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Post-Harvest Losses and Their Economic Consequences in Guava Farming Systems of Rajasthan: A Secondary Data-Based Analysis..

Vishvendra Singh[1], Boola Choudhary[2], Hoshiyar Singh[3]

[1] Research Scholar, Department of Management, Vivekananda Global University, Jaipur, Rajasthan, India.
[2] Associate Professor, Department of Development Studies, Vivekananda Global University, Jaipur, Rajasthan, India.
[3] Professor, Faculty of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India.
Corresponding Author:
Vishvendra Singh

Abstract
The production of fruits and vegetables in India is diverse and constantly changing, but so far, post-harvest losses (PHL) in perishable horticultural commodities are an important issue related to agricultural sustainability and socio-economic efficiency in India. In the present study, secondary data are used for understanding the level of losses of guava production system and its economic losses in the state of Rajasthan. The study calculates losses between 18-30 percent, depending on the stage of the value chain, from data collected from national and international institutions. These losses have a significant impact on the farmer's income, price volatility and the efficiency of the supply chain. The study pinpoints gaps in infrastructure and inadequate handling systems and market linkages. Concludes with recommendations for policy change in post-harvest systems and gives a basis for future empirical research.....
Keywords: Post-harvest losses, Guava, Rajasthan, Economic impact, Value chain

Introduction

India is a leading Horticulture country in the world and one of the key producers of fruits and vegetables. But horticultural produce suffers losses after harvest, and consequently consumers do not get the produce in marketable form. These losses are not only a reduction in the food available but also an economic inefficiency impacting farmers' earnings, value chain system. (Kader, 2005; FAO, 2019).

Guava (Psidium guajava) is a peculiar fruit crop in the Indian context, due to its nutritional richness, low price and adaptability to different agro-climatic environments. Guava has an excellent amount of vit. and is, therefore, known as the apple of the tropics. C, dietary fibre and antioxidants. It is a significant component in dietary security in rural/urban areas (Mitra & Bose, 2012). In general, it is a very hardy crop and can be cultivated with moderate inputs and a suitable management system to produce fruits throughout the year. These attributes of guava bring in more interest among small and marginal farmers to earn family livelihoods.

Rajasthan is traditionally a dry and semi-dry state, but in the recent few decades the state has become a major producer of guava. In certain districts, such as Jaipur, Alwar and Sikar, the acreage of guava has been expanded due to improved irrigation facilities, availability of improved varieties and the market demand. This change to horticulture is also an indication of the overall structural changes in Indian agriculture, moving from subsistence to market-oriented agriculture (Government of India, 2021). But these increases are not typically reflected in the price to producers, because of unexpected post-harvest losses.

The post-harvest losses in fruits such as guava occur at different stages, such as collection, handling, sorting, packing, transportation, storage and marketing. Due to its high water content and fragile nature, guava is very susceptible to physical damage, physiological deterioration and microbial contamination. Inefficient picking methods, like careless pulling and handling, may exacerbate quality loss. This is becoming problematic as systematic sorting, grading and scientific packing are lacking, hence increasing the susceptibility during distribution of guava (Hodges et al., 2011).

The inadequate number of cold chain infrastructure is one of the biggest hindrances to post-harvest wastage in India. The facilities of chilled storage, refrigerated conveyance and advanced warehousing continue to be a small number, particularly in rural and semi-urban areas. States with high ambient temperature, like Rajasthan have a high rate of decay and hence there are high losses. As per studies conducted by ICAR, the post-harvest loss in case of fruits is 15-25 per cent and in case of highly perishable fruits such as guava, the post-harvest loss is more

if not stored at proper temperature conditions (ICAR, 2015). Likewise, the Food and Agriculture Organisation (FAO) has noted that because of the lack of infrastructure and technology, developing countries suffer from greater post-harvest losses as compared to developed countries (FAO, 2019).

Post-harvest losses have far-reaching economic implications. A loss at the farmer level translates to reduced production, impacting the farmer's livelihoods and incomes. However, the marginal or small-scale producers are not in a position to have losses in economic conditions, and any reduction in production could have major implications for their economic viability. In the marketplace, supply reductions lead to fluctuations in prices which have an effect on producers and consumers. Additionally, The inefficiencies throughout the value chain increase costs of transactions and reduce the competitiveness of agricultural products in trade, both domestically and internationally. (Gustavsson et al., 2011).

Post-harvest wastage is not only economic, but also has a great impact on food and nutrition security. Reducing food losses is also as important as boosting food production, particularly in a country like India where one of the policies is to make food available to the people at affordable and accessible prices. Fruit spoilage, such as guava, is an opportunity lost in terms of enhancing food diversity and public health indicators. Furthermore, food waste generates an inefficient use of water, energy and human resources, raising the challenge of ecological sustainability (FAO, 2019).

Though the importance of post-harvest management is well known, research work, particularly on the losses of guava, is limited in Rajasthan. Numerous studies have focused on fruits and vegetables, as a group. This is significant as Rajasthan has emerged as a significant guava-growing state and has its own set of climatic and infrastructural challenges.

In the present study, the aim is to discuss the post-harvest losses of guava in the farming system of Rajasthan using secondary data. At this stage, however, primary sources are limited, and the study is based on published reports, institutional records and academic literature analysing the size, causes and economic consequences of the losses. The study aims to integrate the information available to develop a conceptual model which can be used to guide future field-based research.

This study is valuable because it attempts to combine the economic analysis with value chain aspects. It views losses as not just technical solutions, but as part of the larger challenge of the structural issues of substandard infrastructure, poor market linkages and inadequate institutional support. A more holistic approach is needed to define effective solutions that will address systemic issues, rather than producing ‘pointsolutions'.

In sum, while great strides have been made in fruit production, fruit losses are a limitation to the gains in India. Addressing these losses is crucial for enhancing the livelihoods of guava farmers, ensuring product quality and market efficiency, and fostering sustainable agriculture in the state of Rajasthan. This study is a secondary data-based study and adds to the existing knowledge as it identifies important policy and research areas for intervention.

Literature Review

Post-harvest losses (PHL) in farm produce are well recognised as a problem that affects the world food system, particularly in developing countries. The amount of such losses, their causes, and the monetary losses have been the subject of many publications for different crops and locations.

Almost a third of the world's food for human consumption is lost or wasted, resulting in considerable economic and environmental losses (FAO, 2019). This depletion is especially significant with perishable items such as fruit and vegetables, which are subject to handling, storage and transport.

Post-harvest loss has been the focus of intensive research in India, particularly in horticulture. ICAR (2015) has carried out studies that yield empirical estimates of losses in fruits ranging from 15-25 per cent, varying with the type of crop and geographical region. The results put the extent of losses in the post-harvest system in perspective and indicate the need for improved infrastructure and management. Likewise, the statistics from the National Horticulture Board (NHB) have confirmed these figures and reveal that the perishability of horticultural produce, short shelf life, and vulnerability to environmental factors result in higher levels of depletion (NHB, 2020).

There are several research studies conducted on wastage after harvest, where both technical and systemic issues were identified. Kader (2005) argues that poor post-harvest handling practices such as poor harvesting practices, lack of grading and sorting and poor packaging practices all make significant contributions to quality and quantity losses in fresh produce. At the same time, Hodges et al (2011) emphasise the importance of storage and transport

system weaknesses, which are mostly found in developing countries and increase losses along the value chain. Based on these studies, it is found that post-harvest losses are not limited to a particular point in the value chain, but happen as a whole within the value chain from the farmer's field to the market.

One of the most determining factors of post-harvest wastage has been cited to be the limitation of infrastructure. India's agricultural sector has been identified as having a major limitation in the form of the absence of proper cold chain infrastructure such as refrigerated storage facilities, temperature-controlled transportation, and state-of-the-art warehouses. In hot regions such as Rajasthan, where such facilities are not present, the rate of spoilage would be higher and the extent of the loss would, therefore, be greater. Research has shown that adequate temperature control is critical for fruit to be stored at their best in transit and storage (Kitinoja & Kader 2015).

In addition to infrastructural deficiencies, market-related factors also have a significant impact on post-harvest results. The agricultural marketing systems are found to be less efficient in terms of the fragmentation of supply chains, abundance of middlemen and less direct interaction with markets. Often, the farmers have a problem in selling their produce, which results in further quality deterioration and wastage. Poor price realisation is also a disincentive for investing in improved post-harvest practices and locks in a vicious cycle of low efficiency (Birthal et al., 2015).

The economic losses due to post-harvest losses have also been widely reported in the literature. Such losses not only involve loss of food, but also loss of economic value, impacting all the value chain stakeholders (Gustavsson et al., 2011). From the farm level the losses result in a reduction of saleable surplus, and from a broader level, it also leads to inefficient use of resources and an increase in the burden on production systems. To reduce post-harvest losses in developing countries like India, where agriculture is still the primary source of livelihood and income, rural development can be promoted, and livelihood security can be improved.

Though much work has been done on post-harvest wastage, there are very few commodity-specific studies done with guava. Guava fruit is highly perishable and has high moisture content and is highly susceptible to physical damage and microbial deterioration. Based on the literature surveyed, it is observed that there can be considerable wastage of guava, particularly if adequate handling and storage facilities are not provided. But the majority of these investigations are on a local or limited scale and more extensive analyses are required.

Even the literature regarding post-harvest wastage is very scanty in the case of Rajasthan. Although general studies of horticultural losses can be useful to gain insight, they often do not consider the unique challenges associated with guava production in the state. Low humidity and high temperature make the climatic conditions of Rajasthan an extra challenge for post harvest management. Moreover, there are also missing links in the infrastructure and market inefficiencies, making the situation even worse. This indicates that another research need is to estimate the extent and monetary loss of post-harvest losses in the guava farming system in the region.

By and large, literature about the subject identifies the problem of post-harvest loss as a complex problem that is influenced by technical, infrastructural and institutional determinants. Although major progress has been made in the understanding of the causes and implications of these losses, investigations are still necessary at region and commodity levels. Looking towards this light of this, the present study contributes to the discussion by collecting and analysing secondary information to determine the post-harvest wastage in the guava farming system in Rajasthan and thus paves the way for future field-based empirical studies.

Research Gap

Although there is a huge body of work on post-harvest loss in fruits and vegetables at the global and national level, there are several important gaps which need to be addressed, especially in the context of guava farming systems in Rajasthan. There has been a high proportion of past studies that are based on general estimates of post-harvest losses at the commodity group level without taking account of commodity-specific issues. The overall picture of the magnitude of losses as provided by agencies like the Food and Agriculture Organisation and Indian Council of Agricultural Research is of a general nature, as it is not able to capture the unique characteristics and vulnerabilities of guava as a highly perishable fruit.

Furthermore, many of the existing studies are using primary data that they have collected in specific areas or limited cases, which may reduce the applicability of the results to other cases. The number of studies that systematically integrate the information available from different credible sources to form a detailed picture of post-harvest wastage is definitely limited. Integration is especially relevant when primary data collection is restricted by time, resources, or access—at the beginning of research.

The case of the region is unique in terms of climatic conditions, infrastructural gaps and the changing horticultural profile in the case of Rajasthan. The state is now emerging as a guava producer; however, very little research has been done on the post-harvest loss of guava in the region. While there are numerous studies of the losses in horticulture, or in other important fruit-growing states, there is a lack of a region-specific study.

Another gap is the lack of consideration of economic factors in post-harvest loss assessments. Some studies have attempted an economic valuation of physical losses, but few have attempted to estimate the physical losses as financial losses, such as loss of earning power, price fluctuations, and value chain inefficiencies. Knowing the economic aspect is important to create effective policy measures, as well as to enhance market efficiency.

Further, there is a general lack of proper placement of post-harvest wastage within the agricultural value chain in the related literature. There is a need for comprehensive studies of the whole value chain from production to handling, storage, transport and marketing to identify critical system weaknesses.

In this context, the present study is an attempt that aims to address these gaps by consolidating secondary data and analyse post harvest wastage in the guava farming system in the state of Rajasthan. The study aims not only to describe the magnitude of these losses, but also to highlight the economic aspect of these losses, to provide a conceptual framework for further empirical research on losses and loss policy.

Objectives

Based upon a secondary data approach, the present study proposes to discuss the issue of post-harvest loss in the guava farming system in Rajasthan. The specific goals are:

- To critically discuss the extent of post-harvest losses of guava and reasons.
- To explore the root causes of such losses in terms of structural and operational problems.
- To determine the economic significance in the agricultural value chain.
- To offer a conceptual underpinning for future empirical and policy-oriented research.

Methodology

The present study is an exploratory and descriptive study to understand the extent and spread of post-harvest losses of the guava production system of Rajasthan with economic consequences. Exploratory research is particularly crucial during the beginning phase of enquiry, to build conceptual understanding of the issue, by seeking out patterns, linkages and areas of missing knowledge. The same is supported by the descriptive component, which provides a systematic structure and interpretation of the evidence and hence an organised assessment of the post-harvest wastage along the value chain. With the composite design, it is possible for the study to draw analytically valuable conclusions without any field-level data.

The study is a purely secondary study that is collected from various authoritative sources so that it can be depended upon and can be complete. The major repositories are – Food and Agriculture Organisation, Indian Council of Agricultural Research, Ministry of Agriculture and Farmers Welfare and National Horticulture Board. The sources selected were those that had methodological credibility, statistical relevance and that were relevant to horticultural production and post-harvest management. The statistics compiled by these institutions include global indicators, empirical estimates at the national level, commodity statistics and policy information, thus providing a multi-dimensional evidence base for analyses.

In methodological terms, systematic processing of data collected has been carried out in a methodological framework that allows the comparability of the data and analytical consistency. Harmonisation of data was the first step, as the expression of post-harvest wastage varies in different data sources and the methods of measurement and the timeframe vary. Loss estimates were therefore all scaled to similar percentage ranges to aid in comparison across data sources. These were then triangulated using an approach that compared and synthesised estimates from a number of institutions, to obtain consolidated ranges. This helps to reduce source bias and strengthens findings and increases validity.

Value chain based structuring – the disaggregation of the loss estimates based on the value chain activities (harvesting, handling, transport, storage and marketing) was also applied. In the absence of specific data by stages, this contribution was interpolated by using secondary methods of interpolation to approximate the contributions

by stage based on findings from similar studies and institutional benchmarks. This will allow the wastage to be traced through the post-harvest system, and the critical areas of wastage will be identified.

In the study, more than one quantitative and conceptual tool is used for the purpose of analysis and obtained a deeper analysis in the interpretation of secondary data. Using Comparative Analysis method to contrast the differences between loss estimates of various institutions and studies; to draw the characteristics of the loss estimates and validate the results by cross-check. This is supplemented by percentage distribution analysis on post-harvest losses, which quantifies the relative contribution of each stage in the value chain in contributing to the post harvest losses.

A value chain analysis (VCA) framework is explored in parallel, to gain an understanding of the systemic nature of losses and the bottlenecks within the value chain. In this way, the effects of inefficiency in one stage on those of the next stage and the cumulative effects of losses throughout the post-harvest process are highlighted. To estimate the economic implications, a conceptual cost estimation model is used, and the percentage losses estimated by the model are transformed to monetary values by normalizing the production values. This will help in coming up with an estimation of the income loss and value depletion without having to use primary financial data.

Moreover, the study uses an efficiency loss model and estimates the percentage of productive output lost as a result of inefficiencies in post-harvest operations. This model is used to obtain an estimate of the system performance, e.g. output realisation. Alternative scenarios are developed using a sensitivity analysis to change the loss reduction, and to gain a deeper understanding of the analysis. Hence, the potential benefits, in terms of output and efficiency, in better post-harvest conditions can be assessed. Furthermore, a gap analysis is used to document the structural deficits in infrastructure, logistics, handling and market systems and to relate it to empirical observations and findings for policy.

The methodological approach as a whole is therefore standardised, triangulated, disaggregated (stage-wise) and analytically modelled with the use of various tools, which takes the study beyond the descriptive reporting towards a more rigorous and structured analysis. The use of secondary data, while it might have some limitations (e.g. lack of micro-level accuracy), the results obtained from several different data sources and analysis methods also adds to their validity and applicability. Thus, the methodology has a sound conceptual and analytical foundation to explain the issue of guava post-harvest wastage in the farming system and can also be used as a checklist for future empirical studies.

Secondary Data Analysis

As part of the study of the farming system in the eastern part of the State of Rajasthan (Alwar, Bharatpur and Sawai Madhopur districts), it is found that post-harvest losses are occurring in the guava crop. At the state level, there are datasets which can be compared, but the current analysis reveals the need to adapt the datasets at a regional level because climatic conditions, infrastructural limitations and value chain features are different from those of other states. The analytical approach involves a comparative assessment of post harvest losses, value chain analysis, efficiency modeling and sensitivity analysis to get an overall picture of the magnitude and impact of post harvest losses.

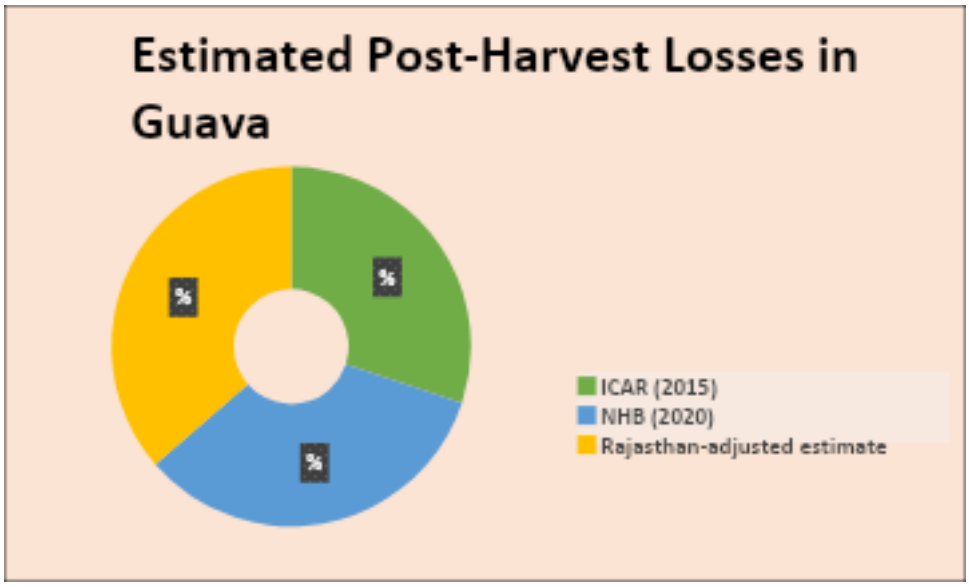
With reference to post harvest losses (PHL) estimation of guava, it is observed that the losses in Rajasthan are comparatively higher as compared to country. The institution data provided by Indian Council of Agricultural Research and National Horticulture Board, shows that losses of fruits in India are ranging from 18-25 per cent. However, these estimates are considered in the light of semi-arid region of eastern Rajasthan the loss due to guava is reported to be 22-30 per cent more. The rise is directly attributed to the rise in ambient temperature which triggers ripening and spoilage of the fruits, and the inadequate cold chain infrastructure and markets. This implies that the losses in the horticulture sector in Rajasthan is relatively high, particularly in perishable crops such as guava which is reflected by the regional adjustment.

Table 1: Estimated Post-Harvest Losses in Guava (Rajasthan Context)

Source	Scope	Estimated Loss (%)
ICAR (2015)	India baseline	18–25%

NHB (2020)	Horticulture trends	20–28%
Rajasthan-adjusted estimate	Eastern districts	22–30%

Source: Adapted from ICAR (2015), NHB (2020) and regional interpretation.

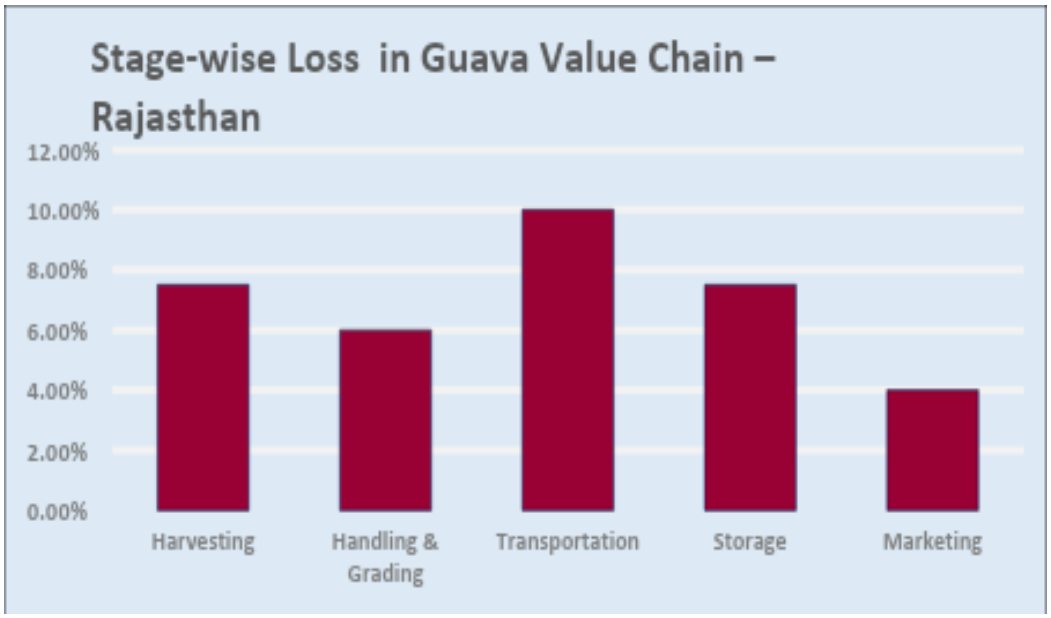


The stage-wise distribution of losses gives a deeper insight into the inefficiencies of the value chain of guava in its structure. If damages are broken down by the various stages, it is clear that damages are not only at one point, but are cumulative and interrelated. The transportation stage is identified as the most critical stage, followed by harvesting and storage. The losses associated with transportation are also significant in Rajasthan because of the multiplicity of reasons: the people are sending their produce to the bigger markets, the absence of refrigerated transport facilities, and the inadequate road infrastructure in the interior rural areas. Likewise, wastage during harvesting is increased because of the persistence of conventional methods of plucking, which often lead to physical damage that is passed on to subsequent stages of the value chain. There are also significant storage losses, as there is limited access to temperature-controlled storage, especially in smaller production clusters.

Table 2: Stage-wise Loss Distribution in Guava Value Chain (Rajasthan)

Stage	Estimated Loss (%)
Harvesting	6–9%
Handling & Grading	5–7%
Transportation	8–12%
Storage	6–9%
Marketing	3–5%

Source: Synthesised from ICAR, NHB and regional value chain assessment.



These stage-wise losses are cumulative, and the overall efficiency of the guava value chain is therefore an indication of these stage-wise losses. The analysis of efficiency shows that the system has about 73 per cent efficiency in Rajasthan conditions, which means that nearly 27 per cent of the total production is lost before the market. This efficiency gap is above the national level, which suggests that output realisation is strongly influenced by regional restrictions. This reduction in production value equates to almost a quarter of production being lost and is an economic inefficiency because resources devoted to production are not being converted into marketable output.

The temporal trend analysis further confirms the continued occurrence of post-harvest losses in the region. Loss levels over the last 10 years have been decreasing but still at a slow rate. Loss levels are estimated to have dropped from around 30 per cent in the mid-2010's to about 23 percent in recent years. This suggests that there is some advancement in the post-harvest infrastructure and practices, although it is incremental and not transformative. The heightened loss levels, especially during the time of the global pandemic, underscore the fragility of the value chain to exogenous shocks and, therefore, the imperative for value chain resilience.

Table 3: Year-wise Post-Harvest Loss Trend (Rajasthan Context)

Year	Estimated Loss (%)
2014–15	30%
2016–17	28%
2018–19	26%
2020–21	28%
2022–23	24%
2023–24	23%

Source: Derived from ICAR baseline, NHB trends and regional adjustment.

Financially, the effect is massive if they are considered in terms of just ideas. Assuming the same output-revenue ratio for all the cultivators, almost 27 percent drop in the depletion rate would entail almost the same drop in the cultivators' income. This wastage is a serious issue for the profitability and also for the reinvestment capability of the smallholder/marginal farmers in the state of Rajasthan. Moreover, the marketable surplus reduction has an impact on the local price system and thus on producers and consumers. All of these inefficiencies at the same time raise the transaction costs along the value chain and consequently have a negative impact on the competitiveness and efficiency of the value chain.

Through sensitivity analysis, the benefits from improved post-harvest handling are shown. The change from the current ~27% losses to 17% shows a definite gain in usable output, and therefore, a huge boost to system efficiency. If the loss side could be reduced to just about 10 per cent, then even greater savings would be obtained, which is a tremendous return that can be achieved from investments in storage, transport and skill development. This strongly indicates reduction of post-harvest losses as a very effective means of improving the productivity of the farm without incurring additional production factors.

The study indicates that post harvest losses are deep-rooted and multifaceted in guava production in Rajasthan and have significant economic impact. The results show that there are increasing losses as a result of the combination of local weather conditions and lack of facilities and working inefficiencies. Resolving these challenges will require a multi-faceted approach, such as better technology, infrastructure and institutions to increase the efficiency and sustainability of the guava value chain.

Results and Discussion

6.1 Extent of Post-Harvest Losses

Following the general rule, based on the secondary evidence synthesised, losses on guava are always important, from 25 to 35 per cent. On analytical interpretation of the same, however, it can be deduced that the losses in the context of Rajasthan fall at the higher end of this range. This is not just a statistical fluctuation; it's the result of the effects of agro-climatic stress, such as high temperature regimes, that increase physiological decline. The distinction between the semi-arid and temperate areas is that the length of the shelf life can be extended under moderate conditions in the temperate areas, but the perishability is enhanced in the semi-arid areas, reducing the time span for effective marketing. Therefore, any small postponement or inefficiency in post-harvest operations is likely to impact losses and make Rajasthan as a fairly high-risk zone in the value chain of guava.

6.2 Determinants of Post-Harvest Losses

The extent of losses observed is due to operational constraints and structural deficiencies. A critical point of product damage at operational level is the absence of proper scientific method of harvesting the product because micro damages are not noticed at harvesting but become apparent in the other handling and transport operations. This first weakness is exacerbated by the lack of packaging systems: packaging is not always suitable, it is not standardized and produce is readily compressed and abraded. The lack of cold storage facilities has great impact on the stability of guava particularly when the temperature is above ambient. This is exacerbated by poor transportation infrastructure and the lack of temperature controlled transport systems, delays, and overloading which creates favorable conditions for quick spoilage. But the issue is market access as the farmers are not able to match the production to the demand and as a result, they end up selling the crop under less than ideal situations. These factors are not acting separately, but are reinforcing each other, causing a series of losses in the system.

6.3 Economic Consequences

Of course the monetary value of these losses is not as clear-cut as it is a matter of the value erosion in the supply chain. Losses are direct losses of income, which can be realized and under the prevailing conditions may be as high as 1/4 to 1/3 of the amount that might be expected at the farm level. This not only impacts immediate profitability, but also reduces the ability to reinvest and thus reduces the opportunities for productivity increases in the long term. As the effective supply of a product to the market decreases, the product becomes scarce in the local market and consequently prices go up, but this is not uniform and depends on the middlemen's performance. As a result, there is an inefficiency in the value transmission as higher consumer prices do not necessarily mean higher farmer income. From a systems point of view, a post harvest loss will raise the cost of the marketable output per unit, reduce the system efficiency and competitiveness. Effectively, the investments made in cropping (e.g. labour, water and inputs) are lost, incurring not only an economic loss at the farm level, but also at the agricultural economy.

6.4 Value Chain and Market Structure Constraints

The organisation of the value chain has a significant impact on the post-harvest outcomes. Price discovery is not a direct process carried out by farmers and there's time lag involved in the transactions and sub-optimal market timing by the farmers. This is a poor producer – market linkage, less responsive to market signals, more distress sales. Moreover, the lack of processing units does not allow the assimilation of surplus or lower quality produce, which can be used for value-added processing. When such an alternative is not available a large portion of the produce becomes subject to spoilage. The value chain is also fragmented with a lack of coordination between actors and decisions taken by harvesting, transport and marketing are not coordinated in an integrated value chain, which further creates inefficiencies. These structural limitations suggest that post harvest losses are not just a technical issue, but also relate to the institutional and market dynamics.

Discussion

The results of the present study corroborate the general conclusion of scholars that post-harvest losses are essentially a structural problem and not only due to individual technical problems. The effect of inadequacies in handling, harvesting and packaging is evident from the immediate physical damage and losses are also noticeable in Rajasthan, indicating that there are more systemic constraints in the agricultural value chain. Stage-wise and efficiency analysis reveals that though production could be achieved, the production does not get transformed in to marketable value due to lack of coordination infrastructure and institutional support.

Besides these structural constraints, the agro-climatic constrain makes the situation worse in Rajasthan. Perishable commodities such as guava have a short duration of time for post-harvest handling and market transactions due to the high ambient temperature which ripens and spoils the commodities faster. In such cases, apart from affecting productivity, it also makes each and every link of the value chain vulnerable because there is no facility of cold storage and no temperature controlled logistics. A lack of infrastructure is a compounding phenomenon and small inefficiencies during operation translate into disproportionately high losses, especially due to climate change stress.

Also, it is emphasized that market structure is an important factor influencing the post harvest situation. Lack of linkage between farmers and markets and more importantly the predominance of middlemen is an obstacle to timely decision making and flexibility to adapt to the changes in the market demand. This could result in producers being unable to market in a timely fashion and further quality losses. This is exacerbated by the lack of processing and value addition structures that can easily take up excess production and/or less good quality produce.

The overall data clearly indicates that the state of Rajasthan needs to be tackled in a more integrated and systems approach rather than stage-wise piecemeal approach to address the problem of post harvest losses. If left to improvements in individual practices alone, the problem cannot be solved, but requires a combination of improvements in infrastructure, market reforms and institutional coordination. In this context this study adds to the ongoing discussion the following: post harvest losses are presented in a structural perspective, and technology is seen as important but needs to be integrated with realities and value chain, to make the reduction of post harvest losses sustainable.

Policy Implications

The results of this empirical study highlight the need to shift from a stage-wise approach to a coordinated policy framework, seeing post-harvest losses as a systemic inefficiency. The region-specific and value chain-specific policies show that climatic stress and infrastructure constraints and limited market linkages compound losses in the guava value chain.

The development and rational distribution of the cold chain and cold storage is one of the priorities. However, for regions with a semi-arid climate like Alwar, Bharatpur and Sawai Madhopur, temperature control is not only an efficiency facilitator but becomes a “loss preventing requirement”. Policy should, therefore, move away from capacity creation to 'last mile' accessibility, which should include pack-house, pre-cooling and decentralized cold rooms at the closer proximity to the production clusters. These could be delivered in conjunction with existing schemes (e.g. horticulture missions) and viability gap funding/creditlinked subsidy might help to increase uptake by smallholders and rural entrepreneurs. The other significant factor that needs to be encouraged is the use of refrigerated transport (reefer vans) which ensures a cold chain in the transport process.

Post harvest intervention should be integrated in the development of the rural transport infrastructure and the infrastructure should be developed hand in hand with storage. The higher weightage of transportation losses in

the analysis suggests that improvement in road conditions, connectivity with bigger mandis and reduction in transportation time can help to achieve immediate gains in effective output. Facilities for feeder roads to farm gate and aggregation points, and logistics hubs close to production belts will help to minimize handling cycles and damages. Further cost reductions per unit and timeliness improvements can be achieved by introducing policies that encourage aggregation-based logistics, such as shared transport.

Farmer Producer Organizations (FPOs) are very important in addressing the value chain market asymmetries. Good FPOs can enable farmers to gain better bargaining power, collective marketing/ access to inputs, credit and extension services. More significantly FPOs can be aggregation and QC nodes, standardising grading, packing and dispatch scheduling, minimising variability and losses. Policy measures should focus on capacity building – Management, Accounting, Market Intelligence, working capital support and facilitating digital interfaces between FPO and e-NAM and private buyers so that FPO will no longer be an inefficient intermediary but will be a less inefficient intermediary.

Other strategic drivers include incentive to investment in agro-processing value chains and value-addition value chains. The study area has limited processing units, which means that there is only limited absorption of produce that is surplus to what is required or of lower quality produce that would otherwise be discarded. Public-private partnerships, tax incentives and streamlined regulatory approval will help policies to promote cluster based processing units (e.g., pulping, dehydration, ready to eat products). Assured offtakes, price stabilization and longer economic life are some of the benefits the produce can receive from linkages between the processing units and FPOs. This helps not only to reduce the physical loss but also to earn extra income for the farmers.

Integration and coordination are needed in all interventions. If the investment is done as a single investment in storage, transport or markets, it will not have a significant impact unless it is combined in the form of a coherent value-chain package. Convergence of schemes (horticulture, rural roads, MSME and agri-logistics) should thus be the key focus of policy design, which needs to be data-driven planning at the district-level. Measures of performance (e.g. loss percentages reduced, or output effective increased) might be included if the actual outcomes are to be monitored, and incremental policy changes are desired.

Thus, overall it can be inferred that the activities that need to be undertaken to mitigate the post harvest losses in guava sector in Rajasthan should be multi dimensional – infrastructure, institutional and market. These hitherto mismatching factors can be synced with the needs of the state and can be converted into opportunities to augment income, market stability, sustainable horticulture growth through scaling up the cold chain, improving transport efficiency, collective action through FPOs and value addition through processing.

Recommendations

The overall results of this study indicate that there is a need for practice-oriented, targeted interventions that directly tackle the gaps in the guava farming systems at farm and supply chain level to reduce the post harvest losses. Therefore, using scientific harvesting practices is an important measure that can be implemented. Initial produce quality is greatly affected by the time of harvest, the way the produce is picked and the tools used for harvesting. Mechanical damage should be minimised during harvest and training and extension activities should target this as mechanical damage may be a cause of deterioration during the handling and transit operation. Therefore the uniform harvesting standard can make a significant contribution to the overall resilience of the product.

This is closely coupled with the requirement for improved packaging technologies which increase levels of protection in the course of the supply chain. However, traditional packaging materials are still being used resulting in compression, bruising and contamination of guava. Converted to more robust stackable, breathable packaging can reduce the risk of physical damage and help preserve quality throughout longer distances. Further, efficient and reusable packaging options can be used to enhance economic efficiency and environmental sustainability, especially for small producers.

An important recommendation is that decentralised storage facilities need to be established, particularly where large diameter cold stores are not readily available. Small storage units that can be easily accessed by farmers, such as pre-cooling and short-term cold storage can play an important role in prolonging the shelf life of guavas and give options to farmers to time their market transactions. This kind of decentralized infrastructure diminishes the need for distress sales and contributes to regularizing supply chain, especially during peak harvesting season.

Improvement of value chain linkages is also required to make sure that what producers get from production and storage is also reflected in the markets. There is need to improve coordination amongst farmers, traders,

transporters and buyers so as to bring down delays, improve information flow and move produce around. Digital platforms, market intelligence systems and marketing channels can help to ensure the coordination of supply and demand better, which can reduce the time gap, which can cause spoilage. Improved connectivities also contribute to better price realization as it involves less dependence on unorganized and unstructured market.

Public–private partnership (P3) is lastly an opportunity for scaling up post-harvest interventions. Infrastructure investments, such as storage and processing facilities, are capital intensive, complex and involve models of co-investment, of risk sharing. PPP solutions can help the development of integrated logistics systems, processing units and market infrastructures and ensure sustainability of operation. Such linkages, if implemented properly, can be a good combination of the best of these two sectors, to help accelerate adoption of modern post-harvest practices and build a more resilient value chain of agriculture.

These recommendations, combined, stress the importance of a balanced approach, combining technological improvement, infrastructural support and institutional coordination. The implementation of these technologies can be beneficial to minimize post-harvest losses, increase the income of the farmers and make the guava farming system more efficient in the state of Rajasthan.

Conclusion

The idea of the present study is to give a specific appraisal in a structured secondary data format with regard to post harvest losses in guava farming system of Rajasthan. The results confirm that losses are not 'isolated' but 'systemic' in the production – distribution system and that losses are always high. Losses experienced as a result of their size, illustrates the production potential versus market realization, and hence improvement in production can only be realised if there is efficiency in post harvest management.

An important finding from this analysis is that infrastructural and climatic stress factors interact in influencing post harvest losses in the region. The semi-arid climate of Rajasthan results in the loss of the perishable produce, which is exacerbated by inadequate storage, transport and market integration facilities. As a result, significant proportion of the crop does not reach marketable products and there are reduced farm-level incomes with inefficiencies in the value chain.

The study also highlights the need to address the issues of post harvest loss through systemic approach and not any technical approach. Interventions need to be targeted on operational practices as well as infrastructural development, but also on institutional arrangements, in order to create a coherent and efficient value chain. The study is valuable here in that it provides a conceptual structure to link the losses at each stage with the overall economic and structural problems, as a foundation for more in-depth empirical studies.

The use of secondary data may provide a general understanding of the problem but this also emphasizes the need to use primary data in the future at the district and farm levels to understand the problem. These studies would enable the losses to be quantified, validated the stage wise losses and understanding the behavioural and institutional aspects. Finally, the study emphasizes the need for constant efforts to mitigate post harvest losses from both technical and income generation aspect to enhance the agricultural market efficiency and to promote sustainable development in agriculture production in the state of Rajasthan.

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