# विकिरण उपचारित भारतीय आम

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# अनुसंधान और विकास नवाचारों से विकिरण उपचारित भारतीय आम की लागत प्रभावी समुद्री-मार्ग से निर्यात

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*खाद्य संरक्षकों में आमों की डुबकी लगाना*

सारांश

आम के विषय में भारत दुनिया का सबसे बड़ा उत्पादक है और भारतीय आम का निर्यात कई देशों में किया जा रहा है। आम के व्यापार विकिरण प्रसंस्करण की संगरोध बाधा को दूर करने के लिए संयुक्त राज्य अमेरिका और मलेशिया, ऑस्ट्रेलिया, दक्षिण अफ्रीका जैसे अन्य आयातक देशों के लिए एक पूर्व-आवश्यकता है और इस फल की अत्यधिक खराब होने वाली प्रकृति के कारण वायु मार्ग, वर्तमान में आम के निर्यात का एकमात्र तरीका है। वर्तमान निर्यात विधियों से जुड़ी उच्च परिवहन लागत और कार्गो क्षमता की सीमाएं भारतीय आम निर्यात के लिए एक बाधा के रूप में कार्य करती है, जिससे देश की बाज़ार हिस्सेदारी पर प्रभाव बढ़ाने और वैश्विक बाजार के भीतर निर्यात राजस्व उत्पन्न करने की क्षमता में बाधा आती है। एफटीडी, भापअ केंद्र में अनुसंधान और विकास प्रयासों के परिणामस्वरूप एक प्रोटोकॉल का विकास हुआ है जिसके परिणामस्वरूप आम की शेल्फ-लाइफ 25-30 दिनों तक बढ़ गया है। यह विस्तारित शेल्फ-लाइफ अंतरराष्ट्रीय बाज़ारों में आम के लागत प्रभावी समुद्री मार्ग परिवहन की सुविधा प्रदान करती है, जिससे बड़ी व्यापार मात्रा की संभाव्यता सक्षम होती है। वर्ष 2022 में समुद्री मार्ग के माध्यम से संयुक्त राज्य अमेरिका में 16 टन आम का एक वाणिज्यिक परीक्षण शिपमेंट किया गया था, जो उत्कृष्ट समग्र उपभोक्ता स्वीकार्यता के साथ संयुक्त राज्य अमेरिका के बाज़ार में सफलतापूर्वक पहुंचा और बेचा गया। यह पूरी तरह से स्वदेशी तकनीक दूर के विदेशी बाज़ार में आम के व्यापार को बढ़ावा देने की क्षमता रखती है।

# Radiation Treated Indian Mangoes

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# R&D Innovations Leading to Cost-Effective Sea-Route Shipment of Radiation Treated Indian Mangoes

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*Dipping of mangoes in food preservatives*

ABSTRACT

India is the world's largest producer of mangoes, and Indian mangoes are being exported to many countries. To overcome quarantine barrier of trade radiation processing of mangoes is a pre-requisite for USA and other importing countries like Malaysia, Australia and South Africa. Air route is currently the only way to export the mangoes due to the highly perishable nature of the fruit. The high transportation costs and limitations in cargo capacity associated with current export methods act as a barrier to Indian mango exports the nation's ability to capture market share and generate export revenue within the global market. The R&D efforts at FTD, BARC has resulted in the development of a protocol which results in the shelf life extension of mangoes upto 25-30 days. This extended shelf life facilitates cost-effective sea route transportation of mangoes to international markets, enabling feasibility of larger trade volumes. A commercial trial shipment of 16 ton mangoes to the USA through sea-route was performed in 2022, which successfully reached and were sold in the USA market, with excellent overall consumer acceptability. This completely indigenous technology has the potential of boosting the trade of mango to distant overseas market.

KEYWORDS: *Delayed ripening, Gamma radiation, International trade, Dip-treatment*

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## Introduction

Mango (*Mangifera indica* L.), belonging to the Anacardiaceae family, constitutes the most economically important fruit crop cultivated in India, which is the world's leading producer of mangoes, contributing approximately 45% of global production, which translates to roughly 18.5 million tons annually (Fig. 1a) [1]. Indian mangoes constitute the most extensive collection of delectable cultivars, distinguished by a remarkable diversity in flavour and aroma; due to which it holds a significant position in the global fruit market. Indian mangoes are currently exported to a wide range of countries, including the United States (the world's leading importer of fresh mangoes), the European Union, Japan, South Korea, New Zealand, Australia, and numerous nations in Asia and the Middle East. Indian mango imports to the United States resumed in 2007, after the gap of 18 years, contingent upon irradiation treatment due to phytosanitary restrictions [2-3]. In 2023, India exported approximately 3000 metric tonnes of irradiated mangoes through air route to the USA.

The break-up of costing (including irradiation and air-freight) involved in trade of mangoes in US market is displayed in Fig. 1b. Current practices in Indian mango export to the USA necessitate air freight following mandatory radiation treatment in accordance with USDA regulations. Since this involves high transportation cost and also limitation in the air cargo capacity, it has resulted in comparatively restricted market share of Indian mangoes and therefore lesser export revenue.

Employing transportation of mango through sea-route presents a compelling alternative, offering significant cost reductions and enabling larger export volumes. This shift in logistics has the potential to facilitate wider market coverage within the USA and other countries. The current findings deal with a successful commercial scale trial for sea-route shipment of Indian mangoes to the USA conducted in 2022. The trial was performed with a protocol developed at Food Technology Division, BARC resulting in delayed ripening of mangoes and therefore extended shelf life.

The hard green 'Kesar' mangoes were harvested from the Agricultural Produce Export Development Authority (APEDA) registered 'Mangonet' orchards [5-6]. Healthy, blemish-free fruits weighing between 220-300 g and total soluble solids ranging between 8 to 10° Brix indicating maturity: 65-70% were selected for the study (Fig.2 a). Desapping was performed for 3 hours and the stalk length of the desapped fruit was between 1-1.5 cm. It was ensured that the fruits are free of pest infestation, sap induced damage, microbial contaminations and any mechanical injury. Fruits with sap oozing out were selectively removed from the lot to avoid sap induced external blackening on the fruit itself and also on the adjoining fruits. Besides, fruits that showed lenticel browning and sap induced blackening were selectively screened out. After desapping, the fruits were subjected to sodium hypochlorite treatment (200 ppm at 52°C for 3 min) in a customized pack house. Following the hypochlorite dip the fruits were subjected to water dip treatment containing Generally Recognized As Safe (GRAS) preservatives at ambient temperature for 3 min. This step, was developed based on R&D done at Food Technology Division, Bhabha Atomic Research Centre, Mumbai, India. After the dip treatment, fruits were air dried prior to packing in foam-nets in a card-board box. Complete removal of moisture was ensured at this stage, without abrasive rubbing of fruits.

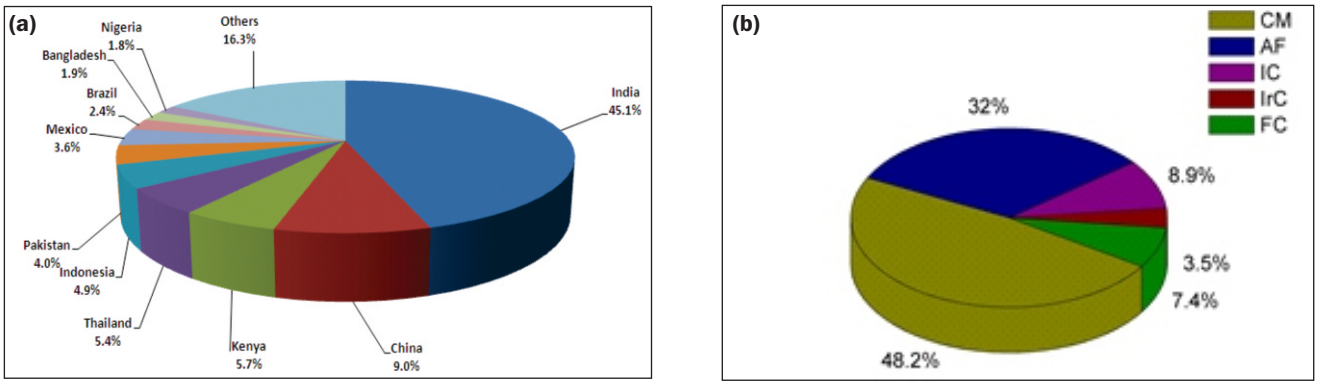


*Fig.1: (a) Leading Mango producing countries; (b) Breakup of mango cost (approx.) sold in US markets (Source: Economic Research Survey: USA Federal Agricultural Agency report). [FC: Farm Cost; IrC: Irradiation Cost; IC: Inspection Cost; AF: Air Freight; CM: Cost & margins in the USA market] [4].*

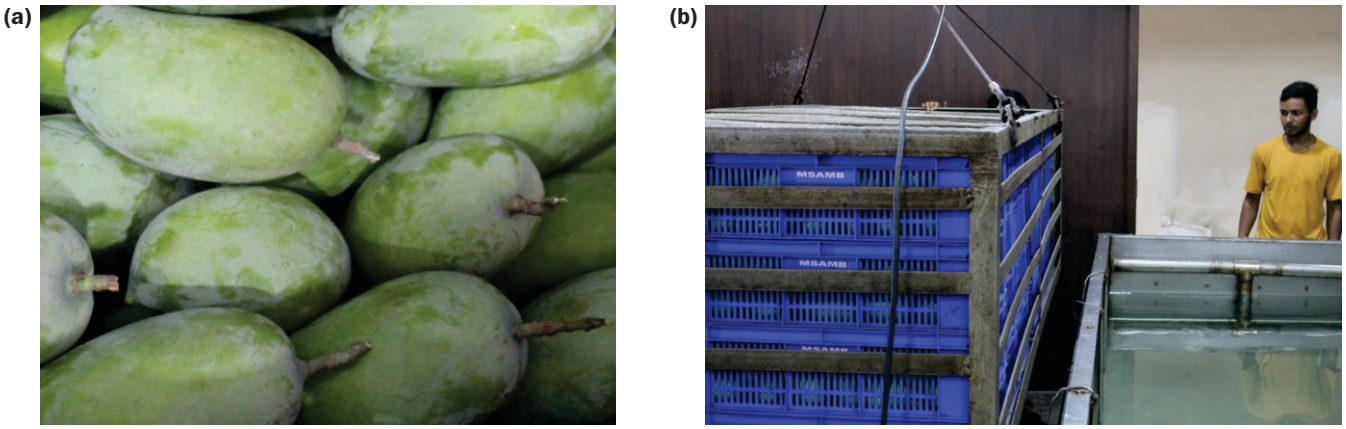


*Fig.2: (a) Figure showing hard mature mango fruits which are fit for processing; (b) Dipping of mangoes in GRAS preservatives.*

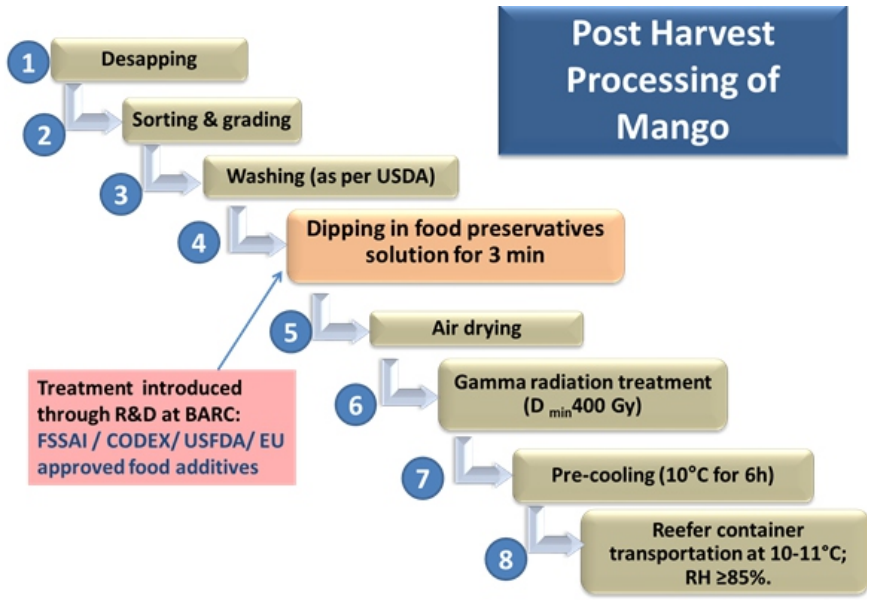


*Fig.3: Process flowsheet describing steps for post-harvest processing of mango.*


*Fig.4: (a) Loading of mango boxes inside the shipping container (b) Reefer controlled atmosphere container (10°C) at NEWARK Port. (c) Sea-route shipped mangoes sold at the US market (d) Box showing mangoes after ripening sold at market.*

The mango fruits were placed in boxes and subjected to gamma radiation treatment (minimum absorbed dosage of 400 Gy & maximum 1000 Gy) at a USDA-APHIS certified Cobalt-60 gamma irradiation treatment facility [7]. Dosimetry was performed as per the set guidelines [8-9].

After radiation treatment, the fruit boxes were palletized, followed by pre-cooling at 10°C for 6 hours. This was required before stuffing the fruits in reefer container for transportation at 10 to 11°C and RH ≥85%. The reefer container was provided with ethylene absorber at the return air vent, with air circulation rate of 30 cubic meter/hour. For a controlled atmosphere (CA) container the oxygen and carbon dioxide conc. were 4% and 6%, respectively. A process flow sheet has been described in Fig. 3.

## Results and Discussion

The current protocol developed at FTD; BARC has resulted in delayed ripening of hard mature 'Kesar' mango. Now, the shelf life of this delicate and quickly perishable mango variety has been extended upto 25-30 days under regulated cold storage. The extended shelf-life makes it feasible to export sizable quantum of 'Kesar' mango through sea-route shipment to distant shores like the USA, which takes approximately 20-30 days. Thus, 16 tons of 'Kesar' mangoes treated with developed protocol were successfully shipped through sea-route to USA (Fig. 4a, b). Upon arrival at US port, after regulatory approvals by the USDA-APHIS (United States Department of Agriculture-Animal and Plant Health Inspection Service), USFDA (United States Food and Drug Administration) and US-CBP (Custom and Border Protection Force), the shipment was successfully sold in the USA market Fig. 4c, d).

Apart from trade volume, the cost of transport has drastically reduced to 1/8th of the prevalent air fare of the cargo. So, this technology is going to encourage a number of small and medium mango farmers as well as traders for partaking in international trade. Parallelly, Indian mangoes are likely to see a major boost in the global market coverage in near future. Apart from the economical aspect; this treatment also

retains the nutritional values, organoleptic qualities (flavor and taste), firm texture, desirable color and excellent overall consumer acceptability of the mangoes upon ripening. This technology is a typical example of self-reliance as the technology is completely indigenous and has the potential of boosting the trade of mango to distant destinations overseas. Moreover, the GRAS chemicals used in the newly developed protocol have also been approved by the USFDA, USDA-APHIS, FSSAI (Food Safety and Standards Authority of India), CODEX, and EU (European Union) as food additives.

## Conclusion

The commercial shipment trial amounting to 16 tons of Indian mangoes through sea-route was successfully accomplished, and the mangoes after ripening retained their overall consumer acceptability as well as the shipment was successfully sold in the USA market. The technology for sea route transportation will result in substantial cost reduction, enable export of larger trade volumes, and capture wider international market.

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