Protocol of post-harvest and cool chain management of mango (*Mangifera indica*) for domestic and export trade.

Introduction: -Postharvest losses in mango continue to be a major factor in the supply chain despite availability of protocols for maturity, harvesting and postharvest operations comprising de-sapping, washing, sorting and grading, treatments, packaging, enhancing shelf life by cold storage, etc. Maturity index of mango is an important factor in post harvest system. The best characteristic of mature fruit depends on producers, handlers and adaptation of quality control technologist. Fruit condition at the time of harvest has important effect on the consumer's level of satisfaction. The term physiological maturity, horticultural maturity, commercial maturity and ripe are used interchangeably to describe the state of fruit when it is ready for consumption. The term mature describes the stage at harvest that will ensure that the fruit's quality will meet or exceed the minimum level acceptable of the consumer. In a climacteric fruit, such as mango, the fruit is not considered to be of desired eating quality at the time it initially becomes mature, but thereafter requires ripening (6 to 10 days) before it achieve the desirable taste, texture and quality. There are several factors contributing directly or indirectly to the postharvest losses of mango viz. maturity indices, harvesting practices, etc.

Maturity indices: - The maturity indices should be simple, readily performed in the orchard and involve inexpensive equipment. It must include a measurement rather than an evaluation, which would consistently relate to quality and post-harvest life of mango. The satisfactory indices already suggested are few and the search for satisfactory and non-destructive maturity indices still continues. Maturity indices involve two viewpoints the first is to predict the time at which fruit will mature and the second to measure maturity at harvest or inspection point.

Many features of fruits have been used in attempting for estimation of maturity like efficient involved elapsed days from bloom to harvest, mean heat units or fruit set to harvest maturity during development and development of abscission layer. The visual attributes are size, shape, fullness of shoulders and external colour of fruits. The physical features of maturity indices are specific gravity, textural properties like firmness and tenderness of fruits. The compositional factors for maturity are starch, sugar, acid, carotenoids and sugar/acid ratio. The efforts have been made to study both compositional, chemical and physiological changes in fruit throughout its development for determining maturity indices. Storage trails and

organoleptic panels also determine the value or level of the maturity index. When the relationships between changes in the maturity index along with post harvest quality and storage life of mango has been determined, an index value can be assigned for the minimal acceptable maturity level.

New opportunities in chemical analysis are exemplified by the development of NIR technology for examining the composition of fruits and rapid sensor technology for determining volatile profiles in harvested fruits. There are several technologies like NIR, MRI, etc. which are able to measure sugar, acids and other compounds non-destructively and is sufficiently rapid to enable determination of mango maturity in the orchards.

Magnetic resonance (MR) and magnetic resonance imaging (MRI) are non destructive sensing methods based upon the interaction of certain nuclei, such as carbon and hydrogen of fruit (water, sugars and oils) with the electromagnetic radiation in the radio frequency range. Areas of increased free water in the internal tissues of fruits are detected by MRI. The water activity in the fruit increased in an outward-moving flux as the fruit ripened and MRI signals in the middle part of the flesh increased during ripening in "Kensington Pride" mangoes.

When light comes in contact with a biological material, the photons of light can interact with the material at the molecular level. The light waves are either absorbed or reflected or transmitted. The wavelength of light absorbed by the molecules indicates the type of molecule (water, sugar, starch, fat, pigment etc.) based on the relationship between the energy of light and energy state of molecules. In mango fruits interactant is non destructive optical technique that allows a light absorbance measurement to be made through a portion of the mesocarp depending on the peel thickness. Till date the ultimate quantifiable unit of mature indices for fruit like mango is yet to be defined for distant market and long-term storage keeping in view the quality and consumers acceptability.

Do's	Don'ts
Maturity determines the fruit quality.	Immature fruits don't have quality
Mango takes about 3 (some may take 3½ to 4) month's time from fruit set to maturity.	The shoulders are in line with the stem- end (premature) don't perform well.
Computation method for maturity Alphonso -111 days, Dashehari -84 days, Chausa - 105 days.	Over-mature fruits don't have prolonged shelf life.
Change in peel colour from olive green to light green	Don't harvest dark green fruits.
Fruit shoulder out grow the stem-end and the colour becomes light- green (mature harvest).	Lacks definite standards don't depend on it especially for export.

Specific gravity >1 in Alphonso but <1 in Dashehari and Banganpalli.	Don't as it is influenced by cultural practices.
Chemical method (TSS: Acid ratio, starch content, carotene content and dry matter) for maturity are accurate.	Don't as it require special skills.
Non destructive like NIR and MRI are accurate to predict maturity.	Don't as NIR and MRI are very costly.
Maturity indices should be:	
• The stage that allows to develop acceptable natural flavour and colour. • The stage which allows fruits to attain good quality when it reaches to the consumer. • Size required by the market. • Have an adequate shelf life	• Not astringent in taste. • Don't have marks or cut surface.

Harvesting: -Harvesting of mangoes coincides with high temperature and high relative humidity posing a problem for further supply chain management. One of the most common mistake growers make is to harvest fruit crops early in the season to fetch the market price even though fruits are immature and do not develop characteristics quality, flavour and taste. If the crop is allowed to grow, fruits will not be uniformly ripe for good eating quality, further it develops jelly formation around the stone. If all the fruits are harvested at once there is every likelihood to have under-mature or over-mature. Mechanical damage during harvesting becomes a serious problem, as injuries predispose the fruits to decay, increased water loss and increased respiration and ethylene production leads to quick deterioration. Manual harvesters should be well trained in the proper way to harvest the fruits to minimise the damage and waste. Mangoes should be picked with care by snapping, cutting or pulling the fruit from the plant in least damaging manner. Exposure to sun should be avoided as much as possible during and after the harvest of fruits. To prevent from becoming warmer than air temperature and reduce the field heat, fruits are placed in the shade or loosely covered. Evening or early morning harvest is best option for harvesting mangoes, when internal temperatures are relatively low; reduce the energy needed for subsequent cooling.

Do's	Don'ts
Harvest only mature fruits.	Don't harvest immature fruits.
Harvesting of mango should be in the morning or evening time of the day	Don't harvest the fruits at noon.
Harvesting should be done by hand / harvester	Don't hit the fruits while harvesting.
Fruit stalk should be of minimum 2 mm.	Don't use fruits with sap oozing out and

	sticking on the surface.
Harvested fruits should be kept in crates and under shade.	Don't pile the fruits on the soils and weeds growing.
These should be immediately shifted to handling room.	Don't throw the fruits while handling.

De-sapping and washing: - Latex or sap flow is associated with the harvesting of mangoes, an additional unavoidable operation in the supply chain. Harvesting of mangoes are carried out late in the morning and fruits infected with oozing of latex do not qualify for acceptability as they are source for further infection in storage, moreover the thin layer of wax coating on the pericarp is disturbed. In order to avoid the sap flow, fruits are harvested with long peduncles which is further trimmed with the help of secateurs and maintained at length of 10mm to ease handling operations. The trimmed fruits are placed in inverted position on the plastic cone for half an hour to complete the flow of sap and prevent stickiness of fruits surface. The fruits are further subjected to washing in the packaging line facilitated with conveyors to carry the fruits post harvest treatments. The quality of water to be used should be portable and not be contaminated with heavy metals. Sanitation is important to control the spread of disease, limit the sporulation in wash water container and packhouse air. Chlorine treatments 100 to 150 ppm can be used in water to help in control of pathogen build up during packhouse operations. Use 1 to 2ml of chlorine per liter of water to clean the walls, floor and packing equipments. The pH of water should be 6.5 to 7.5 for best results. More chlorine is to be used in case of hot water or if it contains organic matter.

Sorting and grading: - Fruits are sorted for cracks; sap sticking to skin, infested with fruit flies and infected with anthracnose are discarded or kept aside. Only sound and healthy fruits free from blemishes are further used for postharvest operations like grading, postharvest treatments, packaging etc. Fruits are graded as per Codex Alimenterious guidelines.

Grade designation and quality of mangoes:

Grade designation	Grade Requirements	Grade tolerances
Extra class	Mangoes must be of superior quality, characteristic of the variety and free of defects	5% by number or weight.
Class I	Mangoes must be of good quality, characteristic of the variety and may have slight defects (shape, suberized stains and healed bruises).	10% by number or weight.
Class II	This grade includes mangoes which do not qualify for inclusion in the higher grades, but satisfy the minimum	10% by number or weight.

	requirements.	

Grading and size tolerance:

Size Code	Weight (grams)	Maximum Permissible difference within the packet (grams)	Max. permissible difference between fruit in each package (grams)
A	100-200	90 - 220	50.0
B	201-350	180 - 425	112.5
C	351 - 550	251 - 650	150.0
D	551 - 800	426 - 925	187.5

Export specifications for mangoes: -

Variety	Countries				
	Middle East	Netherlands / Germany	U.K.	Japan	USA
Alphonso	Wt. 200-250 gm	Wt. 250-300 gm	Wt. 250-300 gm	Wt. 250-300 gm	Wt. 250-300 gm
Kesar	Wt. 200-250 gm	Wt. 225-250 gm	Wt. 225-250 gm	Wt. 250-300 gm	Wt. 250-300 gm
Packing	1 Doz/2.5 kg	1 Doz/2.5 kg	1 Doz/2.5 kg	1 Doz/3.5 kg	1 Doz/3.5 kg
Storage Temp.	13^0C	13^0C	13^0C	13^0C	13^0C
Export	By Sea	By Air	By Air	By Air	By Air

Warnings:

1. Minimum quality standards of mango fruit shall be: -

Do's	Don'ts
Whole, firm, sound and fresh in appearance.	**Don't use fruits of marked bruising.**
Clean, practically free of any visible foreign matter.	**Don't use fruits from damage caused by low/or high temperature.**
Sufficiently developed and display satisfactory ripeness.	**Don't use fruits of any foul smell and/or taste.**
When a peduncle is present, it shall not be no longer than 1.0 cm.	**Don't use fruits that are damaged by pests.**

2. Sorting, grading, packaging and storage of mangoes: (Post harvest technologies of mango)

Do's	Don'ts
Wash the fruits with portable water	**Do not allow the sap to stick on the surface.**
Grade fruits according to weight or as per requirement of importing country.	**Don't use defected, deformed, bruised and diseased fruits.**
Pack only sound and uniform grade of fruits in a package / container.	**Package should be free from any foreign material like nails, pins, etc.**

Provide proper ventilation in the package.	**Don't bruise fruits individually wrap them.**
Package should meet the handling and shipping requirements of international standard.	**Don't forget to label the pack with fruit name, variety, grade and date.**
Fruits could be stored for 6 – 12 days under ambient conditions, according to variety.	**Do not overfill the baskets and crates with moist fruits.**
Pre cool the fruits to required temperature prior to cold storage.	**Do not put the fruits directly for storing at low temperature.**
For increasing the shelf life fruits are stored at low temperature and high humidity.	**Do not stake the crates >10 in numbers.**
Store the fruits at critical low temperature. **Dashehari 12°C** **Langra 15°C** **Chausa 10°C** **Mallika 12°C** **Amrapalli 12°C with 85-90 % R.H.**	**Do not store fruits below critical temperature, as fruits fail to ripen, dis-colouration and predispose to microbes.**
The shelf life of fruits at low temperature is 3 –4 weeks.	**Tropical and subtropical fruits are prone to chilling injury.**
Transfer cold store fruits gradually to room temperature to minimize sweating.	**Do not use flexible containers that get deformed on stacking.**
Stack 8 – 15 containers, as per their strength, in pallets.	**Do not throw the packages during loading or unloading.**
Arrange the boxes in the truck to allow proper air circulation.	**Do not transport the produce during the day.**
Transport cold stored fruits in a reefer van.	**Do not open the reefer van time and again.**

Postharvest treatments:-Postharvest treatments are imposed on mangoes basically to prolong the storage by controlling ethylene evolution, by reducing the incidence of anthracnose (*Colletotrichum gloeosporioides*) and stem end rot. Several chemicals like polyamines, 1-Methyl Cyclo Propane (1-MCP), methyl jasmonates, oxalic acid, acylated salicylic acid, etc. are being used to reduce the ethylene evolution as well as to control the infection from post harvest pathogens. Use of wax is also prevalent but in case of mango there is every possibility of fruits to develop off-flavour. In the recent past nano-materials are also being used for coating to enhance the shelf life beside glossy appearances of fruits. Besides controlling ethylene production and storage pathogens it greatly influences the biochemical properties of fruits also.

The treatment of fruit is associated with changes in metabolic activity as measured by changing pattern of respiration and ethylene production. The drawback with this feature is the variability in absolute rate of ethylene production and respiration among similar individuals of the same fruit. The technique is also complex and expensive to implement on a commercial scale. Mango is a fleshy fruit containing more than 80 per cent water. Mango at

maturity consists of 19 per cent dry matter mainly carbohydrates, 60 per cent of which are sugars and acids. The sugars increase and acids decrease under normal circumstances of storage, but after treatments these components change drastically at an increasing rate up to senescence.

After harvest and postharvest treatments fruit is accompanied by profound changes in their chemical composition. Among the chemicals of fruit carbohydrates play an important role as the basic provider for further biochemical activities. Few of these compositions provide satisfactory shelf-life prediction because they usually require destructive sampling and complex chemical analysis. In the entire storage period reducing sugars were higher than the non-reducing sugars. The peel has higher content of sugar than the pulp in the initial development but at the time of harvest sugars in the peel and flesh were similar. In Dashehari, total soluble solids increase slightly up to 6 days of storage and then decreased upon senescence. Acidity decreases as the fruit kept in storage and pH values increase. Citric acid and malic acids were the major organic acids. A decrease in citric acid and a small decrease in malic acid are responsible for decrease in acidity. Tartaric, ascorbic, oxalic and alpha-ketoglutaric acids were also present in low concentration. At harvest, mature fruit of mango has TSS about 8^{o}Brix, acidity around 1.0 per cent and TSS:acid ratio above 7 are the maturity indices of Dashehari which changes at 12days of storage under room condition.

Visual colour changes during fruit development have been correlated with maturity, storage and ripening. Chlorophyll in the peel declined throughout the storage period. In the pulp, the chlorophyll content decreases and total carotenoids increases as the fruit approaches ripening. With the increase in storage period, the pulp colour changes from cream to yellow due to appearance of yellow pigments mostly carotenoids. Total carotenoids and β-carotene remained at low concentration initially and increase gradually as fruit approaches ripening. The changes in carotenoids content could be correlated to ripening in mango and it decreases upon senescence and could be used as a spoilage loss index.

Packaging: - Mango fruits for domestic markets are packed in wooden boxes/crates, baskets made from stalk of red gram, packed even in jute bags and sometimes carried in open tractor trolleys. The traditional packaging still exists from decades which are the major factor influencing the postharvest management of mangoes. Packaging's of fruits are vital in the supply chain as this operation predicts the acceptability of the produce by the consumers and further the shelf-life of fruits. Each individual mango fruit will be enclosed in a clean, white, soft, expandable and netted type polystyrene sleeve to prevent bruising before packing in a

box. The mangoes must be packed in insect-proof boxes. If ventilated boxes are used, all the ventilator openings of the box should be covered with insect-proof screen and all the sides of box should be sealed with adhesive tape to prevent any entry of pests. The materials used inside the package must be new, clean, and of a quality such as to avoid causing any external or internal damage to the produce. The use of materials, particularly of paper or stamps bearing trade specifications is allowed, provided the printing or labelling has been done with non-toxic ink or glue. Mangoes shall be packed in each container in compliance with the Recommended International Code of Practice for Packaging and Transport of Fresh Fruits and Vegetables (CAC/RCP 44-1995, Amd. 1-2004). The package boxes must have dimensions of 390X260X115 mm for Banganpalli. Corrugated Fibre Board boxes 320X230X90mm are used for packaging of Dashehari mangoes. These CFB boxes are having a ventilation of 5% as they are staked in the cold storage or in the trucks during transportation to distant markets.

Nowadays mangoes are also packed in different films to enhance the shelf life of fruits by storing in cold storage or in modified atmospheric packaging (MAP). New types of **'smart' packaging** are able to mechanically, chemically and electronically respond to their contents For example, a sensor fitted into fruit packaging detects chemicals released by the fruit as it ripens, and changes colour. This allows the customer to choose when to eat the fruit according to their preference. **Active packaging** maintains the quality of products without the use of food additives. The packaging contains substances that absorb oxygen or moisture, or prevent the growth of microbes. In normal **(passive)** packaging, oxygen molecules can pass through the wrapping, encouraging food spoilage and the growth of bacteria. Porous clay hetero structures (PCHs) are an interesting material for use as an entrapping system (for example, as an ethylene scavenger) because of its high surface area with uniform and specific pore sizes are used for packaging of mangoes. Almost all products are packaged in some way for protection during transportation, handling or storage.

The main characteristics to consider are gas permeability, water vapour transmission rate, mechanical properties, transparency, type of package and sealing reliability in selecting packaging films for MAP of fruits. Traditionally used packaging films like LDPE (low density polyethylene), PC (polyvinyl chloride), EVA (ethylene-vinyl acetate) and OPP (oriented polypropylene) are not permeable enough for highly respiring products like fresh-cut produce, mushrooms and broccoli. As fruits are respiring, there is a need to transmit gases through the film. Films designed with these properties are called permeable films. MAP films

developed to control the humidity level as well as the gas composition in the sealed package are beneficial for the prolonged storage of fresh fruits, which are sensitive to moisture.

Storage: - In northern part of India mangoes are harvested in the morning and are exposed to temperature beyond 35ºC accompanied by high humidity is a challenge for enhancing the shelf life of fruits under room temperature. Mango fruits are prone to chilling injury. Below critical temperature, climacteric fruits fail to ripen, dis-colouration and predispose to microbes. Fruits exposed to low temperature loose the cell membrane integrity and ion leakage. Low temperature alters the enzyme activity. Lower the temperature the longer the shelf life. The symptom becomes more severe after removal from chilling temeprature. Varieties of mango differ in their temperature requirement under cold storage Dashehari 12ºC and 85-90% R.H. while that of Langra 15ºC, Chausa 10ºC, Mallika and Amrapalli 12ºC. However, the problems associated with cold storage are power failure during summer needs a quick backup with generators so as to avoid the rise in temperature in the cold storage. The other one is after removal of fruits from the storage there is lot of perspiration on the fruit surface and needs at least two hours of waiting period in order to carry out the next operation. There are alternative operations or packaging along with cold storage of mango to prolong the shelf life and availability for longer duration.

Legal issues: Export Promotion and Regulations.

Do's	Don'ts
Registration of farmers by APEDA for export	Do not use unauthenticated planting materials.
Pre harvest spraying of recommended chemicals	Don't have any pesticide residue.
Maturity Full mature – Export through air 85-90% maturity – Export through sea.	Don't use defected, deformed, bruised and diseased fruits.
Mangoes shall comply with the residue levels of heavy metals, pesticides and other food safety parameters as laid down by the Codex Alimentarius Commission for exports.	Don't pack different varieties and sizes of fruits together.
Nearly 200 pesticides are now registered in India for use in agriculture under section 9 (3) of the Insecticides Act, 1968, which may come into our food chain from their intentional or unintentional use on the fruits as fruits are mostly consumed as fresh.	Do not use banned pesticides like: Aldrin, Aldicarb, Benzene hexachloride (BHC), Calcium cyanide, Chlordane, Chlorobenzilate, Dibromochloropropane, Copper acetoarsenite and Dieldrin
Vapour-heat treatment for export to Japan Temperature of the treatment chamber shall be	Don't use water of inferior quality.

raised step by step to 50^0C for 20 minutes.	
Irradiation at 400 Grays using Cobalt-60 for export to USA	Don't do it without the inspection of USA agencies.
Grade fruits according to weight or as per requirement of importing country	Don't under or over fill fruits during packaging.

Transport: -

Transportation of fruits is the most important operation in the supply chain management. Fast transportation with minimum damage during shipment is essential in successful marketing of mangoes. For the local market Tractor, trolleys and bullock-carts are used and for a distant market transportation is mainly done by the road although it is very costly. For transportation of fruits road is preferred for shipment of fresh fruits simply because of the faster transit of perishable commodities and advantages of door-to-door services and takes less time. Reefer vans should have a special system of ventilation and arrangement to reduce the temperature and maintain proper relative humidity. This can successfully be done by adopting the technique of evaporative cooling without using high cost mechanical refrigeration. The loss in transportation occurs due to physical and mechanical injuries. Injuries under controlled transportation condition mainly temperature and relative humidity losses of huge magnitude may occur. Efficient transport system can in a long way not only reduces the post harvest loss of mangoes but also in stabilizes the price fluctuation of the same commodity available in different corners of the country. Usually, raised wooden plates or planks are place on the floor of the reefer van on to which the palleting of mangoes are done to avoid post harvest losses and maintain quality. There should be a gap of one foot in between the pallets and not more than 15 boxes per pallets. This is done to facilitate the circulation of air during the transport. Now a day there are also sensors attached to the reefer van to detect the temperature and relative humidity build up in the reefer containers. In case of Dashehari mangoes the temperature and relative humidity were 12ºC and 85-90 % relative humidity for one month while transported from Saharanpur to Mumbai and further shipped to Dubai. After transportation the fruits are repacked at the destination after sorting, grading and ripening.