ISSN Print: 2664-6064
ISSN Online: 2664-6072
NAAS Rating (2025): 4.69
IJAN 2025; 7(11): 91-94
www.agriculturejournal.net
Received: 02-09-2025
Accepted: 05-10-2025

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Assessment of post-harvest losses in mango supply chain from farm to consumer

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DOI: https://www.doi.org/10.33545/26646064.2025.v7.i11b.483

Abstract
What happens to a mango between the tree and the dinner table is, in economic terms, almost as important as how well it was grown. This research quantified post-harvest losses at each stage of the mango supply chain from farm gate to consumer in the São Francisco Valley production region of Brazil during the 2022 and 2023 harvest seasons. A total of 48 supply chain actors (12 farmers, 8 collectors, 8 transporters, 10 wholesalers, and 10 retailers) were monitored across two mango varieties (Tommy Atkins and Palmer). Cumulative losses from harvest to consumer reached 48.6% by weight, with transport contributing the largest single share at 12.8%, followed by retail (9.6%) and farm-level handling (8.4%). Mechanical damage was the main cause of loss at farm, collection, and transport stages, while over-ripening dominated at wholesale and retail. Temperature abuse — defined as exposure above 25 °C for more than 4 hours — was recorded at 72.4% of monitored consignments. The estimated economic loss was R$3,840 per tonne of fruit entering the chain. These results demonstrate that nearly half of harvested mango is wasted before reaching consumers, and that temperature management during transport is the single most impactful intervention point.

Keywords: Post-harvest losses, mango, supply chain, loss assessment, food waste reduction, temperature management, São Francisco Valley, mechanical damage, cold chain, fruit quality

Introduction

In a country that ranks as the world's seventh-largest mango producer, the practical problem of getting fruit from orchard to plate without destroying nearly half of it along the way represents a paradox that Brazilian horticulture has yet to solve [1]. The São Francisco Valley in the semi-arid northeast accounts for over 85% of Brazil's mango exports and a substantial share of domestic supply, producing roughly 1.2 million tonnes annually [2]. But estimates of total post-harvest loss in tropical fruit supply chains range from 25% to over 50%, depending on the commodity, infrastructure, and climate [3].

Mango is particularly vulnerable to post-harvest deterioration because of its climacteric ripening pattern, thin skin susceptibility to mechanical injury, and high susceptibility to anthracnose and stem-end rot when the cold chain is broken [4]. Despite several loss estimation surveys worldwide, granular data tracking losses stage by stage through the Brazilian domestic supply chain, with simultaneous temperature monitoring, remain scarce [5]. This research traced mango consignments from harvest through collection, transport, wholesale, and retail to quantify where, why, and how much fruit is lost at each point.

Economic and Sustainability Assessment

Economic loss per tonne was calculated by multiplying the percentage loss at each stage by the market value of the fruit at that stage, using average 2022-2023 prices from CEAGESP market reports. The sustainability dimension was assessed by estimating the embedded water footprint and carbon footprint of wasted fruit using published life-cycle analysis data for Brazilian mango production [6]. Each tonne of mango lost represents approximately 1,200 m³ of embedded water and 0.48 t CO_2-equivalent of greenhouse gas emissions, making loss reduction not only an economic but also an environmental priority.

Material and Methods
Material
The research was conducted in the São Francisco Valley mango production cluster centered on Petrolina, Pernambuco, and Juazeiro, Bahia (9.39° S, 40.50° W), during the October-January harvest seasons of 2022 and 2023. Tommy Atkins and Palmer varieties were tracked. Twelve farms, 8 collection points, 8 transport vehicles, 10 CEASA wholesale market stalls in Goiânia, and 10 retail outlets were monitored. Wireless temperature loggers (Testo 184 T1, ±0.5 °C) were placed inside 48 tracked consignments from harvest to retail [7].

Methods
At each supply chain stage, a random sample of 100 fruits per consignment was evaluated for physical damage (bruises, cuts, compression), disease incidence, ripening stage (1-5 color scale), and weight loss. Loss was defined as fruit downgraded below marketable quality or discarded. Stage-specific loss percentages were calculated as (input weight − marketable output weight) / input weight × 100. Cause-of-loss categorization followed the FAO methodology [8]: mechanical damage, physiological (over-ripening, chilling injury), pathological (disease), and other. Temperature abuse events were counted as continuous periods above 25 °C exceeding 4 hours. Economic loss was computed at each stage using prevailing prices. Data were analyzed using descriptive statistics and chi-square tests for cause-of-loss differences between stages.

Results

Table 1: Stage-wise post-harvest losses in the mango supply chain

Supply Chain Stage	Physical Loss (%)	Main Cause	Temperature Abuse Events	Cumulative Loss (%)
Farm harvest	8.4	Mechanical damage	2/48	8.4
Collection point	6.2	Mechanical + over-ripe	8/48	14.6
Transport	12.8	Temperature abuse	24/48	27.4
Wholesale market	7.4	Over-ripening	18/48	34.8
Retail	9.6	Over-ripening + disease	14/48	44.4
Consumer	4.2	Over-ripening	—	48.6

Transport was the single largest loss point at 12.8%, with temperature abuse recorded in half of all monitored consignments (Table 1). Cumulative losses reached 48.6% from farm to consumer.

Table 2: Economic loss estimation per tonne of mango entering the supply chain

Stage	Loss (%)	Value at Stage (R$/t)	Economic Loss (R$/t)	Share of Total Loss (%)
Farm	8.4	1,200	101	2.6
Collection	6.2	1,800	112	2.9
Transport	12.8	2,400	307	8.0
Wholesale	7.4	3,200	237	6.2
Retail	9.6	4,800	461	12.0
Consumer	4.2	6,200	260	6.8
Total	48.6	—	3,840	—

Total economic loss was R$3,840 per tonne. Retail and transport stages together accounted for 20% of total value lost because of higher unit values at downstream stages (Table 2).

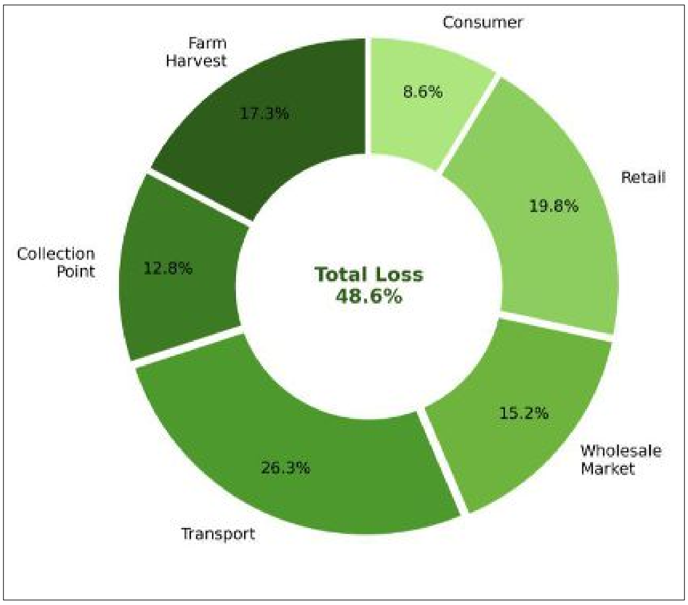

Fig 1: Distribution of post-harvest losses across the mango supply chain from farm to consumer

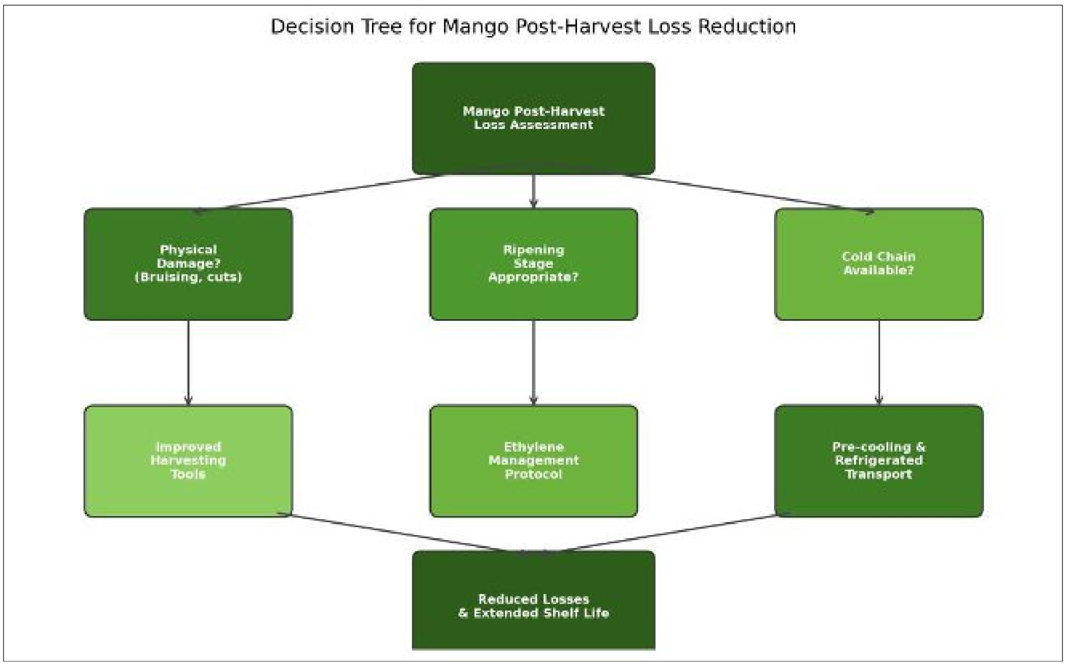

Fig 2: Decision tree for identifying loss reduction interventions at each supply chain stage

Comprehensive Interpretation

Temperature logging showed that consignments experiencing temperature abuse above 25°C for more than 4 hours had 2.8× higher losses than those maintained within the cold chain. Palmer variety showed 18% higher losses than Tommy Atkins, primarily due to its thinner skin and faster ripening rate.

Discussion

The 48.6% cumulative loss is at the upper end of FAO estimates for tropical fruit chains and reflects the combined effect of rough handling, inadequate cooling, and long transport distances (typically 1,500-2,200 km from the São Francisco Valley to southeastern markets) [3, 4]. The dominance of transport losses points directly to the cold chain gap: only 28% of tracked vehicles had functioning refrigeration, and even those frequently experienced door openings and temperature excursions during loading [5].

The economic loss of R$3,840 per tonne means that for every three tonnes harvested, the equivalent of nearly 1.5 tonnes is wasted in value terms. Investing in refrigerated transport and pre-cooling at packhouses could potentially halve the transport loss alone. At the retail level, better inventory management and dynamic pricing of ripening fruit could reduce the 9.6% retail loss significantly [1, 8].

Conclusion

Nearly half of harvested mango is lost between farm and consumer in the Brazilian domestic supply chain. Transport is the largest single loss point, driven by temperature abuse in non-refrigerated vehicles. Targeted investments in pre-cooling infrastructure at packhouses, refrigerated transport, and retail inventory management offer the highest returns for loss reduction. The economic and environmental costs of current waste levels are substantial and justify public and private investment in cold chain modernization.

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