of the capacity of 5 and 10 kg for mangoes and presented best alternative to traditional nailed wooden boxes (Medina and Garcia, 2002). Anonymous (2006) has reported extensive use of CFBs for export purposes. For packaging and transportation of Alphonso mangoes, CFBs were also found to be best and suitable than the wooden boxes (Roy and Pal, 1991). Cushioning material (paper wraps, newspapers, etc.) generally used in the course of packaging to prevent bruising and spoiling during storage and transportation (Gill *et al.,* 2005; Ravindra and Goswami, 2007). However, the low density polyethylene (LDPE) lining maintains humidity and results lesser fruit shrinkage during storage. Polyethylene packaging, thus, gave the best storage to the products retaining the moisture content and sensorial attributes. Similarly, the individual fruit wrapping (uni-pack) using newspaper or tissue paper and honeycomb nets packing helps in ripening with reduced spoilage (Medina and Garcia, 2002; Narayana *et al.,* 1991). But, sealing of mature green fruit in semi-permeable polyethylene can cause quality deterioration in terms of taste and appearance (Anonymous, 2006; Straten and Osthuyse, 1994). Thus, the use of clean, new and qualitative materials particularly paper or stamps with trade specifications should be allowed. The printing or labeling should be allowed with non-toxic ink or glue to avoid any internal and external damage. Recommended International Code of Practice for Packaging and Transport of Fresh Fruits and Vegetables (CAC/RCP 44-1995, Amd. 1-2004) should follow during mangoes packaging in container.

Storage

Storage is an activity through which consumption period increased; market supply is regulated and transportation to long distances achieved. The main objective of storage, however, is to arrest damage and extend the shelf life of agricultural produce. Various storage techniques (low temperature/pressure storage, CA/MA: controlled atmosphere/ modified atmosphere, and use of chemicals, wraps and coatings and ionizing radiation) have been emerged for horticultural produces, so far. Pre-cooling of horticultural crops is required first and then storage before exporting. Dasehari, Mallika and Amrapali should be stored at 12°C, Langra at 14°C and Chausa at 8°C with 85-95% RH. At low temperature, fruits can be stored for 3-4 weeks in good condition.

According to Kader *et al.,* (2002), temperature of storage for mature green mango is 13°C and 10°C for partially and fully ripe mango fruit with 90-95% RH is recommended. The 90% RH and 10-15°C temperature from ambient condition could be achieved in zero energy cool chambers (ZECC) when watering is done twice a day. Using local materials (bricks, sand, bamboo, dry grass, juite, etc.), IARI New Delhi developed ZECC. The ZECC works on the principle of evaporation. After performance evaluation of ZECC in various parts of country, it has been reported that the shelf life of mangoes can be increased by 3-4 days (Roy and Pal, 1991). Economical, in terms of construction and operation, and its satisfactory performance resulted developments of a variety of various ZECC models of capacity between 100 kg and 1000 kg. These were tested and found performed equally well in reducing post harvest losses and maintaining the quality of fruits and vegetables. Improved type ZECC is one of them and satisfactory storage at 7-8% °C has also been reported (Mann and Singh, 1976).

CA/MA (controlled atmosphere/modified atmosphere) can also be recommended for better results. Since, CA provides an effective storage environment (Bender *et al.,* 2000; Raghavan *et al.,* 2003) while the role of MA is to maintain the quality of fruits after harvest is very significant (Ding *et al.,* 2002; Rodov *et* *al.,* 2002). For instance, storage under controlled atmosphere (3-4 % CO_2 and 4-5% O_2) with a continuous flow system at 13-15°C is found to be very effective in prolonging the shelf life of Alphonso cultivar for 30 days including 4 to 5 days ripening period. Lalel *et al.,* (2001) has recommended atmospheric composition 6% CO_2 and 2% O_2 for enhancing the shelf life of mangoes (cv. Kesington Pride). For CA/MA storage of mango, an atmospheric composition of 4-10% CO_2 and 1-8% O_2 have been studied and recommended by Lalel *et al.,* (2005), Bender *et al.,* (2000), etc. in varying combinations for a given cultivar and maturity of fruits. For instant, optimum matured fruit do no exhibit symptoms of chilling injury, have longer storage shelf life and may withstand maximum limit (25%) of CO_2 (Roy and Pal, 1991) showed insecticidal effects during storage (Yahia and Vazquez-Moreno, 1993). However, storage of mango in the atmospheric composition of 15% CO_2 and 1% O_2 results quality degradation in terms of off-flavor and skin discoloration. Modified packaging inhibited the mango ripening process (Sornsrivichai *et al.,* 1992).

Transportation

Mango transportation needs careful handling to avoid damage and spoilage. Mangoes in ripening stage become too soft during transportation and are susceptible to easy injury that reduces the eating and keeping quality (Anon, 2012). Prior to loading of treated mangoes packets, a careful inspection of empty trucks or vans is needed to ensure that these are free from pest and any type of biological debris. For this purpose, before exporting the mangoes from India to USA a joint inspection by the Animal and Plant Health Inspection Service (USDA: United State Department of Agriculture) and Plant Protection, Quarantine and Storage, Ministry of Agriculture (NH IV, Faridabad) is carried out. Similarly, the second disinfection is required for empty van or truck if any pests are found in the first round inspection. Thorough disinfection of empty van of truck is ensured/ or effectively controlled using suitable insecticide. All suspected areas such as space between doors, every nook and corner, etc. should be disinfected carefully. The loading area should be covered by inspect-proof screen for the prevention of hitchhiking pest entry during loading. The doors of van or truck is closed and secured by a lock after loading. Finally a seal required to be fixed.

Conclusion

The roles of novel techniques for post harvest management of mangoes are very important to maintain its economical and nutrition value in national and international markets. To reduce the losses after harvest, sustaining the overall value (nutritional and economical) and extending the shelf life of mangos, application of these novel practices could be very effective and the profits of growers and marketers consequently increased. For local markets a simple washing of mangoes, however, only required to remove dust, dirt and latex spot if any. But, for the exporting of mangoes various post harvest treatment/management activities for mangoes are required. For example, mangoes are dipped in hot water containing fungicide to control disease. As hot water reduced the chances of damage/infection due fruit fly, anthracnose, stem-end-rot, etc, the hot water treatment has been found an effective treatment after harvest for mangoes. The post harvest activities (pre-cooling, sorting, grading, packaging, storage and transportation, etc.), therefore have important impact on quality management and add values before marketing of mangoes. This paper presents an overview of recent applied technologies for post harvest management of mangoes and it could be the basis for mango grower and marketer.

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