



Estimating Post-harvest Losses in Fruits Supply Chain in Middle Gujarat Region

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10.18805/ag.D-6112

ABSTRACT

Background: This paper attempt supply chain and post-harvest losses in fruits cultivation. India ranks second in fruit and vegetable production in the world.

Methods: A data was collected from seven districts of middle Gujarat for identifying the existing supply chain in fruit supply chain and calculate the post-harvest losses. Tabular Analysis method was used to calculate post-harvest losses.

Result: In middle Gujarat average production of banana, mango, papaya and lime was 863.80, 105.00, 810.97 and 540.00 q/ha respectively, where total damaged fruits at filed level was 6.59, 2.50, 2.30 and 1.01 per cent in banana, mango, papaya and lime, respectively. Losses at wholesale level is quite high as compared to field level because after harvesting this fruit passes through village level suppliers in banana or pre-harvest contractors in case of mangoes and papaya and APMC wholesaler in lime supply chain. Post-harvest losses in different fruit crops at retail level, highest loss at retail level found in papaya which was 8.70 followed by mango 8.09, banana 4.41 and lime 2.70 per cent. These losses can be minimized using new advancement and mechanization in harvesting and postharvest losses like, mechanical harvesting, pre-cooling immediately after harvesting, proper packaging and storage.

Key words: Fruits, Mango, Marketing channels, Supply chain.

INTRODUCTION

The varied climate of India guarantees the availability of all kinds of fresh fruits and vegetables. In terms of global fruit and vegetable output, it comes in second place to China. India produced 204.84 million metric tonnes of vegetables and 107.24 million metric tonnes of fruits in 2021–2022, according to the National Horticulture Board's National Horticulture Database (apeda.gov.in). Fruits were grown on 7.5 million hectares of land, whereas vegetables were grown on 11.35 million hectares.

India can take advantage of great export potential due to its large production base. Fruits and vegetables exported from India in 2022–2023 brought in a total of ₹ 13185.30 crores (or 1635.95 USD million). Fruits brought in ₹ 6219.46 crores (or 770.70 USD million) and vegetables brought in ₹ 6965.83 crores (or 865.24 USD million) (apeda.gov.in).

The majority of fruits exported from the nation are grapes, pomegranates, mangoes, bananas and oranges, whilst the majority of vegetables exported are onions, mixed vegetables, potatoes, tomatoes and green chilies. The USA, UAE, Bangladesh, China, Saudi Arabia and the Netherlands are the main markets for Indian fruits and vegetables.

Though India's share in the global market is still nearly 1% only, there is increasing acceptance of horticulture produce from the country. This has occurred due to concurrent developments in the areas of state-of-the-art cold chain infrastructure and quality assurance measures. Apart from large investment pumped in by the private sector, public sector has also taken initiatives and with APEDA's assistance several Centres for Perishable Cargoes and integrated post-harvest handling facilities have been set up in the country. Capacity building initiatives at the farmers,

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How to cite this article: Pundir, R.S., Vahoniya, D.R., Singh, R. and Rajwadi, A. (2025). Estimating Post-harvest Losses in Fruits Supply Chain in Middle Gujarat Region. *Agricultural Science Digest*. 1-7. doi: 10.18805/ag.D-6112.

Submitted: 03-07-2024 **Accepted:** 18-12-2024 **Online:** 26-02-2025

processors and exporters' levels have also contributed towards this effort (apeda.gov.in).

Recent time, post-harvest losses is major concern for the world, mainly in developing countries and under developed countries where hunger and malnutrition prevail. Lack of awareness and technological facilities are the problems that these countries face. Food loss in the post-harvest supply chain means a large loss of investment in packaging, transport and storage operations. However, the developed nations have overcome it with the advanced technological approach.

Post-harvest handling is a critical phase in the fruit supply chain, involves sorting, grading and packaging-processes that are crucial for maintaining the quality and extending the shelf life of fruits (Rastogi and Saikanth,

2023). In India, recent report of ICAR cited that total post-harvest losses in banana, mango, papaya and lime was 6.60, 12.74, 7.36 and 6.38 per cent, respectively Anonymous (2014). From 2001-02 to 2016-17 area, production and productivity of horticultural fruit crops increased by 61.59, 115.916 and 33.68 per cent, respectively. With increasing area and production there is also increasing post-harvest losses due to lack of infrastructure available in different areas. Major post-harvest loss occurs due to poor transportation facility and non-availability of better infrastructure for value addition and storage facility. This all shows that there is need to study the post-harvest losses of fruits to calculate the amount of losses faced by farmers and retailer and identify the area where major post-harvest losses occur which further leads to suggest remedial measure to overcome the post-harvest losses.

MATERIALS AND METHODS

This paper is based on project report entitled “Research on supply chain and market integration for key agro commodities for farmers awareness and income enhancement in middle Gujarat”. The project is sponsored by Government of Gujarat which is restricted to Middle Gujarat region of Gujarat state. Hence data from the Middle Gujarat region was collected. Before starting of the survey, pilot survey was conducted to test the questionnaire.

Middle Gujarat was selected as the study area and the data was collected in the year 2016-17. Sample was collected through personal interview method from Anand, Ahmedabad, Kheda, Vadodara, ChhotaUdepur and Dahod districts of middle Gujarat as these districts contribute major share in fruit production of the region (Anonymous, 2016). A total 540 farmers were surveyed among them 240

banana, 120 mango, 120 papaya and 60 were cultivating lime. A 135 Commission agent, 135 wholesaler and 105 retailers were selected for the study. Secondary data was collected from different websites. The post-harvest losses were calculated through tabular analysis.

RESULTS AND DISCUSSION

Supply chain steps in major fruits crops in middle gujarat

The main fruit crops in the middle Gujarat region are shown in Fig 1's supply chain. The table illustrates how goods are transferred from farmers to customers via cold storage, retailers and wholesalers. Fruits were transferred in part from farmer to wholesaler, retailer and consumer and in part from farmer to retailer, retailer and consumer. While some retailers and wholesalers kept their goods in storage to earn more money later, some producers and wholesalers chose to export their goods directly and some farmers chose to hold their goods for better prices. This supply chain performs a number of tasks, including packing, transportation, grading and sorting. These tasks are all carried out at the producer, distributor, or retailer levels (Fig 2). According to Kumari and Dhingra (2024) in their study also they revealed that farmers have performed the same post-harvest operations like, sorting, grading, cooling, value addition and packaging.

Sorting

Sorting is the process of separating the many fruit varieties from a fruit lot. Agribusiness items are ranked according to their dimensions and quality. They are sorted according to this grade and allocated to various sales channels. When each item is appropriately distributed based on its unique properties, it may produce a higher income. Larger and

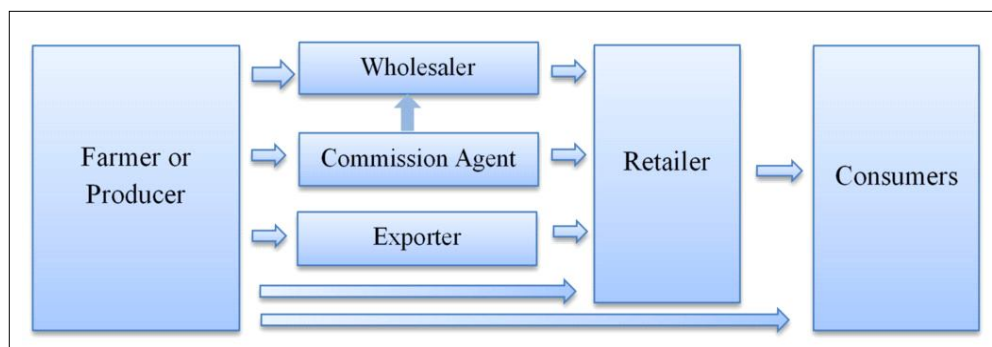


Fig 1: Supply chain of major fruit crops.



Fig 2: Steps involved while marketing.

higher-quality agricultural goods typically bring in more money. Grading in the past was dependent on people. Agricultural items were then classified according to their weight and size using mechanical instruments. Even now, these gadgets remain a dependable way to grade and classify materials.

Hand sorting

Sorting is the manual operation, which is done after harvesting to differentiate the produce by quality wise as remove the product or fruit which was deteriorated by pest and diseases. In banana sorting is mostly done manually or by labour and separates the cracked and pest and disease attacked fruit, same operation was done in mango, papaya and lime.

Grading

Hand grading

The second operation after sorting was grading which is done for separation of fruit by its quality, size and maturity level. Banana was graded by its market requirement, like export quality grade-A banana was graded on its size and quality parameters and washed through chemical water and grade-B banana was graded by its size only and washed through tap water.

Mango grading was done for different markets as per their demand i.e. if mango was sent to metro city grading is based on quality, equal size and maturity indices. Maturity indices help in deciding that when a given commodity should be harvested to provide some marketing and to ensure the attainment of acceptable eating quality to the consumer. While for local and small city grading is based on quality and size.

Mechanical grading

Fruits required mechanical grading is banana and mango and that too for export purpose only. In banana there was packaging house located in different banana cultivating area, where banana was mechanically graded by grading machine by its size and quality parameters. Whereas in mango pre-harvest contractor also had mechanical grading instrument for checking fruit size, maturity level and quality. The use of mechanical grading will smoothen the supply chain by doing proper and accurate grading of fruits. Farmers can improve their grading by using mechanical grader.

Packaging

Packaging practises was done in fruits as per the distance of the market that how far produce will travel. If produce travels long distance, it is packed either in boxes or crates while for short distance market it is packed either in gunny bags or plastic bags. The use of proper packaging material protects product during transportation and reduce the losses that occurs during transportation.

Crates

Crates are generally strong plastic box structure with capacity of 20 kg and aeration facility, banana and lime are mostly packed in crates (Fig 3).

Wooden box

Wooden boxes are wooden structure with 10 or 20 kg capacity and with or without aeration facility (Fig 4). Mango and Papaya are mostly packed with wooden box because both fruit being juicy after ripening and it may lead to transportation loss so wooden box structure used for preventing loss, wooden box generally used for interstate transportation or long-distance markets.

Paper box

Paper box are generally the boxes which are made from hard and thick papers, generally used in mango and papaya for short distance market or intrastate transportation which consumes low time in transportation, while in banana box packaging was done for export packaging for maintaining quality parameters also in other fruits like mango and papaya paper box was used for the export packaging (Fig 5).

Transportation

Transportation was done in selected fruits in middle Gujarat in truck, tempo and other small commercial vehicles. Banana was mostly transported through 4 tonne capacity tempos for short distance market and for long distance market wholesalers send maximum 10 tonne capacity trucks to local banana suppliers or agents, while in mango and papaya fruits same transportation facility were used.



Fig 3: Plastic crates.



Fig 4: Wooden box.

Storage

The proper storage facility is must for efficient supply chain management and post-harvest losses management. In middle Gujarat, Traditional storage methods are being supplemented and slowly replaced by modern, temperature-controlled warehousing. Storage facility was quite well in middle Gujarat with over 50 ripening chamber for banana and almost 200 cold storages. Banana and lime require ripening chamber and cold storage, while mango and papaya do not require cold storage and ripening chamber as both fruit can ripe in open condition or chemical treatment.

It is not always possible to wait for the fruit to ripen naturally. More often than not, they need to be transported over long distances and if they had been harvested in a ripe stage, they get spoilt before reaching their destination. For such situations, farmers harvest them much before they get ripe. The traders then ripen them artificially at the destination using certain chemicals. Most fruits produce a gaseous compound called ethylene that starts the ripening process. Its level in under-ripe fruit is very low, but as the fruits develop, they produce larger amounts of the chemical that speeds up the ripening process or the stage of ripening known as the "climacteric."

In addition, industrial grade calcium carbide is often found contaminated with trace amounts of arsenic and phosphorus, which are toxic chemicals. The symptoms of arsenic and phosphorous poisoning include vomiting, diarrhea with/without blood, weakness, burning sensation in the chest and abdomen, thirst, problem in swallowing, burning of eyes, permanent eye damage, ulcers on the skin, mouth, nose and throat.

According to studies, calcium carbide can also affect the neurological system by inducing prolonged hypoxia. It causes symptoms like headache, dizziness, high sleepiness, memory loss, cerebral oedema, numbness in the legs and hands, general weakness, cold and damp skin, low blood pressure and seizure. Pregnant women particularly need to be very careful and should not consume such fruits and vegetables.

The Food Safety and Standards Authority of India (FSSAI) have banned calcium carbide under the Prevention of Food Adulteration (PFA) Act, 1954. Anyone using it can be

imprisoned for three years along with a fine of Rs 1,000. However, no effective action plan has been devised to implement it and still local fruit traders are used carbide for early fruit ripening.

Post-harvest losses

Post-harvest losses at field level (farm level)

Table 1 shows farm level loss of major fruits cultivated in middle Gujarat that is banana, mango, papaya and lime. Results shows that average production of banana, mango, papaya and lime per ha was 863.80, 105.00, 810.97 and 540.00 q/ha respectively, where total damaged fruits was 6.59, 2.50, 2.30 and 1.01 per cent in banana, mango, papaya and lime respectively, causes of post-harvest loss on farm was found harvesting or mechanical injury in fruits which includes cracking of fruits and dropped fruits, other causes were immature or small fruits, black spotted fruit due to latex, diseased and pest infected fruits and other malformed fruits leads post-harvest loss, but most of quantity of this fruits were harvested in early maturation stage and good farming practices may lead to decrease the losses at farm level. Murthy *et al.*, (2007) also studied the post-harvest losses in banana and revealed that at field level, it was 5.53 per cent. Kumari and Dhingra (2024) found that at national level post-harvest losses in banana, mango, papaya and lime were 5.17, 6.03, 3.77 and 5.53 per cent, respectively while carrying out farm operations. It is also important that if farmers use better harvesting techniques



Fig 5: Paper box.

Table 1: Post harvest losses in selected fruits a farm level.

Particular	Banana	Mango	Papaya	Lime
Production (q/ha)	863.80 (100.00)	105.00 (100.00)	810.97 (100.00)	540.00 (100.00)
Quantity of good fruit (q)	806.88 (93.41)	102.38 (97.50)	792.32 (97.70)	534.55 (98.99)
Quantity of damaged fruit (q)	56.93 (6.59)	2.63(2.50)	18.65(2.30)	5.45 (1.01)
Post-harvest loss				
Harvesting/mechanical injury	12.09 (1.40)	1.31 (1.25)	4.05 (0.50)	3.05 (0.56)
Immature/small fruits	27.64 (3.20)	0.79 (0.75)	8.11 (1.00)	-
Black spot due to latex	8.64 (1.00)	-	-	-
Disease/bird infected fruits	-	0.53 (0.50)	6.49 (0.80)	2.40 (0.44)
Malformation	8.56 (0.99)	-	-	-
Total	56.93 (6.59)	2.63 (2.50)	18.65 (2.30)	5.45 (1.01)

Source: Field survey.

like mechanical harvesting and reduce the pre-maturation harvesting stages in fruits, then losses at farm level can be reduced and meanwhile farmers can observe increased yields and marketable surplus in fruits cultivation. The recent technological advancement, will help in reducing postharvest losses. Pre-cooling immediate after harvesting will delay or reduce microbial growth and extend the shelf life of fruits.

Post-harvest losses at wholesale level

Losses at wholesale level is quite high as compared to field level because after harvesting the fruits pass through village level suppliers as in case of banana or pre-harvest contractors as in case of mangoes and papaya and APMC wholesaler in lime supply chain. Where these fruits may grade and sorted again send it to long and short distance market as per demand from different markets, Table 2 shows post-harvest losses at wholesale level operations. Wholesale level packaging size varies in different fruit crop as banana packed in 20 kg crates, mango and papaya packed in 10 kg paper or wooden boxes and lime packed in plastic bags or gunny bags in 20 kg weight, so at wholesale level post-harvest losses are calculated through its packaging size. Results show that post-harvest loss in banana per crate was 7.23 per cent and major causes of loss handling and mechanical injury during transportation (2.10%), followed by pressed damage in vehicles (3.00%), over ripened fruits (1.25%) and disease infected fruit (0.90%), while in mango total loss was 8.85 per cent and causes of post-harvest losses included 4.00 per cent in mechanical

injury, 2.50 per cent in pressed damage and almost 1 per cent due to over ripened and disease infected fruits. In case of Papaya, total post-harvest loss at wholesale level was 9.58 per cent out of which almost 4 per cent is lost at the time of handling and pressed damage while transportation and 1 per cent each is lost due to over ripening and diseased fruits. In case of lime total post-harvest loss was relatively low as compared to other fruit crops which is 2.03 per cent because lime was green and not much ripened at wholesale level, causes of post-harvest loss were only mechanical injury and disease infected fruits. Murthy *et al.*, (2007) also revealed that at wholesale level, post-harvest losses in banana was 6.65 per cent, which was similar to the findings of the study. The use of rapid and temperature controlled logistic at wholesale level and proper packaging material will improve the shelf life of fruits and reduce the post-harvest loss that occurs during transportation.

Post-harvest losses at retail level

It was found that at retail level post-harvest losses was quite high in mango and papaya because both are seasonal fruit crops and while season changed quality of both fruits deteriorate fast, whereas in banana and lime that seasonal effect was low because both fruits are available round the year. Table 3 shows post-harvest loss and causes of post-harvest losses in different fruit crop at retail level, highest loss at retail level found in papaya which was 8.70 per cent followed by mango 8.09 per cent, banana 4.41 per cent and lime 2.70 per cent. Major causes of post-harvest loss

Table 2: Post harvest losses in selected fruits at wholesale level.

Particular	Banana (Per crate average weight)	Mango (Per crate/box)	Papaya (Per crate/box)	Lime (Per bag 20 kg)
Quantity sample (Kg)	20.00 (100.00)	20.00 (100.00)	20.00 (100.00)	20.00 (100.00)
Quantity of good fruit (Kg)	18.55 (92.77)	18.23 (91.15)	18.08 (90.42)	19.59 (97.97)
Quantity of damaged fruit (Kg)	1.45 (7.23)	1.77 (8.85)	1.92 (9.58)	0.41 (2.03)
Post-harvest loss				
Handling/mechanical injury	0.42 (2.10)	0.80 (4.00)	0.75 (3.75)	0.20 (1.00)
Pressed damage	0.60 (3.00)	0.50 (2.50)	0.72 (3.60)	-
Over ripened fruits	0.25 (1.25)	0.20 (1.00)	0.20 (1.00)	-
Disease infected fruits	0.18 (0.90)	0.27 (1.35)	0.25 (1.25)	0.21 (1.05)
Total	1.45 (7.25)	1.77 (8.85)	1.92 (9.60)	0.41 (2.05)

Source: Field survey.

Table 3: Post harvest losses in selected fruits at retail level.

Particular	Banana (Per crate average weight)	Mango (Per crate/box)	Papaya (Per crate)	Lime (Per bag 20 kg)
Quantity sample (Kg)	20.00 (100.00)	20.00 (100.00)	20.00 (100.00)	20.00 (100.00)
Quantity of good fruit (Kg)	19.12 (95.59)	18.38 (91.91)	18.26 (91.30)	19.46 (97.30)
Quantity of damaged fruit (Kg)	0.88 (4.41)	1.62 (8.09)	1.74 (8.70)	0.54 (2.70)
Post-harvest losses				
Handling/mechanical injury	0.38 (1.90)	0.95 (4.75)	0.70 (3.50)	0.54 (2.70)
Over ripened fruits	0.50 (2.50)	0.67 (3.35)	1.04 (5.20)	-
Total	0.88 (4.40)	1.62 (8.10)	1.74 (8.70)	0.54 (2.70)

Source: Field survey.

found at retail level were over ripened fruits which were not sold to consumers. It was noticed that when fruits came out with cold storage and chemical treatment for ripening it had only few days to sold out otherwise fruits leads to over ripening and deteriorate the quality of fruits and it remains unsold to consumers and at end those fruits in dustbin. The over ripened fruits accounted for 2.50 per cent loss in banana, 3.35 per cent loss in mango, 5.20 per cent loss in papaya, whereas mechanical injury or handling injury due to transportation led to 1.90 per cent loss in banana, 4.75 per cent loss in mango, 3.50 per cent loss in papaya and 2.70 per cent loss in lime. Murthy *et al.* (2007) found that at retail level, post-harvest losses in banana was 16.66 per cent which was much higher.

Overall post harvest losses in selected fruits in middle gujarat

Table 4 depicts the post-harvest losses in supply chain of banana at different levels. It was found that post-harvest losses were higher at wholesaler level (7.23%). At producer's level PHL was 6.59 per cent and retailer's level it was 4.41 per cent. In lime PHL was higher at retail level (2.70%) and producers' level PHL was very low (1.01%). The post-harvest loss in supply chain of mango was higher at retail level (8.09%), followed by pre-harvest contractor (4.50%), wholesaler level (4.35%) and at producers' level (2.50%). In papaya post-harvest loss in supply chain was

higher at wholesaler level (9.58%) and at producers' level it was very low (2.30%). The total post-harvest losses in banana, mango, lime and papaya were 18.23, 19.44, 5.74 and 20.58 per cent, respectively. Kumari and Dhingra (2024) also found that total post-harvest losses at national level in banana, mango, papaya and lime were 12.8, 14.6, 10.4 and 13.3 per cent respectively.

The ongoing analysis highlights the scope of using the infrastructure facilities like cold storage structure, ripening centres, pack house etc. at all levels. the harvesting losses and grading/sorting losses can be minimized by doing machine harvesting and mechanical grading/sorting. Use of technological advancement like, different applications that shows the prices of commodities and various e-commerce platforms that provide direct marketing facilities to the farmers and consumers.

Being a highly perishable fruit, banana needs proper infrastructural facilities and backward and forward linkages to avoid PHL. Good transportation facility like refrigerated trucks for transfer of produce to distant places and its quality distribution in another major area of great concern specially to boost up the export of fruit, since the major share of marketing cost is spent on transportation. The development of cold chain network throughout the supply chain will help in reduction of PHL. Due to lack of these facilities at every end the volume and quality of produce is greatly affected.

Table 4: Overall post harvest losses in selected fruits in middle gujarat.

Fruits	Stages of handling	PHL (q/ha) (%)	Major cause/Reasons of PHL
Banana	Sorting and grading at field level	6.59	Harvesting Injury, Immature and small fruits, black spot due to latex, cracks
	Wholesaler level	7.23	Press damage, separated bananas, mechanical injury, rotten fruits
	Retail level	4.40	Over ripe fruits, crushed fruits
	Total	18.23	-
lime	Sorting and grading at field level	1.01	Harvesting injury, immature and small fruits, disease and insect affected fruits
	Wholesaler level	2.03	Aging, press damaged fruits.
	Retail level	2.7	Over ripe fruits, bacterial infection.
	Total	5.74	-
Mango	Sorting and grading at field level	2.5	Mechanical injury, bird damage, black spot, insect attack.
	Pre-Harvest contractors	4.5	Harvest not done properly, rough handling, over loading transportation, mechanical injury
	Wholesaler level	4.35	Press damage, over ripening,
	Retail level	8.09	Chemical ripening, over ripening, loss during transits
Papaya	Total	19.44	-
	Sorting and grading at field level	2.3	Malformation, immature fruits.
	Wholesaler level	9.58	Press damage during transportation, loss due to diseases
	Retail level	8.7	Over ripe fruits, due to diseases
	Total	20.58	-

Source: Field survey.

Suggestions

There is need to strengthen post-harvest management with the use of existing advanced technology and need to spread awareness regarding post-harvest management practices so more farmers can take benefit of it.

There is need to use machine harvesting and grading to reduce the losses that occurs during harvesting and grading. Incorporation of value chain in existing supply chain of fruits to increase the shelf life of the fruits.

Need to strengthen the existing supply chain in the study area by vertical and horizontal integration with use of existing storage and proper packaging material which ultimately reduces the post-harvest losses that occurs while handling of the product.

Middle Gujarat area having processing units but they are less in numbers, so to reduce the losses and increase the shelf life, there is need to establish more processing units with the help of government subsidies.

The standard pre and post-harvest management practices is established by scientific research. But, the awareness and adoption rate of technology for post-harvest management of fruits in the study area have considerable gap at the field level. So there is need to spread awareness and disseminate these standard technologies so majority farmers in the study area can take benefit of it.

Presently, Middle Gujarat has a good basic infrastructure like roads, processing industries, communication, etc., for adequate post-harvest management of fruits but need to be strengthen in the study area. There is need of refrigerated transport facility and storage facility to overcome the handling losses. The use of different digital tools for communication, digital tools to check perishability of the product, use of tracking device while transportation will reduce the post-harvest losses and strengthen the supply chain.

Strengthening and scaling up of the packaging is needed. Designing and manufacture of good quality and affordable packaging materials for perishable are the need of the time.

Recent era is of mechanization, where low-cost and efficient technology is available for storage, handling, harvesting, packaging and value addition. Development of appropriate training manual by experts and conduction of training by extension specialist of post-harvest management including harvesting, grading, sorting, packaging, transportation, storage (conventional and modern), processing and nutrition is needed.

Development of value chain in existing supply chain of fruits to extend the shelf life and proper low-cost technology like, precooling immediately after harvesting minimize the losses that occurs at field level.

CONCLUSION

Fruits are perishable in nature so post-harvest losses is higher in fruits. Study concluded that larger amount of quantity was lost due to improper post-harvest handling

and inefficient supply chain management, implying that supply chain plays a major role in extending the shelf life as well as reducing losses. It was concluded that farmers of middle Gujarat were not using new technological advancement in harvesting and post-harvest management which leads to improper handling and losses of the commodity. Storage facility and transportation was adequate in the study area although farmers were not found of using it. Mechanical grading and advanced packaging were also available to farmers as limited farmers were using it.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

There is no involvement of any type of animal and no animal is harmed while conducting the research.

Conflict of interest

The authors declare that there are no conflict of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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