Alliance for an Energy Efficient Economy

Cool Coalition
a UNEP-convened initiative

MANGO
COLD CHAIN GUIDELINES

JUNE 2025

United Nations Environment Programme (UNEP) Cool Coalition in partnership with the Alliance for an Energy Efficient Economy (AEEE), is implementing the project “Scaling-up Investment in Clean and Efficient Cold chain in India.” The project aims to accelerate the development of sustainable and integrated cold chain in India and selected states. It is supporting the national government and two states, namely Bihar and Haryana, in mainstreaming energy-efficient, renewable energy-powered, and low-GWP refrigerant cold chain infrastructure and services in rural areas, particularly focusing on packhouses and reefer transport as part of an integrated cold-chain. The project is contributing to the implementation of India’s Cooling Action Plan and is working to enhance rural livelihoods.

The Cool Coalition is a global multi-stakeholder network that connects a wide range of key actors from government, cities, international organizations, businesses, finance, academia, and civil society groups to facilitate knowledge exchange, advocacy and joint action towards a rapid global transition to efficient and climate-friendly cooling.

Alliance for an Energy Efficient Economy (AEEE) supports policy implementation and enables the energy efficiency market with a not-for-profit motive. AEEE promotes energy efficiency as a resource and collaborates with industry and government to transform the market for energy-efficient products and services, thereby contributing toward meeting India’s goals on energy security, clean energy, and climate change.

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INTRODUCTION

Effective post-harvest management and cold chain practices are essential for extending the shelf life and maintaining the quality of mangoes in Bihar. Investing in infrastructure, training, and awareness and fostering collaboration among stakeholders can significantly reduce losses, improve market access, and boost farmers' incomes. By adopting these practices, Bihar's mango can continue to satisfy consumers both domestically and internationally.

United Nations Environment Programme (UNEP) Cool Coalition in partnership with the Alliance for an Energy Efficient Economy (AEEE) are providing technical assistance to Bihar's Department of Agriculture under the India Cold-Chain Programme (ICCP). Through the Directorate of Horticulture, the Department has recommended developing specific cold chain guidelines for mangoes in Bihar. This document aims to provide these guidelines, tailored to the state's needs and can be shared with the Department of Horticulture, the Department of Industry, and Farmer's Producer Companies (FPCs) to benefit smallholder farmers, cold chain operators, and other stakeholders involved in the mango value chains.

Despite Bihar's abundant mango production, post-harvest management (PHM) faces several challenges that must be addressed to ensure optimal quality and market access. Key challenges include:

Spoilage Losses: Inadequate handling, storage, and transportation facilities lead to significant post-harvest losses, reducing yield and profitability.

Quality Deterioration: Mangoes are highly perishable, making them vulnerable to rapid quality decline, which diminishes consumer satisfaction and market value.

Limited Awareness and Training: Many farmers, traders, and stakeholders lack the facilities or awareness of proper PHM practices, resulting in suboptimal handling and increased losses.

Inadequate Cold Chain Infrastructure: The lack of modern packhouse facilities and transportation is the key hindrance to preparing and maintaining the produce at the necessary temperature and humidity parameters, crucial for preserving the saleable value and quantity as mangoes travel from farms to markets.

Due to these infrastructure gaps, farmers in Bihar are forced to sell their produce at the lowest price points in markets near the farms. This document aims to educate farmers, packhouse operators, policy stakeholders, and cold chain owners about activities and post-harvest handling practices for mangoes, ultimately enhancing the market value of the produce.

As of 2023, Bihar has 313 cold storage facilities with a capacity of 14,76,557 MT but has only 30 packhouses as of FY 2018-19. Cold chain development has mainly focused on the creation of cold stores and modernizing outdated storage facilities, often neglecting the need to develop modern packhouses at the first mile. The output from these packhouses needs to be connected through refrigerated transport to ensure a seamless cold chain with extended markets. Packhouses are the entry point to the cold chain for most fresh horticultural produce, particularly those with a short marketable life, with other components like reefer transport and cold storage following. Without proper aggregation and preconditioning at packhouses, the rest of the cold chain remains energy-inefficient and ineffective.

A preliminary analysis by UNEP and AEEE estimates that Bihar will require approximately 1,600 first-mile packhouses and 3,200 reefer vehicles over the next 12-15 years to connect horticultural produce to distant markets and consumption centers. This initiative aims to improve the efficiency of horticultural supply chains, ensuring freshness and quality while facilitating the smooth transportation of Bihar's renowned mangoes to wider markets.

02 MANGO PRODUCTION IN BIHAR

Bihar is India's third-largest mango producer, contributing 7.5% of the national output, with 1576.06 thousand metric tons produced in 2022-23. The state's leading mango-producing districts are Darbhanga, East Champaran, Vaishali, Muzaffarpur, and Samastipur. (Ministry of Agriculture & Farmers' Welfare, 2023)

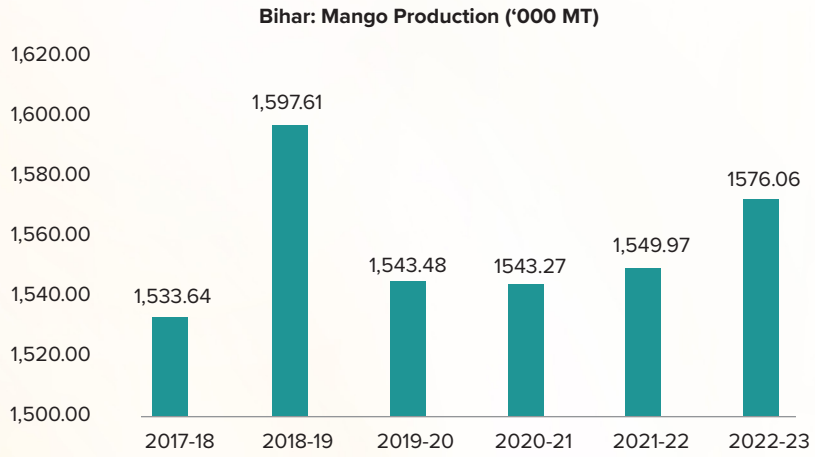

Figure 1: Year-wise Mango Production in Bihar

Source: MoA&FW

Table 1 presents the district-wise mango production in Bihar, with Darbhanga, East Champaran, Vaishali, Muzaffarpur, and Samastipur districts leading in both cultivation area and production.

Table 1: District-wise production of Mango in Bihar

	2022-23		2021-22		2020-21	
	Area ('000 Ha)	Production ('000 Tonnes)	Area ('000 Ha)	Production ('000 Tonnes)	Area ('000 Ha)	Production ('000 Tonnes)
Darbhanga	13.30	145.65	13.29	145.62	14.29	148.63
E. Champaran	12.07	128.85	12.06	128.82	12.06	128.82
Vaishali	12.04	121.15	9.51	95.98	9.51	95.98
Muzaffarpur	10.87	113.76	10.86	113.74	10.59	113.52
Samastipur	10.70	99.52	10.69	99.50	10.67	99.43
W. Champaran	7.46	74.52	7.45	74.50	7.42	73.36
Bhagalpur	8.13	74.14	8.13	74.13	8.13	74.13
Patna	7.76	73.80	7.75	73.78	7.75	73.78
Rohtas	5.86	60.02	5.85	59.99	5.85	59.99
Madhubani	5.89	58.64	6.18	61.70	6.18	61.70
Sitamarhi	5.46	52.82	5.43	52.61	5.43	52.61
Saran	5.21	51.31	5.20	51.28	5.20	51.28
Katihar	5.18	45.86	5.17	45.84	5.17	45.84
Begusarai	4.23	41.55	4.22	41.51	4.22	41.51
Bhojpur	3.62	35.98	3.59	35.97	3.59	35.97
Gopalgunj	3.47	35.26	3.45	35.24	3.45	35.24
Kaimur	3.43	34.53	3.43	34.52	3.43	34.52
Nalanda	2.98	30.83	2.97	30.81	2.97	30.81
Siwan	2.59	28.73	2.59	28.72	2.59	28.72
Munger	1.92	27.44	1.90	24.71	1.43	18.54
Buxar	2.80	27.34	2.78	27.33	2.78	27.33
Sheohar	2.75	27.25	2.74	27.23	2.74	27.23
Purnea	2.62	25.53	2.60	25.49	2.60	25.49
Saharsa	2.37	23.54	2.36	23.52	2.36	23.52
Gaya	1.67	18.66	1.65	18.64	1.50	16.95
Madhepura	2.05	18.15	2.04	18.13	2.04	18.13
Supaul	1.64	15.95	1.62	15.92	1.62	15.92
Khagaria	1.63	15.06	1.62	15.04	1.62	15.04
Jamui	1.20	11.80	1.19	11.79	1.19	11.79
Nawada	0.94	8.70	0.92	8.67	0.92	8.67
Aurangabad	0.79	8.52	0.78	8.51	0.78	8.51
Kishanganj	0.83	7.56	0.83	7.54	0.83	7.54
Sheikhpura	0.71	7.07	0.69	7.04	0.69	7.04
Araria	0.78	6.07	0.76	6.02	0.76	6.02
Lakhisarai	0.60	5.88	0.57	5.85	0.57	5.85
Banka	6.51	5.32	6.50	5.30	6.50	5.30
Jehanabad	0.47	4.87	0.45	4.56	0.42	4.21
Arwal	0.53	4.48	0.51	4.46	0.51	4.46
Bihar	**162.99**	**1576.06**	**160.24**	**1549.97**	**160.25**	**1543.27**

(Area – '000 Hectare, Production – '000 Tonnes, Source: Economic Survey, 2023-24)

Mango trade in Bihar is typically conducted through pre-harvest contracts for orchards or the selling of the fruit directly at wholesale markets. Common varieties of the fruit include Bombay Green, Chausa, Dashehari, Fazli, Gulabkhas, Kishen Bhog, Himsagar, Zardalu, and Langra. While the mango season spans from May to August, the primary harvest occurs in June and July. The farms are auctioned in January during the flowering stage. After harvest, contractors either sell the produce locally or send it to distant markets. Wholesalers operate on a commission or wholesale basis. According to the Bihar Mango Growers' Association, due to the heat wave in 2022, which destroyed nearly 60% of the crop, many horticulturists have auctioned their orchards to contract farmers to mitigate risks (Zia Haq, 2023).

As shown in Table 2, India exported 22,963.74 metric tons (MT) of mangoes worth Rs. 37,849.39 lacs in 2022-23 and 27,651.62 MT valued at Rs. 39,827.15 lacs in 2023-24. Efforts to expand export markets have led to new destinations, including Japan, New Zealand, Australia, and South Africa. Although Indian mangoes are exported from April to August, Bihar's late-season varieties limit their export contribution. In 2022-23, Bihar's mangoes contributed only Rs. 34.39 lakhs, or 0.08% of the total export value. The low export contribution from Bihar is due to several factors, including the lack of quality produce, gaps in post-harvest infrastructure such as integrated packhouse facilities, limited awareness about essential treatments like hot water treatment and vapor heat treatment, and the absence of direct air connectivity from Bihar.

Table 2: State-wise Mango Export from India

	2023-24 (April-January)		2022-23		2021-22		2020-21	
States	**Qty (MT)**	**Rs. Lacs**	**Qty (MT)**	**Rs. Lacs**	**Qty (MT)**	**Rs. Lacs**	**Qty (MT)**	**Rs. Lacs**
Maharashtra	21,173.96	32,619.54	18,933.05	32,634.85	20,873.92	28,259.11	19,184.24	24,145.82
West Bengal	1,618.86	690.58	609.13	409.83	279.29	166.24	46.22	28.28
Bihar	1,203.19	308.42	103.84	34.39	415.37	122.88	322.87	84.30
Kerala	771.68	957.41	1,332.41	1,969.15	992.81	1,189.65	572.81	767.40
Gujarat	681.14	1,618.86	279.18	599.76	448.92	929.08	237.85	711.70
Karnataka	597.42	1,690.55	244.98	610.73	222.90	537.69	110.68	652.09
Uttar Pradesh	567.62	240.38	527.59	187.02	4,122.79	848.71	105.44	125.83
Uttarakhand	309.49	92.85	218.11	65.43	78.77	23.63	8.68	2.20
Telangana	256.95	524.07	282.58	554.45	146.12	182.38	108.09	226.87
Tamil Nadu	213.10	385.92	190.09	298.01	185.49	254.74	272.05	364.88
Delhi	206.11	596.79	53.15	103.46	102.67	224.16	43.99	64.13
GOA	51.66	100.48	86.19	184.21	0.00	0.00	0.50	3.33
Rajasthan	0.44	0.17	16.55	7.13	0.00	0.00	0.00	0.00
Haryana	0.00	1.13	1.02	1.73	0.00	0.00	0.00	0.00
Punjab	0.00	0.00	69.95	175.46	3.55	6.76	0.00	0.00
Sikkim	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Andhra Pradesh	0.00	0.00	0.00	0.00	0.00	0.00	11.95	9.78
Odisha	0.00	0.00	0.00	0.00	0.17	0.09	8.21	1.23
Assam	0.00	0.00	15.92	13.78	0.00	0.00	0.00	0.00
Total	**27,651.62**	**39,827.15**	**22,963.74**	**37,849.39**	**27,872.77**	**32,745.13**	**21,033.58**	**27,187.84**

Source: APEDA, Note: 2023-24 data is from April-Jan

03 HARVESTING OF MANGO

This section and the following sections compile relevant information from existing guidelines and resources for mango post-harvest management. The key documents include:

- APEDA, *Guidelines for Export of Indian Mangoes to the USA*
- APEDA, *Standard Operating Procedures-Packinghouse Facilities for Export of Indian Mangoes to USA.*
- Department of Agriculture & Cooperation, *Post-Harvest Profile of Mango*
- Food and Agriculture Organization of the United Nations. (2018). *Post-harvest management of mango for quality and safety assurance Guidance for horticultural supply chain stakeholders*
- ICAR - Central Institute for Subtropical Horticulture, *Protocol of post-harvest and cool chain management of mango (Mangifera Indica) for domestic and export trade.*
- Ministry of Food Processing Industries, *Assessment Studies for Identifying Gaps in Infrastructure & Processing Facilities for Development of Potential Value Chains for Perishable Products under Operation Greens Scheme.*

The following sections briefly highlight key aspects of these documents. Readers are encouraged to refer to these documents for more detailed information.

3.1 Maturity Indices

Maturity indices are critical in determining the appropriate time to harvest mangoes, ensuring they achieve optimal quality, flavor, and shelf life. These indices vary with the variety of mangoes and the intended market (domestic or export). Several indicators are used to assess the maturity of mangoes, including external colour, appearance, pulp colour, and soluble solids content (TSS).

Figure 2: Immature (left) and mature (right) mangoes as shown by shoulder development and fullness of cheeks

Source: IFAS Extension, University of Florida

The overall appearance of the fruit, including its size and shape, can indicate maturity. The lenticels (small dots on the skin) may also change colour or become more prominent as the fruit matures. Fully mature fruits typically reach their maximum size and exhibit a smooth, full shape. Immature mangoes have pale or greenish pulp, which turns into a vibrant yellow or orange as they ripen. A mature mango emits a sweet, strong aroma near the stem end. This is a qualitative indicator used by many farmers and traders.

TSS, measured in degrees Brix, indicates the sugar content in the fruit, which increases as the mango ripens. A refractometer is used to measure TSS. For export markets, mangoes are usually harvested when the TSS content ranges between 7 to 9, ensuring a longer shelf life (20 to 25 days). For air transport, fruits with a TSS of 10 to 13 are selected, offering a shelf life of 17 to 20 days.

Langra mangoes are harvested when they start to develop a slight yellowish hue on the skin while still predominantly green. A unique maturity indicator for Langra is that the fruit sinks in water when it reaches the right maturity stage. Dashehari mangoes turn from green to a light greenish-yellow color as they mature. (Department of Agriculture & Cooperation, 2013)

3.2 Harvesting

Harvesting should be done at the appropriate maturity stage. For mangoes, this is usually when the fruit reaches full size, and the skin changes color. Harvesting of the fruits at the right stage of maturity is important for their quality and long-distance transport. Use sharp, clean tools to cut the fruit from the tree, leaving a small stem attached to avoid damage. Handle fruits gently to prevent bruising. The manner in which the fruit is detached from the tree and the time of harvesting are important considerations. The Indian Council of Agricultural Research - Central Institute for Subtropical Horticulture (CISH), Lucknow, developed a portable harvesting device that ensures minimal fruit damage and operator safety. (ICAR - Central Institute for Subtropical Horticulture, 2021). Harvesting, preferably in the early morning or late evening, reduces latex flow and staining of fruits.

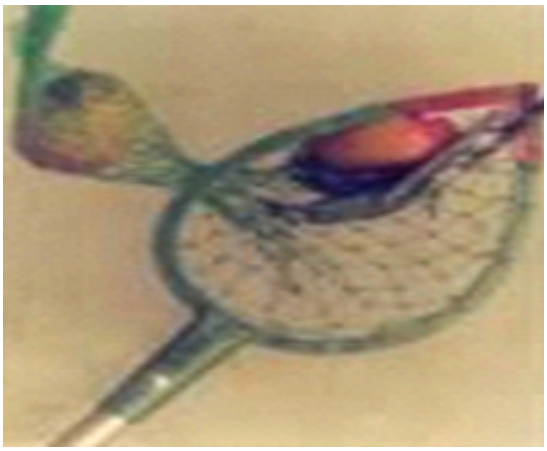

Figure 3: Harvesting Device

Source: ICAR-CISH, Lucknow

04 POST-HARVEST MANAGEMENT OF MANGO

4.1 De-sapping

De-sapping is a vital step in post-harvest fruit handling. It removes latex, a milky fluid that can seep from the fruit after harvesting. If not properly managed, latex can cause unsightly blemishes on the fruit's surface, leading to infections during storage and significantly reducing the fruit's marketability. In modern handling processes, both de-stemming and de-sapping should occur at packhouses. Mangoes should ideally arrive at packhouses with long stems, preferably with a leaf or two attached, as this helps delay physiological deterioration and provides more time for handling and pre-cooling.

It is advisable to perform this process as soon as the fruits are harvested to avoid their sticky appearance. Depending on the distance between the packhouse and the farm, this operation can be performed in the field or in the packhouse.

There are two main methods to perform de-sapping:

(a) *(b)*

Figure 4: Latex removal on racks (a), dipping in 1 % alum solution (b)

Source: FAO

Inversion Method: After the fruit is de-stemmed, it should be placed upside down on plastic or steel desapping tables / mesh stands, allowing the latex to drain out and down naturally. This process takes about 30 minutes. It's important to avoid using burlap sacks for this step, as they can cause the latex to coagulate at the base of the fruit, potentially leading to uneven drainage and surface blemishes.

Alum Dipping Method: The pedicel (the small stem) is first trimmed to approximately 10 mm. The fruit is then positioned upside down on plastic cones for 30 minutes to allow the sap to drain. The fruit is then dipped in a 1% alum solution for one minute. The alum helps coagulate the remaining latex, ensuring it doesn't ooze onto the fruit's surface later. These steps are critical to ensuring the fruit remains free from surface blemishes and preserve its quality and market value. (Food and Agriculture Organization of the United Nations, 2018)

4.2 Activities at the packhouse

Various activities are conducted in the packhouse to ensure that harvested mangoes are prepared for preconditioning, precooling, storage, transportation, and eventual sale while maintaining their quality. The key activities include Receiving, Sorting and Grading, Washing and Cleaning, Hot Water Treatment, Packaging and Labeling, Pre-cooling, and storage

Figure 5 provides a pictorial representation of these processes for domestic markets.

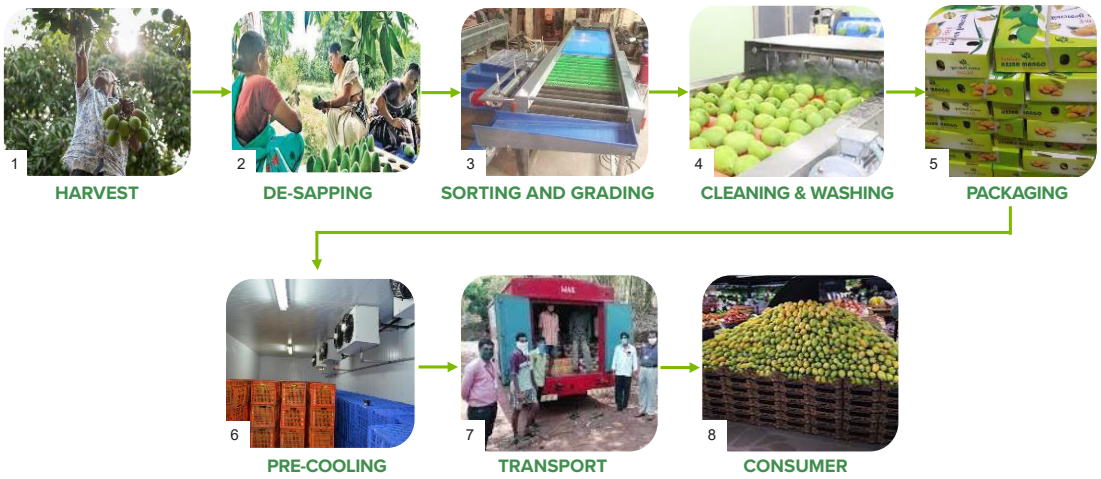

Figure 5: Process flow at Mango Packhouse for Local market

Depending on the destination country and buyer specifications, additional steps, including vapour heat treatment and irradiation, may be required for the export market. Figure 6 provides a pictorial representation of these processes.

Figure 6: Process flow at Mango Packhouse for Export purpose/domestic premium market

a. Receipt and Unloading

Prompt unloading of fruits is crucial to avoid delays in processing and cooling, which are essential for preserving quality and preventing spoilage. Efficient unloading accelerates the entire value chain, ensuring fruits are promptly cooled and processed, thus enhancing overall operational efficiency and reducing waste.

The unloading process should be conducted with care to ensure minimal mechanical damage and maintain the freshness of the produce.

- **Gentle Handling:** Mangoes should be handled with care to avoid impact damage, bruising, or cracks. Dropping or throwing fruits can lead to internal injuries that accelerate spoilage.
- **Avoid Overstacking:** Loose produce should not be overstacked to prevent compression damage. Excess weight can cause pressure bruising, reducing fruit quality and shelf life.
- **Shaded Unloading Areas:** To prevent heat buildup, unloading should take place in a shaded area or under a covered structure. Exposure to direct sunlight can increase the fruit's temperature, making subsequent cooling less effective.
- **Minimize Rough Handling of Unpackaged Produce:** If mangoes are being unloaded in bulk, extra caution should be taken to avoid impact with hard surfaces. Fruits should not be dumped from heights; instead, they should be carefully placed onto soft padding or directly into crates.
- **Use of Proper Containers:** If unloading from sacks or loose baskets, transferring mangoes into ventilated plastic crates immediately after unloading can prevent pressure-induced damage and allow better air circulation.

b. Fruit Inspection

The initial inspection by a quality supervisor, where fruit data on maturity and defects are recorded, is a critical step in the mango packhouse process. This step ensures that only fruits meeting the established quality standards proceed to the next stage, which helps maintain the overall quality and consistency of the product. By identifying and removing defective or infected fruits early, the inspection minimizes the risk of contamination and spoilage, reduces waste, and enhances the marketability of the final product. (APEDA, 2007)

Figure 7: Staging mangos inside the packhouse

Source: IFAS Extension, University of Florida, Wageningen University and Research

c. Sorting and Grading

The grading process ensures consistency in origin, variety, size, and quality. High-quality mangos should be full, firm, and shiny. It is crucial to carefully separate those showing decay, damage, or defects like cuts, bruises, and latex stains to maintain overall quality and market standards. (Department of Agriculture & Cooperation, 2013)

Figure 8: Fruit Grading
Source: IFAS Extension, University of Florida

Agmarknet developed the grading mechanism for mangoes for export. The grades and criteria are provided below in Table 3.

Table 3: Grade Designation

Grade Designation	Grade Requirements	Grade Tolerances
Extra class	Superior quality, characteristic of variety, free of defects except minor superficial ones that don't impact overall appearance, quality, or presentation.	5% may not meet grade requirements but must meet Class I standards or be within its tolerances.
Class I	Good quality, characteristic of the variety, with minor defects like slight shape irregularities, skin blemishes, or healed bruises (up to 2-5 sq. cm. depending on size group).	10% may not meet grade requirements but must meet Class II standards or be within its tolerances.
Class II	Minimum quality standards, with defects such as shape irregularities, skin blemishes, or bruises (not exceeding 4,5,6,7 sq. cm. for size groups A, B, C, and D, respectively).	10% may not meet grade requirements but must meet minimum quality standards.

Source: Agmarknet

d. Washing and Cleaning

Mangoes are cleaned and washed at the packhouse facility through an automated washing system equipped with overhead sprayers and smooth rotating brushes. This system ensures that the fruits are thoroughly cleaned while minimizing damage. The process begins with workers gently placing the de-sapped mangoes into trays fitted onto a conveyor belt. These trays then convey the fruits to the automated water spraying platform, where they are washed with potable-quality water mixed with a neutral detergent, such as Teepol, Sandovit, or Indtron, at a concentration of 0.1% (1 ml of detergent per liter of water) (Teepol, Sandovit, or Indtron). The washing process, which lasts 3-5 minutes, effectively removes dirt, latex, and other contaminants from the mangoes. (APEDA, 2007a).

Figure 9: Initial fruit washing by tank immersion (left), spraying (middle), and on a brush bed (Right)

Source: IFAS Extension, University of Florida

The water temperature is maintained at 27°C to ensure optimal cleaning without harming the fruit. Smooth rotating brushes further aid in cleaning the mangoes by gently brushing away any remaining debris. After washing, the fruits proceed to the drying stage, where excess moisture is removed, preparing them for grading and further handling.

For local market sales, mangoes typically only need a wash to remove latex and dust.

e. Packaging

The informal sector that sells into domestic markets traditionally packages the mangoes in wooden boxes or crates, red gram stalk baskets, and jute bags and may transport them in open tractor trolleys. These traditional methods impact postharvest management, affecting consumer acceptance and fruit shelf life (ICAR—Central Institute for Subtropical Horticulture).

The quality of mangoes is highly influenced by the packaging system, which mitigates factors like skin and flesh damage, moisture loss, and decay. Poor packaging is often the cause of premature spoilage. Therefore, packing materials must minimize chafing, protect against dynamic stresses during transport, and buffer individual fruits. CFB cartons are widely used for this purpose, providing both environmental benefits through recyclability and structural strength to withstand stacking.

However, when availing of a modern packhouse facility, the mangoes should be packaged in ventilated corrugated fiber-board boxes of modern packhouse facility, the mangoes should be packaged in ventilated corrugated fiber-board boxes, which can be stacked onto pallets for safe movement. When stacking the boxes, care must be taken that the top and side vent holes are aligned with other boxes to ease the flow of air. The complete pallet must allow air circulation through each box to cool the fruit and evacuate the gases (ethylene and CO2) that are emitted and envelopes each fruit. Without such a design, the produce would suffocate, surrounded by its own respired gases. Simply keeping the ambient air cool around the box is insufficient; air must be able to circulate within the box and around each fruit to maintain freshness and avoid overheating. The pallet of boxed mangoes must be secured with corner boards and straps to give it a rigid structure for subsequent handling by pallet movers. This also prevents boxes from toppling or getting dislodged during transportation. The goal is not just temperature control but ensuring a breathable, living atmosphere for the mangoes. Well-designed packaging and unitized loads also facilitate easier handling, protect the fruit from damage, and optimize storage space, all while supporting effective ventilation during transportation.

Ensure packaging materials are new, clean, and high-quality. To prevent bruising, each mango may be enclosed in a clean, expandable polystyrene sleeve. Insect-proof and well-screened boxes are essential.

Table 4: Specification details for Corrugated Fibre Board (CFB) Boxes for packing mangoes for exports

	Ring & Flap (4 Kg Box)	Full Telescopic (4 Kg)	Ring & Flap (8 Kg Box)	Full Telescopic (8 Kg)
Material	3 Ply CFB	3 Ply CFB	5 Ply CFB	5 Ply CFB
Grammage (g/m sq.), Min (outer to inner)	*230/140/140	*230/140/140	*230/140/140	*230/140/140
Bursting strength kg/cm sq., Min	6.50	6.50	10.50	6.50
Puncture resistance, ozs inches/tear inch Min	110	110	280	110
Compression strength, kg., Min	275	275	250	250
Cobb (30 minutes) g/m sq, Max	130	130	130	130

Source: APEDA

Table 5: Specifications of wooden boxes for domestic marketing

Type of Carton	Inner Dimension(cm)	Capacity (kgs)
Wooden crates	45X30X30 (Ratnagiri)	16-18
	21.6X21.6X42 (Malihabad)	10-11

Source: APEDA

Figure 10: Corrugated Fibre Boxes

Source: APEDA

f. Palletization

Palletization is an essential part of packaging, particularly in the cold chain, where the box serves as the primary or secondary package, and the pallet acts as the tertiary package. Palletizing improves handling efficiency and reduces physical damage by minimizing the need for individual carton handling. Boxes should be stacked in a vertical column pattern, with ventilation holes are aligned to facilitate air to circulate and pass through each box. This arrangement helps ensure that cold air reaches every carton, allowing the produce to cool evenly and quickly and dissipate any gas pockets that may build up. Poor alignment or excessive compression can block these ventilation paths, causing temperature variations that may lead to inconsistent cooling, hot spots, ethylene or moisture buildup, potentially affecting fruit quality.

g. Labelling

Labeling occurs both at the box and pallet levels. According to local regulations and client specifications, each box should be labeled with essential details such as packhouse code, size/class, batch number, fruit name and variety, and net weight. Pallet labeling can be done either before or after the pre-cooling process, depending on the final destination. Accurate labeling helps in traceability and quality control throughout the cold chain, ensuring compliance with both domestic and international standards. (APEDA, 2007a).

Figure 11: Labelling and palletizing

Source: IFAS Extension, University of Florida, Wageningen University and Research

h. Pre-cooling

Pre-cooling is a critical step in the post-harvest management, designed to remove the field heat accumulated during harvesting. This process is essential because it significantly slows the fruit's respiration rate, reducing deterioration and extending shelf life. The primary goal of pre-cooling is to quickly reduce the temperature, which is vital for maintaining their quality during storage and transportation.

Forced-air cooling is the most commonly used pre-cooling method for mangoes. In this process, cold air is circulated through the palletised boxes and around the fruits, rapidly lowering their temperature. Typically, mangoes are pre-cooled at a temperature of 12°C with 90% relative humidity using the forced-air method. This technique is particularly effective when the fruit is harvested in warm conditions, as it quickly eliminates the excess heat, helping to preserve the mangoes' texture, flavor, and overall quality. (Infrastructure Leasing & Financial Services Limited (IL&FS), 2010)

Figure 12: Pre-cooling Tunnel

However, it's important to note that pre-cooling is not always necessary, especially for the fruit destined for nearby markets, i.e., within a day. In all cases, where the fruit is expected to reach consumption within 48 to 60 hours, the costs and logistical efforts of pre-cooling may outweigh the benefits of pre-cooling. For longer journeys or when mangoes are destined for distant domestic markets and export markets, pre-cooling becomes an indispensable part of the post-harvest process, ensuring that the fruit remains in optimal condition throughout its journey till it reaches the consumers

i. Staging cold room

The staging cold room is an insulated and refrigerated chamber that serves as a transient staging space, typically attached to a pre-cooling unit. It is a necessary component of modern packhouses, especially at the farm gate, where it temporarily stores preconditioned fresh produce while awaiting transport to a distribution point or cold store near the market. The staging cold room ensures an efficient workflow by freeing up the pre-cooler space for the next batch of freshly harvested mangoes. The purpose of staging cold storage is to maintain the fruit's temperature and freshness until it is evacuated, not for long-term storage. (National Centre for Cold-chain Development (NCCD), 2015)

Mature mangoes have a marketable life of 6 to 12 days after pre-cooling. Pre-storage treatments like growth regulators and waxing can extend this by 3-4 days. Dashehari, Mallika, and Amrapali are best stored at 12°C, Langra at 15°C, and Chausa at 10°C, all with 85-90% RH, offering a 2-3-week shelf life under cold conditions. Facilities should maintain uniform temperature and humidity, with separate chambers to prevent cross-contamination (Ravishankar & Misra, 2010).

j. Loading

Proper loading is essential to prevent damage and maintain fruit quality. Workers should be trained to handle packages carefully, avoiding rough handling, throwing, or forcibly stacking wooden boxes. Mangoes should be kept in a temperature-controlled ante-room before loading to prevent thermal shock, and the loading dock should be maintained at the right temperature to avoid condensation. Stacking must lock packages securely while ensuring proper air circulation. Clean paddy straw should cushion packages to prevent damage from truck body protrusions. White tarpaulin should be used instead of dark-colored ones to reflect heat and allow ventilation. Large containers should be avoided as they can affect stacking and airflow. Following these practices ensures mangoes reach their destination in optimal condition.

k. Transport

Mango transportation for domestic markets uses road and rail networks. Common modes for first-mile transport for short distances (8-10 km) include tractors, vans, and jeeps. A cold chain with reefer transport is essential for longer distances, maintaining mangoes at 12°C. For local markets, trucks at ambient temperature are sufficient if the weather is moderate, and where pre-cooling is not needed. However, pre-cooled mangoes should be transported in refrigerated vehicles for longer distances, with systems in place to monitor and maintain temperature and humidity throughout the journey (Ravishankar & Misra, 2010).

Rail transport is 30% faster and cost-effective for bulk shipments over long distances. However, normal coaches can cause damage due to heat build-up and stacking, making air-conditioned coaches, which maintain temperatures of 12.8-15.6°C and 60% relative humidity, preferable for preserving quality. Air transport is the fastest but most expensive, essential for high-value, short-life commodities. It lacks refrigeration facilities, and the low pressure and low relative humidity at high altitudes increase water loss; thus, pre-cooled mangoes and PE film liners with perforations are necessary. Due to the absence of cold storage at airports in India, pre-cooled produce must be transported in insulated or refrigerated trucks to avoid delays. Inland waterways offer an effective means for transporting fresh fruits and vegetables over long distances. Although marine transport is slower, it is the most cost-effective and energy-efficient for inter-continental shipments. Refrigerated modular containers with adequate ventilation are used to minimize CO_2 and ethylene build-up, and these containers are loaded at the packing house and transported by truck to the port for onward shipping. (Department of Agriculture & Cooperation, 2013)

Before loading pre-cooled mangoes, it is crucial to bring the internal temperature of the reefer container down to 12°C. This prevents exposure to higher temperatures during loading, thereby reducing thermal fluctuations and maintaining a consistent temperature throughout the journey, which is critical for preserving fruit quality and minimizing losses.

To ensure safe and efficient handling, unitized cargo lots are preferred. Globally, pallets are commonly used to standardize the unit load, allowing mangoes to be transported in a uniform manner. These pallets are then loaded onto carriers such as reefer trucks or larger reefer containers, which facilitate transport across multiple modes—road, rail, and waterways—without the need for multiple handling of the produce. This practice not only reduces the risk of damage but also ensures the integrity of the cold chain. The uniformity of load units enables the harmonization of handling equipment and promotes standardization across cold-chain operations, enhancing efficiency and reducing variability. Throughout the transportation process, reefer trucks and containers should maintain a constant temperature of 12°C to avoid fluctuations that could harm the mangoes. Proper air replenishment systems are necessary to prevent the build-up of ethylene and moisture, which could affect the fruit's quality. Loading and unloading should be carried out with care, using standardized pallets to ensure adequate airflow between boxes and minimizing handling to prevent bruising. By following these practices, mangoes can be transported over long distances while maintaining their freshness and quality.

4.3 Activities for Export Market

Additional packhouse activities ensure fruit quality and compliance with international standards when exporting mangoes. Depending on the destination and client requirements, mangoes undergo hot water, vapor heat, or irradiation treatments to manage pests and extend shelf life. Rigorous quality control, careful packing, cold storage, and accurate documentation are essential to meet export requirements and preserve fruit integrity during transit.

a. Hot Water Treatment

Mangoes destined for the USA, Europe, and the Middle East undergo rigorous quarantine treatments to ensure they meet export standards. The primary method is hot water immersion. Mangoes are treated by dipping them in a 0.05% carbendazim solution at 52±2°C for 10 minutes. This effectively controls post-harvest diseases such as anthracnose (caused by *Colletotrichum gloeosporioides*) and stem end rot (caused by *Diplodia natalensis*).

Figure 13: Hot Water Treatment

Source: APEDA

Alternatively, if the use of carbendazim is not preferred, mangoes may undergo a 30-minute hot water treatment. This process is also effective against fruit fly infestations. It involves heating the core of the fruit to 43-46.7°C for 35-90 minutes to ensure pests are eradicated. These treatments are crucial for maintaining fruit quality and meeting the phytosanitary requirements of the destination countries (Food and Agriculture Organization, 2018).

b. Vapour Heat Treatment

Vapour-heat treatment (VHT) is used for exporting mangoes to enhance ripening and ensure uniform peel color while slowing fruit softening. In VHT, heated air saturated with water vapour raises the temperature without causing damage. Fruits are conditioned at less than 100% relative humidity before VHT. For fruit fly control, the pulp temperature is raised to 46-48°C for 4 hours, with an additional 30 minutes at the target temperature. Immediate cooling is crucial, achieved by letting the fruits stand in insect-proof, well-ventilated chambers for at least 30 minutes. (Ministry of Food Processing Industries, 2021)

Figure 14: Vapour Heat Treatment Chambers

Source: APEDA

c. Hydrocooling

Hydrocooling mangoes immediately after hot water or vapour heat treatment is an effective method for accelerating the cooling of the fruit and minimizing the risk of hot water injury. This process is preferred over air cooling due to its efficiency in rapidly reducing the fruit's temperature. The USDA Animal and Plant Health Inspection Service (APHIS) approves hydrocooling if it follows hot water treatment, provided an additional 10 minutes is added to the heat treatment time. Alternatively, if the fruit is allowed to cool at ambient temperature for at least 30 minutes before hydrocooling, no adjustment to the heat treatment time is required

For optimal results, APHIS mandates that the temperature of the hydrocooler water should not be lower than 21.1°C (70°F) to prevent excessive chilling and potential damage to the mangoes.

d. Irradiation

Mangoes intended for export to the United States are required to undergo irradiation. Irradiation of mangoes is typically done at a specialized irradiation facility before exporting. Irradiation is a process where food is exposed to special energy for a specific time to eliminate or sterilize bacteria, microorganisms, or pests. Cobalt-60 and kGy are typically used for irradiation, often followed by hot water treatment, which helps control anthracnose and stem-end rot. (Department of Agriculture & Cooperation, 2013)

Figure 15: Irradiation Chamber

Source: MSAMB

Table 6 outlines the specific requirements for exporting mangoes to various destination countries.

Table 6: Treatment required on Mangoes for export

Destination	Treatment	Variety	Standards	Box Size
USA, Australia	Irradiation Treatment	Alphonso, Kesar, Benganpalli, Rajapuri, Totapuri	Irradiation range: 400-1000 Greys	Small Box (Alphonso, Kesar): 3.5 kg, 370 mm x 275 mm x 90 mm Big Box (Benganpalli, Totapuri, Langra, Rajapuri): 4.2 kg, 365 mm x 265 mm x 110 mm
Japan	Vapour Heat Treatment	Maharashtra & Gujarat: Alphonso, Kesar AP: Benganpalli UP: Chausa, Langra West Bengal: Mallika	Pulp temperature at 47.5°C for 20 minutes or more.	CFB or thermocol box with screen mesh <1.6 mm Label "For Japan" Screen mesh <1.6 mm on boxes and bundles Test non-laminated CFB boxes for pesticide residues
European Union	Vapour Heat Treatment	All Indian Mango Varieties	46.5°C for 30 minutes 47.5°C for 20 minutes	As per importing country norms
New Zealand	Vapour Heat Treatment	All Indian Mango Varieties	48°C for 20 minutes	As per importing country norms Mesh netting compulsory
South Korea, Mauritius	Vapour Heat Treatment	All Indian Mango Varieties	47.5°C for 20 minutes	As per importing country norms Mesh netting compulsory
Iran, South Korea	Hot Water Treatment	All Indian Mango Varieties	Up to 500 gms: 48°C for 60 minutes 500-700 gms: 48°C for 75 minutes 700-900 gms: 48°C for 90 minutes	As per importing country norms Mesh netting compulsory for Korea.

Source: MOFPI

05 RIPENING OF MANGOES

Produce is prepared for retail distribution in the ripening chamber near the point of sale. Due to its adverse effects on fruit quality, the use of acetylene gas (carbide gas) for artificial ripening is strictly prohibited under the Food Safety and Standards Regulation, 2011. Instead, the regulation permits the use of ethylene gas at concentrations up to 100 ppm, tailored to the specific crop, variety, and maturity level (FSSAI, 2018).

Figure 16: Ripening Chamber

Source: IFAS Extension, University of Florida

Calcium carbide ripening leads to uneven results, often changing only the skin color while leaving the fruit acidic and poorly developed. Excessive use can result in overripe, tasteless fruits. Safer alternatives like Ethrel/ Ethephon or ethylene gas are recommended. For instance, immature fruits can be uniformly ripened by immersing them in a 750 ppm Ethrel solution in hot water at 52±2°C for 5 minutes. Ethylene gas is also effective; exposing fruits to 10-100 ppm in airtight rooms at 20-25°C and 90-95% RH for 24 hours ensures even ripening. It's essential to regularly change/replenish the air in these rooms (every 4-6 hours) and reapply ethylene to prevent carbon dioxide buildup, which can hinder the ripening process. After ethylene treatment, fruits should be stored at 18-25°C with 85-90% RH to achieve optimal ripening (Ravishankar & Misra, 2010).

Table 7 outlines the ripeness stages of mangoes and the corresponding flesh firmness measured in pounds-force (lbf) using a 5/16-inch tip penetrometer.

Table 7: Ripening Stages

Ripeness stage	Flesh firmness (pounds-force [lbf] with 5/16inch tip penetrometer)	Notes
Mature green	> 14	Treat with ethylene for 48 hours
Partially ripe	10–14	Treat with ethylene for 24 hours
Firm ripe	6–10	Best stage to send to retail stores
Soft ripe	2–6	Best stage for eating
Overripe	< 2	Good for juice

Source: IFAS Extension, University of Florida

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