

# Identification of Root Causes of Post-harvest Food Losses in the Mango Supply Chain: A Case of Sindh and Punjab, Pakistan

Sher Khan<sup>1</sup>, Anwar Shah<sup>2</sup>, Nauman Ijaz<sup>3</sup>

<sup>1</sup>Lecturer, Department of Economics, National Defence University Islamabad, Pakistan.

<sup>2</sup>Professor, School of Economics, Quaid I Azam University Islamabad, Pakistan.

<sup>3</sup>Assistant Professor, Department of Economics, International Islamic University Islamabad, Pakistan.

Correspondence: [Sherkhan@ndu.edu.pk](mailto:Sherkhan@ndu.edu.pk)<sup>1</sup>

## ABSTRACT

**Aim of the Study:** This study aims to contribute to the achievement of SDG 2, SDG 12, and SDG 12.3 by identifying the root causes of post-harvest food losses in Pakistan's mango supply chains.

**Methodology:** Employing a multifaceted approach, the researchers conducted detailed surveys, interviews, focus group discussions, and stakeholder meetings across the Punjab and Sindh provinces to gather first-hand insights regarding the post-harvest losses. The data is then analyzed through thematic analysis.

**Findings:** The analysis indicates lack of governance and managerial mismatch are major sources of the continuing post-harvest losses. Contrary to early harvesting and the use of traditional methods that play key roles in increasing post-harvest losses, some farmers adopt advanced technologies to boost productivity and reduce post-harvest losses. Hot Water Treatment (HWT), cold storage and de-sapping are some commonly adopted advanced methods. Nevertheless, under pressure of the market rivalry and the tight schedules, the adoption of de-sapping and HWT is not very high, with mango exporters being the main users of the methods. Analysis also highlighted that cases of bribes clearing cargo at a port and the bureaucratic obstacles have led to discouragement of exports and contribute to post-harvest losses.

**Conclusion:** The study concludes that lack of governance and traditional agriculture practices are the main causes of post-harvest food losses in mango supply chain. The analysis further suggested that de-sapping, HWT, and availability of trained labor during peak season can be used to minimize the post-harvest losses within the mango supply chain in Sindh and Punjab, Pakistan.

**Keywords:** Post-harvest Food Losses; Root Cause Identification; Mango Supply Chain.

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## 1. INTRODUCTION

The post-harvest loss is a serious problem, as it not only deteriorates the quality of food but also causes food shortages and crises. In developing countries like Pakistan, post-harvest loss poses a significant threat to food security, necessitating urgent attention (Khan et al., 2024). The problem further worsens as mishandling of agricultural produce further exacerbates post-harvest losses and may lead to reductions in yield and quality. This, in turn, results in a price increase, which is a burden to consumers. Post-harvest losses have been estimated at nearly 35-40 per cent of the fruits and vegetables produced in Pakistan, which is about 13.764 million tons of produce (Ahmad et al., 2021). Due to severe post-harvest losses in the agriculture sector, developing countries, specifically Pakistan, experienced severe malnutrition and food shortages. Post-harvest losses occurred at different phases of the supply chain; however, pre-harvest practices also played a vital role in it. Therefore, Osei-Kwarteng et al. (2024) stated that pre-harvest practices should be taken into consideration to reduce post-harvest losses.

Pakistan is under a serious challenge of post-harvest losses, and it's a national-level concern because fruits and vegetables are mostly degraded during harvesting, processing, storing, transporting and marketing. Post-harvest losses not only reduce farmers' income but also trigger food shortages and malnutrition. As per the report of the Asian Development Bank (ADB), Pakistan stands the chance of saving about 1.13 billion US dollars each year in case post-harvest losses is cut down by 75 per cent (Ahmed, 2019). Firdous (2011) highlights the problem of post-harvest losses in fruits and vegetables because of poor handling of perishable foods, shortage of transport carriers, warehouse facilities and market infrastructures. All these problems add up to the total loss of agricultural production, which is estimated at 30-40 per cent in Pakistan. Kaur and Watson (2024) also highlighted that supply chain mismanagement and traditional technologies are the main causes of post-harvest losses.

The State Bank of Pakistan (2008) report also presents that there are substantial post-harvest losses in major agricultural commodities, such as 10 per cent loss in wheat and 15 per cent loss in rice. It is even worse when it comes to fresh produce and vegetables, where post-harvest losses could amount to 35-40%, which is what happened with tomatoes in Pakistan (Firdous, 2021). These substantial losses can be primarily attributed to improper handling, transportation, and storage practices at the farm level. Furthermore, critical factors such as soil-borne diseases, insects attack, temperature fluctuations, moisture loss, and traditional harvesting practices contribute significantly to the high post-harvest losses across the agricultural sector.

Mangoes are one of Pakistan's most valuable fruits in terms of exports, generating significant foreign revenue. However, the country faces substantial post-harvest losses that hinder its full export potential. According to Zahid et al. (2022), Pakistan is the world's 5th largest mango producer and 3rd largest exporter, exporting around 125,000 metric tons annually, mainly to the Middle East, Europe, the US, Japan, and Australia, earning approximately \$100 million (Shabbir, 2023). The government of Pakistan also aimed to achieve 125,000 metric tons of mango exports for the year 2025 to earn around \$100 million in foreign exchange earnings (Ahmed et al., 2025).

Nur (2023) also stated that Pakistan exported approximately 100,000 tons of mangoes, totaling \$100 million in 2022. The main export destinations for Pakistani mangoes are the Middle East and Europe, with around 40% of the exports going to the UAE, Saudi Arabia, Oman, and Iran. The country produces nearly 2.3 million tons of mangoes annually, but faces severe post-harvest losses, leading to low exports and domestic consumption. Shabbir (2023) further stated that the Association of Pakistan Fruit and Vegetable Exporters, Importers, and Merchants (PFVA) has reduced the export target from 150,000 metric tons to 125,000 metric tons due to decreased production in 2022.

### ***1.1 Research Problem***

Pakistan's mango industry plays a crucial role in the country's economy, significantly contributing to export earnings and domestic consumption. Nevertheless, the industry is continuously confronted with a

key issue, high post-harvest losses, which are estimated at about 50% (Reuters, 2022). Such losses damage the economic capacity of the mango industry and hinder its ability to satisfy both domestic and international mango demand. The causes of these losses are highly diverse, extending across the whole mango food chain. Poor harvesting techniques, improper cold storage, along with a lack of proper transportation, also lead to massive loss/waste and competitiveness of the industry.

In addition, other environmental conditions like high temperatures and water crises also contribute to the post-harvest food losses (Sivakumar et al., 2011). These factors add up to the severe post-harvest losses, with far-reaching implications as far as the Pakistani economy and its food security are concerned. These losses turn into low export volumes, ultimately reducing foreign exchange revenues, and a decrease in local supply results in an increase in consumer prices.

## ***1.2 Significance of Research***

The mango industry in Pakistan is very crucial to the economy of the country as it contributes both to the export revenue and to consumption. However, Mohsin et al. (2021) highlighted that the leading challenge to this industry is the post-harvest losses, which significantly impact the mango sector. These losses destroy the economic prospects of the mango industry and its capability to meet both domestic and international demand. Responding to this challenge is important to economic growth and sustainable food systems in Pakistan. Therefore, the current study is of immense importance to identify and provide solutions to the challenges/hurdles which contribute to the post-harvest food losses in the mango industry. Identification and providing solutions to the post-harvest losses will assist Pakistan in largely enhancing its export of mangoes, increasing foreign exchange earnings and contributing to the total economic value of the industry. In addition, the mitigation of post-harvest losses will increase the supply of mangoes in the country, stabilize consumer prices, environmental sustainability, and adherence to the international food security agenda. In addition, effective post-harvest loss reduction measures will make farmers more empowered to maximize their profits and livelihoods and make the agricultural sector more robust. Finally, by reducing post-harvest losses, Pakistan can enhance the competitiveness of its mango industry in international markets, expanding its export reach and reputation.

The above discussion shows the importance of post-harvest food losses in Pakistan and how they create economic and social disparity. Based on the above discussion, the current research examines the key factors/challenges contributing to the post-harvest losses in the mango supply chain in the Punjab and Sindh Provinces of Pakistan. The following research questions and objectives are addressed and achieved in the current paper.

## ***1.3 Research Questions***

- What are the critical reasons for post-harvest losses in the mango supply chain of Sindh and Punjab, Pakistan?
- How can post-harvest losses in the mango supply chain be reduced to enhance the yields and monetary outcomes of farmers in Sindh and Punjab Province?
- What is the role of technology in advancing post-harvest practices to reduce food losses and achieve sustainable farming in Sindh and Punjab?

## ***1.4 Research Objectives***

- To assess the critical reasons for post-harvest losses in the mango supply chain of Sindh and Punjab, Pakistan.
- To identify ways to reduce post-harvest losses in the mango supply chain in Sindh and Punjab to enhance mango yields and farmers' income.

- To analyze the role of advanced technology in post-harvest practices for post-harvest loss reduction to achieve sustainable mango farming in Sindh and Punjab.

## 2. LITERATURE REVIEW

The literature review gathers dynamic perspectives of researchers on post-harvest losses and how potential strategies help in reducing post-harvest losses in general and specifically in the mango value chain. Further, there needs to be more research on post-harvest losses in the mango supply chain in Pakistan. The study thus compiled the literature available in various countries and even on various agricultural products. To begin with, one should learn what post-harvest losses are. Post-harvest food losses are defined as the quantity or quality of food that is less during the time between harvest and its consumption (Priyadarshi et al., 2020; Van Gogh et al., 2013) and are critical concerns within the food supply chain. Such losses are unusually large in perishable crops and have been estimated at up to 60 per cent in developing countries (Yahia et al., 2019). These losses are multi-dimensional, which can be attributed to the perishable nature, inadequate knowledge and limited capital (Hailu & Derbew, 2015). Different efforts have been made to solve this problem, such as the proposal to have a Network of Excellence to minimise post-harvest losses (Van Gogh et al., 2013). Such plans can curb food losses, enhance food access, food security, and small-scale farmers' sustainable livelihoods (Hailu, 2015; Yahia, 2019).

The issue of post-harvest losses has been viewed as a rampaging menace to the agriculture sector of the developing world. Likewise, in Pakistan, mangoes play a very important role in agricultural and economic terms. Sun et al. (2011) point to the Chinese market potential as a potential nation to export Pakistan mangoes, but insist on the necessity of a coordinated supply chain. Khushk and Smith (1996) emphasize the need-to-know marketing channels and margins of mango producers in Sindh Province. According to Saleem et al. (2010), training and extension programmes are necessary to enhance production methods in mango plantations, especially in Faisalabad. Lastly, Badar et al. (2016) write about how to better the workings of domestic mango value chains by paying attention to consumer value preferences, especially along the dimensions of good taste, healthfulness, and seasonal range.

Mango is one of the vital fruits in developing nations, and it draws foreign reserves and is very much in demand by the people. Nevertheless, it experiences major post-harvest food wastage. The high post-harvest losses in the supply chain of mangoes have also been pointed out by many studies, with Roy et al. (2019) estimating a total loss of 30.65 per cent and Tarekegn (2022) noting a 41 per cent loss in the Gamo Zone, Southern Ethiopia. These losses have been explained to be due to sub-standard handling procedures, the absence of appropriate transport and storage systems, ignorance of the stakeholders, the utilisation of local varieties, disease and insect pests, and enhanced harvesting tools (Tarekegn & Kelem, 2022). Sekar et al. (2018) also recommend better post-harvesting handling practices with regard to better storage facilities and cold transport frameworks to reduce such wastages. Ntsoane et al. (2019) demonstrate the necessity of using post-harvest technologies to minimise losses and preserve the quality of fruit.

Evaluation of the post-harvest loss is also relevant and necessary. The post-harvest loss in the agriculture sector is, however, not an easy assessment. Such is because the various stages of the supply chain are linked to overall post-harvest loss of agri-products. The study by Kitinoja et al. (2018), which reviews the assessment of post-harvest losses in plant-based food crops, pointed to the existence of different measurement tools, i.e., quantitative, qualitative, and economic losses. The case study presented by Underhill and Kumar (2015) on tomato supply chains in Fiji described the role of the worst contributors to post-harvest losses and even measured how much loss occurred over time. The topics of economic effects and temperature effects were mentioned by Yadav et al. (2022), speaking about the peculiarities of post-harvest losses during the transportation and storage of potatoes. Lastly, Harvey (1978) emphasised the need to reduce post-harvest losses in fresh fruits and vegetables, suggesting that a focus on maintaining overall quality can help achieve this.

A variety of approaches have been suggested to address post-harvest losses in mangoes. Iram and Ahmad (2013), as well as Alemu (2014), stress the significance of disease management, with Alemu (2014) explicitly pointing out the potential of integrated disease management. Rehman et al. (2015) highlight the importance of preharvest factors in influencing post-harvest disease development and fruit quality, indicating that interventions at the production level are critical. Additionally, Bambalele et al. (2021) offer an extensive overview of post-harvest technologies such as 1-methylcyclopropene, edible coatings, hot water treatment, gaseous ozone, controlled atmosphere, and pulsed electric field - all showing promise in preserving mango fruit quality.

## **2.1 Research Gap**

The literature review provides valuable insights regarding post-harvest losses in different agricultural products, specifically mangoes. Some studies also suggest key reasons and solutions to reduce post-harvest losses; however, in the case of Pakistan, critical factors that contribute to the post-harvest losses in the mango supply chain need to be correctly identified. Similarly, identifying the critical reason for post-harvest losses is necessary to attempt to reduce post-harvest losses in Pakistan's mango supply chain. The current study attempts to fill this research gap to identify the critical factors contributing to the overall post-harvest losses in the mango supply chain. The current study is based on extensive field surveys, semi-structured interviews, focus group discussions, and stakeholder meetings in Sindh and Punjab provinces of Pakistan. The research will help farmers, the private sector, exporters, and the government reduce post-harvest losses, resulting in economic gains for all the supply chain actors.

## **3. RESEARCH METHODOLOGY AND DATA SOURCES**

This research employed an exploratory design that specifically emphasized utilizing qualitative research methodology. Qualitative research can provide in-depth textual explanations of how individuals perceive and experience a particular research problem. It offers insights into the "human" aspects of issues by capturing and analyzing the often-contradictory behaviors, beliefs, perspectives, emotions, and interactions of individuals involved (Bricki and Green, 2007). This approach enables researchers to understand beyond simple statistical measures or quantitative analysis.

Thematic analysis based on the results of individual interviews with progressive farmers, focus group interviews, and the meeting of stakeholders has been deployed to interpret the findings. The thematic analysis determines emerging themes that best define the essence of the phenomenon under study. Braun and Clarke (2006) assume this method to be flexible and useful in research since they provide an in-depth and detailed observation of the data. Fereday and Muir-Cochrane (2006) equally indicate that in thematic analysis, reading of the data is carried out sequentially to draw out main themes.

It is quite helpful in applying this method of analysis in deriving and making relevant observations on the occurrences of real life and making sense of the same within the social setting. This process as it is described by Braun and Clarke (2006) builds on six stages that are critical in the process of carrying out a thematic analysis, which include familiarizing oneself with the data, generating the initial codes, identifying themes in the data, revising the initial themes, describing and naming the themes, and finally writing detailed reports of the findings.

A phenomenological approach was chosen to address the research questions as it provides a solid philosophical foundation in meaning and understanding. This methodology is deemed appropriate for this study because it emphasizes individuals' narrative experiences, facilitating understanding. By conducting conversational interviews with progressive farmers, stakeholders, and focus group members, this approach enabled us to gain insights into the post-harvest losses of mango produce, including physical and nutritional losses. Furthermore, inductive reasoning and a grounded theory approach have been adopted to generalize the research study's results on agriculture, specifically mango farmers in Pakistan.

### 3.1 Data Collection and Sampling

The current study examines the post-harvest physical losses at mango farms in Sindh and Punjab. The study uses purposive sampling techniques to select farmers who self-harvest mangoes, as they depict more valuable information regarding post-harvest losses and how to mitigate these losses to enhance financial gains from mango farms. The current study, therefore, selected three progressive farmers from Sindh (Hyderabad), naming the farms Farm 1, Farm 2, and Farm 3 and the respective farmers Farmer 1, Farmer 2, and Farmer 3. Further, 3 farms are taken from Punjab (Multan) and are entitled Farm 4, Farm 5, and Farm 6, with respective farmers as Farmer 4, Farmer 5, and Farmer 6. Further, Sindh and Punjab stakeholder meetings are entitled S1 and S2. Similarly, focus group discussions at Sindh and Multan are taken as FGD1 and FGD2 to better understand the post-harvest losses and how these could be mitigated with the help of relevant stakeholders.

Another reason for purposive sampling is to collect information from farmers who do self-harvesting so that we can identify their harvesting techniques and technologies, and identify critical advanced technologies they have adopted at their farms. Another reason is that most small-scale farmers give their farms on contract, and the contractor does not care about post-harvest losses (physical or nutritional), nor is the contractor concerned about using advanced technologies or techniques in harvesting, as they own the farm only during the harvesting season. The data regarding post-harvest losses in mango farms were collected from farmers, private sector business entities, and government officials, and the data was used to determine how these losses could be mitigated/reduced.

**Table 1: Details of Focus Group Discussions**

No. of FGD's	Category	District	No. of Participants	Date conducted
1	Focus Group Discussion 1	Karachi	25	27/5/2023
2	Focus Group Discussion 2	Multan	20	31/5/2023
<b>Total: 2</b>			<b>45</b>	

The information of two focus groups conducted in Karachi and Multan is presented in Table 1. The initial FGD in Karachi had 25 people on 27<sup>th</sup> May 2023, and the second FGD in Multan comprised 20 people on 31<sup>st</sup> May 2023. Therefore, 45 stakeholders were engaged in the two sessions, and they gave a qualitative perspective on the topic of the research.

**Table 2: Distribution of FGD Participants by Age (%)**

Age Groups (years)	FGD 1	FGD 2
	Karachi	Multan
	Female	Male
25-29	0	5
30-34	2	8
35-39	3	7
40-44	3	6
45-49	2	4
50-54	2	3

In Table 2, the age-wise composition of FGD participants is extracted in Karachi and Multan. Most of the participants (accounting for both groups) had the age category of 30-44 years, implying the active engagement of the mid-aged professional participants. Participants less than 30 and more than 50 were very few and very minimal as well, and in Multan, all the participating persons were male and in Karachi, there was a minimum number of female participants.

**Table 3: Target Groups, Type of tools and Method of Data Collection**

<b>Target Group</b>	<b>Type of Tool</b>	<b>Method</b>	<b>Number of Interviews</b>
Farmer 1 (Sindh, Hyderabad)	Semi Structured Interview questionnaire	Field Survey	1
Farmer 2 (Sindh, TandoJam)	Semi Structured Interview questionnaire	Field Survey	1
Farmer 3 (Sindh, Hyderabad)	Semi Structured Interview questionnaire	Field Survey	1
Farmer 4 (Punjab, Multan)	Semi Structured Interview questionnaire	Field Survey	1
Farmer 5 (Punjab, Multan)	Semi Structured Interview questionnaire	Field Survey	1
Farmer 6 (Punjab, Multan)	Semi Structured Interview questionnaire	Field Survey	1
<b><u>Focus Group Discussions</u></b>			
<b>FGD 1: Hotel Move and Pick (Karachi)</b>	<b>Guidelines</b>	<b>Focus Group Discussion</b>	<b>25</b>
<ul style="list-style-type: none"> <li>• Professors/Faculty of Quaid I Azam, Islamic International, LUMS and Karachi University</li> <li>• Consultant from Institute of Population Studies, Sri Lanka</li> <li>• Consultant from Karachi (Fortunate Agri Business)</li> </ul>			4 1 1 1
<b>Other Stakeholders</b>	Semi structured questionnaire		
<ul style="list-style-type: none"> <li>• Government Departments</li> <li>• Aarthi (Commission Agents)</li> <li>• Private Processing Companies</li> <li>• Progressive Farmers</li> <li>• Exporters</li> </ul>		Key Informant Interview	3 3 5 5 2
<b>FGD 2: Maryam Hall, Ramada, Multan</b>	<b>Guidelines</b>	<b>Focus Group Discussion</b>	<b>20</b>
<ul style="list-style-type: none"> <li>• Professors/Faculty of Quaid I Azam, Islamic International, LUMS and Karachi University</li> <li>• Consultant from Institute of Population Studies, Sri Lanka</li> <li>• Professor from Australia (Online)</li> <li>• Consultant from Karachi (Online)</li> </ul>			4 1 1 1
<b>Other Stakeholders</b>			2

• Government Departments	3
• Aarthi (Commission Agents)	4
• Progressive Farmers	4
• Exporters	

The table presents a description of the target groups; data collection tools and methods applied during the study. Six separate interviews on Sindh and Punjab farmers were conducted based on field survey questionnaires of a semi-structured type. The focus group discussions of 25 people in Karachi and 20 people in Multan involved the academics, consultants, and agribusiness professionals and were elicited by FGD protocols. Secondly, 18 key informant interviews were done with the stakeholders such as the government officers, commission agent (Aarthi), processors, exporters and good farmers. Interviews and FGDs achieved depth and diversity in terms of the variety of information gained within the various regions and participants in the agricultural value chain.

**Table 4: Structure of Thematic Analysis**

Phase	Description of the phase
<b>Familiarisation with Data</b>	If needed, transcribe the data, review and revisit the information multiple times to ensure accuracy, and document initial thoughts or concepts.
<b>Initial Coding</b>	Systematically organize and categorize significant aspects of the data throughout the entire dataset, gathering pertinent information for each category.
<b>Identifying Initial Themes</b>	Analyzing codes and organizing them into potential themes, collecting all relevant data for each theme.
<b>Review of Themes</b>	Examining the compatibility between the themes, the coded excerpts, and the complete dataset produces a visual representation of the analysis through a thematic 'map'.
<b>Defining and Naming Themes</b>	A continuous examination is being conducted to enhance the details of each theme and the overall narrative that emerges from this analysis. This process involves developing precise definitions and identifying appropriate names for every theme.
<b>Report Writing</b>	The ultimate chance to conduct an in-depth examination. I choose vivid and compelling examples from the extracts, thoroughly analyse them, connect the analysis back to the initial research question and existing literature, and ultimately produce a scholarly report presenting the findings of this analysis.

## 4. ANALYSIS / RESULTS

Four major themes were identified during interviews and by thoroughly examining the transcripts. The respective themes demonstrate the key issues most relevant to the research domain.

### 4.1 Theme 1: Key Reasons for Post-harvest Losses

Government inefficiency in addressing post-harvest food losses is a significant issue in many countries, hindering food security and export potential (Ogundele, 2022; Shende, 2017; Parmar, 2017). For example, Nigeria's failure to implement effective measures to reduce post-harvest losses has led to significant waste (Ogundele, 2022). Similarly, in Cameroon, inadequate post-harvest management options due to a lack of technologies and infrastructure and insufficient capital and technical know-how have resulted in substantial food losses (Shende, 2017). The situation is further exacerbated by the mismatch between supply and demand during peak and lean seasons (Parmar, 2017). These issues contribute to food

insecurity and limit the export potential, as the quality and quantity of available produce are affected. **Farmer 1** focused on the export of Mango, so when the team asked about post-harvest losses, he said that *“the main reason for food losses is the governance issues at organisations that deal with export. Miss management and government officials-induced barriers hinder exports and lead to food losses”*. Zorya et al. (2011) stated that government inefficiency hinders exports and leads to post-harvest food losses in Sub-Saharan Africa.

Similarly, **Farmer 2** mentions that *“we have only one month for harvesting. We should harvest all the mangos in a single month, as the prices are also high in this month”*. Further, He added that *“cutting all mangoes, either mature or immature, leads to food losses in terms of nutrition”*. Harvesting of mature and immature mango is also expensive, as well. Premature picking of the mangoes will cause substantial food losses as fruit loss is considered quite high, and more fruits cannot be marketed (Samwel et al., 2020). These losses are also influenced by the post-harvest losses through improper handling, absence of storage facilities and crude consumer handling (Rajapaksha et al., 2021). Post-harvest losses due to early harvesting of mangoes, along with overall post-harvest losses, could be up to 17.9 per cent and 14.4 per cent, respectively (Srinivas et al., 1997). The losses are also supported by the widespread occurrence of the post-harvest diseases, which may further exclude the fruit regarding quality and profitability (Iram and Ahmad, 2013). Under the same context, FGD1: Respondent 1 added that, *“in the agriculture sector, early sowing and harvesting are the major problems”*.

Furthermore, it has been emphasised by many studies that mangoes also incur high post-harvest losses because of the conventional harvesting techniques. According to the findings of Prasad et al. (2019), it was revealed that mechanical harvesting could prevent such losses, extend the shelf life, especially in certain types of cultivars. Farmer 3 continued that *“the means of labour is the traditional harvesting method, even with hands or a metal net and down to a lifted tree before throwing it to the labour on the ground; he picks it with the sack (كروب) in his hands; the sack has sticks on its both sides. To get the mangos, they set a sack (كروب) net”*.

Post-harvest applications such as hexanal and calcium chloride, as well as cold storage, have been proposed by Baltazari et al. (2020) to increase shelf life and reduce the number of instances of the disease. Msogoya and Kimaro (2011) and Roy et al. (2019) note that poor handling practices, poor and inefficient transport and storage infrastructure and lack of awareness among the stakeholders are major causes of post-harvest losses.

Other than post-harvest activities, severe food losses in mangoes, disease attacks like powdery mildew and mango harper are some of the factors which bring significant losses in mangoes. Powdery mildew is a disease that is dangerous to the production of mangoes, caused by the fungus *Oidium Mangifera* that results in terrible food waste. The disease is endemic, whereby crop losses in different regions have been reported to range between 5-20 per cent in India and 80-90 per cent in South Africa (Chavan et al., 2009). S1 continued, *“The critical challenge that we saw in this season is Powdery Mildew (Fungus Disease), and it costs a lot in terms of losses in the mangoes these days, and the major cause of this disease is mismanagement”*. Moreover, he also said, the second dish that is prevalent in mango is the mango harp. Chavan et al. (2009) added that Powdery Mildew majorly destroys flowers, stalks and small fruits, resulting in huge losses. Application of fungicides, especially when the plant is under the 30-40 per cent flowering stage, has also been noted to be an effective control option (Akhtar & Alam, 2000). However, the development of fungicide-resistant strains and the need for further research on disease resistance and management strategies highlight the ongoing challenges in addressing this issue (Nasir et al., 2014). Furthermore, S2 added that the *“main issue with mango in the current season is the Mall Formation, and most farmers need to learn about it, which causes 70-80% of losses in different areas of Tando Jam Sindh”*.

#### **4.2 Theme 2: Advanced Technologies/Techniques in the pre-and post-harvest phases**

A range of advanced technologies, including hot water treatment, have been developed for the pre- and post-harvest phases of the agriculture sector (Anghel, 2009). Advanced technologies significantly reduce pre- or post-harvest losses, especially in the mango food supply chain. **S1** expresses his experience using hot water treatment: *"We harvest Mango and then dip it in cold water to stop the ripening process; then, we dip it in wax to cover it with a layer of wax. After that, we put it upside down on a rack to desap the Mango. After that, we transfer it to cold storage, and this process helps export the mango"*. Hot water treatment (HWT) technology, for instance, has effectively cleaned and disinfected fresh produce, reducing the need for chemical treatments (Fallik et al., 2021). This technology has been further explored as a seed disinfection technique for organic and eco-friendly crop cultivation, with potential benefits for seed quality (Kim et al., 2022). Additionally, hot water treatment is a feasible and efficient practice for disease control in vegetables, with positive effects on growth, disease incidence, and yield (Singh et al., 2020). **Farmer 2** also mentions that *"nowadays, exporters are directly coming into farms to collect quality Mango and give reasonable prices to the farm Owners now; the trend is changing, and farmers are adopting excellent and advanced practices to avoid food losses in terms of physical as well as nutritional so they can get a reasonable price for their produce"*.

**Farmer 4** mentioned that *"many seminars were held in Multan regarding mango pre- and post-harvest practices, and we have taken a lot of help from them. Further, he added that farmers are turning towards pruning, an Australian technique to increase yield and reduce food losses"*. Pruning is a crucial practice in the mango sector, with various strategies and techniques being employed to maximise production and fruit yield. Davenport (2006) highlights tipping, formation, and severe pruning to control tree size and enhance productivity. Shinde et al. (2003) emphasized the effectiveness of light pruning and center opening in promoting vegetative growth, flowering, and fruiting. Rahayu et al. (2013) underscore the significant impact of pruning and fertilizing on mango production and post-harvest quality. Oosthuysse (2014) further discusses the benefits of pruning in maintaining tree size and improving yield. Contrastingly, **S5** said, *"Before 10 years ago, Australia was using vehicles for de-sapping, and we also used it, and it was also successful, but the main issue is that it was costly and time-consuming. So, it was not feasible in competition"*. Saleem (2010) emphasised the need for comprehensive training and extension programs to address the need for more modern production technology awareness among mango growers. These studies underscore the need for targeted interventions to improve the adoption of advanced technology in the Pakistani mango sector.

#### **4.3 Theme 3: Government's Inefficiency Causes Food Losses**

One of the main reasons for food losses is the alarming climate change; however, management and government inefficiency significantly contribute to the food losses. Despite Pakistan being an agricultural country, there needs to be more policy formulation and implementation that reduce food losses, specifically in the mango supply chain. **FGD 2: Respondent 1** highlighted that *"port clearance for our consignments is a major reason for low export and high mango post-harvest losses"*. Due to critical issues in export, Pakistan was only allowed to export 125,000 tons of mango, although production is 1.8 million tons. Similarly, **Farmer 1** said, *"Responsible personnel only pass the container at Karachi port once they are given money. Miss management and government officials-induced barriers hinder exports, leading to post-harvest food losses"*. Khan et al. (2008) stated that despite increased production and rising demand in the export market, the potential of mango export has yet to be fully achieved.

Similarly, Lee and Weng (2013) also mentioned that bribery within the home country decreases firm exports. Other factors, along with port bribery, significantly increase shipping costs and distort exports (Sequeira, 2009). Farmers also raised serious concerns regarding government soil testing facilities, which led to low production and pre- and post-harvest losses in Mango. **Farmer 4** added, *"Soil testing in government labs takes too much time; he said I had given my soil samples for the last five years, and I still didn't get the lab report"*. The inefficiency of soil testing in mango orchards has been linked to food

losses due to the resulting low productivity. Studies in India and Brazil have found that nutrient deficiencies, such as zinc and boron, can significantly limit mango productivity (Kumar et al., 2012; Adak & Pandey, 2020).

Farmers and stakeholders further raise serious concerns about the use of wooden crates and the availability of financial support to the farmers. The prolonged process of gaining financial support from the government discourages farmers and stakeholders from adopting advanced practices and enhancing food production with food loss reduction. **FGD2: Respondent 2:** *“Banks and Government institutions take too much time and delay processing and granting loans; however, Aarthi gives loans in a couple of hours”*. Similarly, there is no subsidy on plastic and cardboard crates, which results in using wooden crates that create huge food losses in mangoes. **FGD2: Respondent 3:** *“In the case of wooden crates, he added that transportation is easy, and wooden crates are cheaper than cardboard and plastic crates. However, food losses are higher in wooden crates than plastic or cardboard crates.”* Using wooden crates in mango packaging has been found to contribute to higher food losses due to increased bruising and heat transfer (Anwar, 2008; Chonhenchob, 2003). This is particularly significant in the case of mangoes, as they are highly susceptible to bruising and damage during transportation and handling. Corrugated cardboard packaging has been suggested as a more practical alternative (Anwar, 2008). Mangoes' harvesting and storage behaviour can also impact food losses, with fruits harvested with stalks and stored in wooden boxes showing reduced decay loss and higher mar, marketability (Singh, 1993).

#### **4.4 Theme 4: Remedial Measures to Reduce Post-harvest Food Losses**

Farmers and stakeholders suggested several remedial measures during the survey and focus group discussions. Most of the farmers recommend de-sapping, hot water treatment plants, pruning, trained labour, and value addition as the most important remedial measures to cut post-harvest loss of the mango. Farmer 6 says, *“the de-sapping procedure dramatically decreases the amount of food that leaks because it discourages the loss of sap when harvesting, and in addition to that, increases of shelf life of mango too”*. Farmer 5 also indicated that *“desaping and cold storage are the main measures to curb food losses in mangoes; it also makes mangoes last longer on the shelves to be exported.”* Whether it is through desapping or cold storage, research has invariably confirmed that there is a high amount of mango losses that can be mitigated by either of the methods. Baltazari et al. (2020) discovered that such methods have the capability of improving shelf life and the rigidity of the fruits, as well as decreasing the cases of diseases.

Likewise, Msogoya and Kimaro (2011) indicated that keeping mangoes in shade and hot water treatment were some of the ways of reducing post-harvest losses, and cold storage is a lasting remedy. The findings were further corroborated by Castro et al. (2004), who established that exposure of mangoes to modified atmosphere packaging and cold storage has the capability of enhancing mango quality. Lastly, Rahman et al. (2019) incorporated bagging of the fruits before harvesting and enhanced post-harvest management measures, which hugely diminished losses.

Likewise, Seid (2017) reported that the use of hot water treatment has greatly paralleled the anthracnose disease occurrence and symptoms in mango and extended their shelf life and quality. S2 continued, *“HWT is one of the post-harvest methods that may address various problems and illnesses. He further said that another upcoming Mango post-harvest method, which replaces the post-harvest losses and prolongs the shelf life of mango, is irradiation.”* Sripong (2015) pointed out that under conditions of combination treatment using hot water and UV-C irradiation, such treatment can additionally inhibit the symptoms of anthracnose and improve the activity of the enzymes involved in the defense process, retarding fruit ripening and keeping it in good condition (Sripong 2015). Additionally, hot water treatment at 50°C for 30 min has been found to effectively reduce lenticel browning in mangoes, improving their quality and reducing decay (Prasad 2016). Conditioning mango fruit at 40°C for 8 hours before hot water treatment can further alleviate hot water injuries and increase resistance to post-harvest diseases (Jacobi 2000).

Besides technology, labour training at mango farms significantly impacts post-harvest food losses in mangoes. Farmer **S4** said, *"Mango farms have faced a trained labour shortage during peak season. We are ready to give high wages, but at least the labour should be trained labour, which will reduce our financial and food losses"*. **Farmer 2** *"further, there is a need for trained employees and harvesters to reduce physical food losses. The impact of trained and untrained labour on mango food losses in Pakistan is significant."* Saleem and Ahmad (2010) emphasize the need for comprehensive training and extension programs for mango growers, particularly in modern production techniques. This is supported by Hafeez (2020), who found that training on improved post-harvest handling technology significantly reduced post-harvest losses. Nonetheless, according to Ahsan et al. (2018), on-farm labourers struggle with insufficient training opportunities and underpayment, which may negatively affect labour quality and even cause food losses. Hence, trained labour is critical and trained labour can greatly minimise post-harvest wastage of mangoes and hence high value to the farmer and the labourers manually used.

One of the imperative methods listed to help prevent food losses is value addition in agriculture by maintaining post-harvest processing and lean manufacturing processes (Hinai et al., 2022; De Steur et al., 2016). This is specifically vital in the rural setting where a greater part of the publicly utilised setting is reliant on farming as their main occupation (Lakshmi & Aparna, 2022). The agricultural sector has the potential to undergo value addition, and it is possible to increase the income of the farmers by half using value addition through the post-harvest process (Chavan & Alam, 2020). The S4 stated that *"the value of Value Addition has also been pointed out: I would recommend the establishment of a pulp manufacturing facility in Multan. It will curb the B-quality and C-quality dumping of mangoes and minimize losses of food."* S3 *"we supply 20- 25tons of mangos to pulp plants like Nestle, Iftikhar and Co and Hunza. He further stated that we have a large pile of mangos, the time is running out, and therefore, we ought to embark on value addition to saving food wastage and generate more economic value from the mango."* Abirami et al. (2020) also stress the economic and employment opportunities that can be realized by the creation of production and sale of certified value-added mango products. Ravani and Joshi (2014) equally emphasize the use of by-products in mango processing that help in minimizing waste and value addition.

## 5. DISCUSSION

In Pakistan, post-harvest food losses in the horticulture sector are an essential issue, and there are shortcomings in the production sector of fruit and vegetable losses. The inefficiency of government has resulted in massive waste, obstructing food security and the prospects of export. Absence of incentives to manage the orchards properly and to maintain disease-free crops, and the ownership of fruits by contractors led to poor farming and marketing practices that farmers had been unwilling to change. The result indicates that farmers need improved farm management information, training on new mango growing technologies, and access to formal credit, all of which can make them more productive and contribute to the elimination of some of the inefficiencies in this market.

Furthermore, traditional harvesting methods, sub-standard handling practices, and disease attacks significantly contribute to post-harvest mango losses. Advanced harvesting technologies, post-harvest treatments, and disease management strategies have been recommended to mitigate these losses and improve shelf-life. The need for proper processing facilities and the uneven distribution of returns favoring intermediaries have further hindered the development of the mango industry in Pakistan. The government should encourage and support the private sector to spearhead integrated value chains in Pakistan. The involvement of the private sector is crucial for improving the situation, as the government alone cannot adequately address these issues due to limited resources. These findings highlight the necessity for enhanced post-harvest practices, efficient disease management, and governmental intervention to minimise food losses and bolster export potential in the horticulture sector.

The results highlight the importance of advanced technologies in reducing pre- and post-harvest losses in the agriculture sector, particularly in Pakistan's mango food supply chain. HWT technology has been shown to effectively clean and disinfect fresh produce, reducing the need for chemical treatments. HWT

has also been explored as a seed disinfection technique for organic and eco-friendly crop cultivation, with potential benefits for seed quality. Additionally, HWT is a feasible and efficient practice for disease control in vegetables, with positive effects on growth, disease incidence, and yield. Adopting advanced technologies such as HWT can reduce post-harvest losses and improve the overall value chain in the agriculture sector.

Pruning is another crucial practice in the mango sector, with various strategies and techniques being employed to maximise production and fruit yield. Farmers in Pakistan are turning towards pruning, an Australian technique to increase yield and reduce food losses. Pruning techniques such as light pruning and center opening have been emphasised for promoting vegetative growth, flowering, and fruiting. Advanced technologies and pruning techniques can help farmers in Pakistan improve the quality and marketability of their produce, leading to better prices and increased competitiveness in the global market. However, comprehensive training and extension programs are needed to address the need for more technology awareness among mango growers. The adoption of advanced technologies and pruning techniques, along with targeted interventions and improved infrastructure, can help reduce post-harvest losses and enhance the competitiveness of the agriculture sector in Pakistan.

Some key reasons for food losses are climate change, government inefficiency, and mismanagement. The lack of policy formulation and implementation has resulted in significant food losses, hindering the potential of mango exports. The delay in port clearance for consignments and bribery at ports are significant reasons for low exports and high post-harvest losses. The inefficiency of soil testing in mango orchards has also been linked to food losses due to low productivity. Farmers and stakeholders have raised serious concerns about the use of wooden crates and the availability of financial support to farmers. Using wooden crates in mango packaging has been found to contribute to higher food losses due to increased bruising and heat transfer. The adoption of advanced technologies such as hot water treatment and pruning can contribute to reducing post-harvest losses. Corrugated cardboard packaging has been suggested as a more effective alternative to wooden crates. The need for targeted interventions to improve the adoption of advanced technology in the Pakistan mango sector has been emphasised. Comprehensive training and extension programs are required to address the need for more technology awareness among mango growers.

## **6. CONCLUSION**

The issue of post-harvest food losses in Pakistan's horticulture sector is a significant concern, with weaknesses in the fruit and vegetable production sector contributing to these losses. The government's inefficiency in addressing these issues has led to substantial waste, hindering food security and export potential. The lack of incentives for proper orchard management and disease control, as well as the ownership of fruits by contractors, has resulted in farmers' reluctance to change their farming and marketing practices. The survey reveals that farmers demand better farm management information, training in modern Mango growing technology, and access to formal credit, which can increase productivity and help remove some of the inefficiencies in this market. Furthermore, public and private sector partnerships can further improve the mango value chain in Pakistan, decreasing pre- and post-harvest losses in mango.

Furthermore, traditional harvesting methods, sub-standard handling practices, and disease attacks significantly contribute to post-harvest mango losses. Mechanical harvesting, post-harvest treatments, and disease management strategies have been recommended to mitigate these losses and improve shelf life. The need for proper processing facilities and the uneven distribution of returns favoring middlemen have further hindered the development of the mango industry in Pakistan. The government needs to facilitate and motivate the private sector to take initiatives to develop integrated value chains in Pakistan. These findings underscore the need for improved post-harvest practices, effective disease management, and government intervention to reduce food losses and enhance export potential in the horticulture sector.

In conclusion, addressing post-harvest losses in the mango supply chain is crucial for improving food security and economic growth in Pakistan's agricultural sector. Implementing desapping, hot water treatment, pruning, trained labour, and value addition can help reduce post-harvest losses and improve mangoes' quality and economic value. The potential for value addition in Mango is significant, with the opportunity to double farmers' income through post-harvest processing. Integrating pre-harvest fruit bagging and improved post-harvest management practices has significantly reduced post-harvest losses. The adoption of advanced technologies and pruning techniques, along with targeted interventions and improved infrastructure, can help reduce post-harvest losses and enhance the competitiveness of the agriculture sector in Pakistan.

### **6.1 Research Limitations**

Due to limited time and resources, only progressive farmers are considered for the research. Further, the quantitative aspect of the research should be undertaken to validate the research outcomes. Due to qualitative analysis, respondents' biases can be presented in the analysis.

### **6.2 Policy Suggestion**

The government should promote a one-window policy to support and enhance exports, specifically in Mango. Further, the government should facilitate farmers' provision of loans in a smooth and timely way. A substitute for wooden crates should be provided to the farmers to reduce post-harvest losses in Mango. The government should subsidize advanced technology to the farmers so that the production yield can be increased and post-harvest losses in Mango can be reduced. Training of labour, specifically in the central regions of mango production like Multan and Tando Jam, should be provided to enhance laborers' skills and reduce the post-harvest losses in the mango supply chain.

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### **ORCID iDs**

Sher Khan <sup>1</sup>  <https://orcid.org/0009-0000-5801-2424>

Anwar Shah <sup>2</sup>  <https://orcid.org/0000-0002-8158-3986>

Nauman Ijaz <sup>3</sup>  <https://orcid.org/0009-0003-7325-4394>

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