ACTION RESEARCH REPORT

Feasibility Study on Commercial Adoption of Passive Modified Atmosphere Packaging (MAP) Bags to Reduce Post-Harvest Loss of Fresh Vegetables

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EXECUTIVE SUMMARY

- **Project objectives:** Mandala Agrifresh Pvt. Ltd. in collaboration with Commercial Agriculture for Smallholders and Agribuisness (CASA) project investigated the feasibility of adopting passive MAP bags and ethylene absorbers to reduce postharvest losses and extend shelf life of vegetables, thereby improving market access for rural farmers in Nepal.

- **Methodologies:** The methodologies included action research, commercial demonstrations, and impact assessments through detailed documentation and data collection.

- **Key findings:** MAP bags significantly outperformed control packaging in preserving vegetable quality, showing reduced weight loss and better retention of freshness, color, and firmness. This enhanced shelf life will improve marketability, leading to higher farmer income and reduced waste for traders. While MAP's effectiveness across produce types varies, it was most notable in perishable leafy greens. However, for widespread adoption some challenges remains in the supply chain management and awareness among the actors involved. A holistic approach, including local government support, capacity building, and successful case studies, is essential for wider adoption and integration of MAP technology into the agricultural supply chain.

HIGHLIGHTS OF THE PROJECT:

- *Conducted a collboartive action research across different vegetable supply chains in various regions of Nepal, engaging local farmers, traders, and key agricultural supply chain actors, to understand and improve postharvest practices.*

- *Conducted over **22** trainings and/or oreination sessions on post-harvest management and technologies as a part of capacity building to empower the stakeholders involved in fresh vegetable trading. Reached over **1,000** farmers and traders through training and demonstrations.*

- *Conducted **four** commercial-scale demonstrations successfully integrating the postharvest technologies like Modified Atmosphere Packaging (MAP) bags, ethylene absorbers, and germination sheets.*

- *Successfully introduced and showcased practical benefits of postharvest technologies like MAP technology in real-world supply chains of selected commodities like spinach, green peas, tomatoes, and capsicum.*

1. INTRODUCTION:

1.1. PROJECT BACKGROUND:

1.1.1. Nepal's agricultural challenges in Post-harvest Management:

Post-harvest loss (PHL) is a significant challenge in Nepal's agriculture, impacting both the quality and quantity of produce from harvest to consumption. Defined as the measurable loss of food quality and quantity (De Lucia & Assennato, 2006), PHL encompasses reductions in availability, edibility, and wholesomeness (FAO, 1989). Globally, approximately one-third of fresh produce is lost between harvest and consumption (Kitinoja & Kader, 2002). In Nepal, PHL occurs at various stages of the supply chain, including harvesting, collection, processing, storage, transport, and distribution. Farmers lose about one-third of harvested grain due to inadequate storage and handling (Kandel, 2021), while perishable fruits and vegetables experience losses ranging from 20% to 50% due to high moisture content and spoilage susceptibility (Bhattarai et al., 2017). These losses are largely attributed to traditional storage methods, pest infestations, and improper handling practices (Kandel, 2021; Adhikari & G.C., 2021).

Nepal's horticultural sector faces significant post-harvest challenges, characterized by high product perishability, inadequate infrastructure, and fragmented value chains, leading to substantial losses throughout the supply chain (Adhikari et al., 2021). Various research studies indicate that the general postharvest loss of fresh produce in Nepal ranges from 20 to 50% because of improper harvesting methods and postharvest handling, insufficient sorting and grading practices as well as inadequate storage and poor infrastructures and facilities (Bhattarai, 2018; Khatiwoda et.al, 2022). This issue is exacerbated by poor harvesting techniques, improper handling, and substandard packaging, all of which contribute to significant losses.

On the other hand, with traditional practices, such as using toxic chemicals for pest control, poses additional health risks, the quality and safety of the product is neither asked for by large section of consumers nor assured by the government through strict implementation of available legislative measures (Khatiwoda et.al, 2022). Additionally, Nepal's agricultural sector faces broader challenges, including technological constraints, resource limitations, and inadequate governmental support (Gyawali & Khanal, 2021).

Being a highly potential area of national economy, horticultural sector requires systematic interventions to implement policies aimed at improved production and postharvest management of fresh produce to ensure safety and quality as envisaged by Agricultural Development Strategy[1]. Implementing effective post-harvest management strategies is crucial for improving food security and agricultural sustainability in Nepal.

1.1.2. Need of PH-interventions in the agricultural supply chain:

Increased agricultural production and the subsequent distribution have also resulted in higher post-harvest losses. Produce from rural areas travels long distances to urban markets, encountering risks such as temperature fluctuations, physical injuries, and spoilage. Farmers often use inadequate techniques, while traders pass food loss costs onto consumers, showing little incentive to invest in improved practices. During peak seasons, excess produce overwhelms storage and transportation capacities, leading to further losses.

Global post-harvest losses are estimated at 13.8%, equating to 1.3 billion tons annually (FAO, 2011). In Nepal, losses range from 20-50% (Gautam & Bhattarai, 2012) due to improper practices and insufficient infrastructure. The country's diverse topography and climate require specific post-harvest measures, yet modern technologies remain largely unexplored. Traditional packaging materials contribute to weight loss and quality deterioration, making it hard for small-scale farmers to compete with those closer to markets.

Poor practices by middlemen, such as rough handling and poor sanitary conditions, exacerbate the postharvest losses. To address these challenges, effective post-harvest interventions are imperative as these inefficiencies not only impact the supply chain but also have broader implications for food security, climate change, and the economic well-being of farmers.

- **Food Security:** Post-harvest losses reduce both the availability and affordability of fresh produce in Nepal. Inefficiencies in the supply chain mean a significant amount of harvested fruits and vegetables never reach consumers. Effective post-harvest management can ensure more produce gets to market in good condition, enhancing food security. By cutting losses, we maximize the use of harvested crops, stabilizing and improving food supply for communities.

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[1] *Agriculture Development Strategy 2015-2035 (henceforth ADS) is a report prepared by the Ministry of Agricultural Development in consultation with National Peasants' Coalition to formulate a 20-year strategic plan including a 10year Action Plan and Roadmap based on the assessment of the current and past performance of the agriculture sector.*

- **Climate Change Mitigation and Adaptation:** Post-harvest losses contribute to climate change as decomposing produce emits greenhouse gases like methane. Improved post-harvest practices can extend produce shelf life and cut spoilage, thereby reducing these emissions. Climate change worsens post-harvest issues through higher temperatures, increased pests, and other environmental stresses. Implimenting improved practices can help farmers adapt to these conditions, reduce their carbon footprint, and support global climate change efforts.

- **Economic Benefits:** Reducing post-harvest losses boosts farmers' incomes by preserving produce quality longer, allowing them to bargain for higher prices and increase access to the distant markets. Enhanced practices also decrease dependency on imports, retaining more income within the country and spurring local economic growth. Moreover, investing in post-harvest technologies create new business opportunities within the supply chain, from packaging to cold storage solutions that will not only improve livelihoods of smallholder farmers but also contribute to overall agricultural sector development.

- **Balanced and Predictable Market:** Post-harvest interventions help create a more balanced and predictable market by reducing the volatility caused by seasonal gluts and shortages. By extending the shelf life of produce, farmers can better manage supply and demand, reducing the pressure to sell immediately after harvest. This leads to more stable prices and reduces the risk of market oversupply, which often results in significant waste. A balanced market also benefits consumers, who gain access to a consistent supply of fresh produce throughout the year. Furthermore, a predictable market environment encourages investment in agricultural production and post-harvest infrastructure, contributing to long-term sector stability.

Overall, post-harvest interventions are crucial for reducing food loss, enhancing food security, and improving the economic stability of rural farmers. By addressing both production and post-production stages, a more sustainable and efficient agricultural supply chain can be achieved, benefiting all stakeholders involved. Implementing these interventions will not only mitigate current challenges but also build a resilient agricultural sector capable of adapting to future demands.

1.2. BACKGROUND OF MANDALA AGRIFRESH:

Mandala Agrifresh was established in 2020 with the mission to address one of Nepal's most pressing agricultural issues: post-harvest losses. Recognizing that inefficiencies in post-harvest management contribute significantly to food waste and market inefficiencies, the company aims to revolutionize the fresh produce value chain through innovative, cost-effective solutions.

Mandala Agrifresh's holistic approach to post-harvest management involves:

- **Market Access and Fair Pricing**: By directly sourcing fresh fruits and vegetables from farmers, Mandala Agrifresh reduces the involvement of middlemen, ensuring fair pricing and improved market access. This equitable supply chain model benefits both farmers, who receive better prices, and consumers, who gain access to fresher produce.

- **Access to Post-Harvest Management Technologies**: Beyond MAP bags, the company offers other forms of post-harvest technologies such as ethylene absorbers, anti-fungal pads, thermal pallet covers, and cost-effective cold storage solutions. These innovations enhance supply chain efficiency, reduce food loss, and maintain produce quality.

- **Consulting and Capacity Building**: Mandala Agrifresh provides consulting services and capacity-building programs to supply chain actors. Leveraging their expertise in commodity trading and technology implementation, they guide clients on the optimal use of post-harvest technologies, improving market reach and operational efficiency.

In addition to MAP, Mandala Agrifresh has introduced a range of low-cost packaging solutions tailored to Nepal's unique agricultural landscape. These solutions address the specific challenges faced by smallholder farmers and traders, including local climatic conditions, transportation constraints, and traditional handling practices. Mandala Agrifresh employs *advanced packaging technologies*[2] such as Modified Atmosphere Packaging (MAP) and ethylene absorbers to enhance the packaging process. MAP bags works by regulating oxygen and CO_2 levels, slowing down respiration rates, maintaining optimal moisture, and regulating the release of ethylene gas, a natural plant hormone that accelerates ripening, hence effectively delaying ripening and spoilage. Ethylene absorbers further preserve freshness by capturing ethylene, preventing premature decay. Together, these solutions create optimal storage conditions, preserves quality, freshness and weight of the produce and hence extending shelf life, and significantly reduce post-harvest losses, ensuring that produce reaches consumers in peak condition with minimal weight loss.

[2] Brief info and features of the postharvest technologies as packaging solutions are provided in the Annex 1.

Mandala Agrifresh's commitment to enhancing the agricultural supply chain in Nepal aligns with their vision of creating a sustainable, efficient, and resilient food system. Their innovative technologies and holistic approach are paving the way for a more effective and equitable agricultural landscape.

1.3. PROJECT OVERVIEW & OBJECTIVES:

This project aims to demonstrate the commercial viability of MAP bags and ethylene absorbers in reducing post-harvest losses and extending shelf life. Objectives include conducting action research and commercial demonstrations, assessing the impact on quality and marketability, and providing recommendations for broader adoption.

The "Action Research on the Commercial Trials of Modified Atmosphere Packaging Bags in Vegetables" addresses the critical issue of post-harvest losses in Nepal's vegetable sector, where losses reach up to 40% due to inadequate packaging and storage. These losses undermine the economic stability of smallholder farmers, contribute to food security challenges, and cause environmental issues from the decay of unsold produce.

This action research is part of the CASA programme, a seven-year initiative (2019-2026) funded by Foreign Commenwealth and Development Office (FCDO). CASA aims to increase economic opportunities for smallholder farmers by demonstrating the commercial viability of businesses with significant smallholder supply chains and attracting more investment into the sector. CASA is shifting how investors, donors, and governments view and invest in agribusinesses that work with smallholder supply chains.

Mandala Agrifresh, a pioneer in post-harvest management, introduced passive MAP bags, branded as "*Magic Bags*". As the only company in Nepal to successfully integrate MAP technology into its supply chain, Mandala Agrifresh has significantly reduced food loss and enhanced post-harvest management. MAP technology creates a controlled atmosphere inside the packaging that extends the shelf life of fresh produce by minimizing respiration rates, reducing moisture loss, and delaying ripening. This technology addresses the challenges of maintaining produce quality during aggregation, transportation, storage, distribution, and retailing.

Despite the potential of these technologies, they are not yet categorized as agricultural inputs, leading to high import duties and making them expensive for smallholder farmers compared to traditional packaging materials. To showcase the effectiveness as well as the benefits of MAP packaging and collaborate with the government to explore the possibility of reclassifying it as an agricultural commodity, potentially leading to reduced costs for farmers, it is crucial to generate evidence demonstrating how these technologies can extend the shelf life of fresh vegetables and address market inefficiencies. This approach will highlight the value of MAP packaging in supporting farmers and making these solutions more accessible and affordable for widespread adoption.

To overcome this challenge, Mandala Agrifresh, with support from CASA, undertook the action research to demonstrate commercial viability of MAP bags through commercial trials. Mandala Agrifresh conducted comprehensive trials of MAP bags in collaboration with smallholder farmers and market participants across the Province 3 and 5 in Nepal. The goal was to gather empirical evidence on the effectiveness of MAP bags in real-world conditions, validating their impact on reducing post-harvest losses and improving economic returns for farmers.

PRIMARY OBJECTIVES

- **Demonstrate the Effectiveness of MAP Bags:** Conduct rigorous commercial trials to evaluate the impact of MAP bags on reducing post-harvest losses. These trials will involve collaboration with smallholder farmers and market actors across selected provinces to gather comprehensive data on the technology's efficacy.

- **Promote Adoption of Post-Harvest Technologies:** Increase awareness and usage of MAP bags among smallholder farmers through targeted training and outreach. The project aims to distribute MAP bags and ethylene absorber sachets to at least 1,000 farmers, showcasing their practical benefits and facilitating hands-on learning.

- **Advocate for Policy Support:** Engage with government officials and agricultural knowledge centers to promote MAP bags as a valuable agricultural commodity. This includes advocating for reduced taxes and import duties to enhance the affordability and accessibility of the technology.

By achieving these objectives, the project aims to establish a sustainable model for mitigating post-harvest losses in the vegetable sector, validate the commercial viability of innovative packaging technologies, and foster increased investment in agribusinesses that support smallholder farmers.

2. LITERATURE REVIEW:

2.1. Modified Atmosphere Packaging (MAP) technology:

MAP bags extends the shelf life of fruits and vegetables by altering the gaseous environment within sealed packaging (Sivertsvik et al., 2002; Rai et al., 2002). By reducing oxygen and increasing carbon dioxide levels, MAP inhibits microbial growth, slows respiration, and maintains product quality (Sivertsvik et al., 2002). Proper packaging film selection, temperature, and humidity control are crucial for successful MAP implementation (Rai et al., 2002; Church, 1994). MAP has demonstrated effectiveness in reducing weight loss, physiological injury, and fungal growth in various fruits and vegetables (Kargwal et al., 2020). Passive MAP is an effective technique for extending the shelf life of fresh produce, particularly when optimal refrigeration is unavailable. Studies have shown that passive MAP can maintain quality and prolong storage life for various fruits and vegetables.

Fruits and vegetables continue respiring post-harvest, leading to quality decline. MAP helps preserve these products by reducing oxygen and increasing carbon dioxide levels, slowing down ripening and microbial growth, ultimately extending the shelf life. While effective, MAP requires careful management to prevent negative outcomes. Despite challenges, MAP has become a widely used technology in the fresh produce industry. has significantly extended shelf life and increased consumption of fresh produce since the mid-1990s.

2.2. Efficacy of MAP for selected commodities:

Spinach: Like other leafy greens, spinach is highly susceptible to postharvest losses due to factors such as respiration, transpiration, and microbial growth. These factors lead to quality deterioration, including weight loss, discoloration, and decay *(Kader, 1989; Cantwell & Kasmire, 2002)*. Modified Atmospheric Packaging (MAP) has been explored as an effective intervention for mitigating postharvest losses. Studies have shown that passive MAP can effectively reduce postharvest losses in spinach, maintain quality, and extend its shelf life *(Khan, 2020)*. Research findings indicate that storing spinach in passive MAP bags significantly prolongs its freshness and maintains its quality better than in control conditions. However, the effectiveness of MAP can vary depending on packaging materials, storage temperature, and other factors *(Lee & Dulal, 2018)*.

For instance, Batziakas et al. (2020) demonstrated that MAP bags effectively slowed yellowing and reduced water loss in spinach. Mudau et al. (2018) found that the shelf life of spinach stored in MAP at 20°C was extended by three days. Additionally, a study by Thapa et al. (2019) revealed that MAP bags reduced the spoilage of Broad Leaf Mustard (BLM) by almost 200% compared to BLM stored in open air over six days, and showed nearly 20 times less weight loss. These findings underscore the potential of MAP bags to significantly reduce postharvest losses in spinach and other leafy greens, enhancing their shelf life and quality during storage and transport.

Tomatoes: Tomatoes with a high water content of approximately 90% are prone to rapid spoilage (Bouzas et al., 2021). Research has shown that MAP effectively extends post-harvest shelf life and preserves quality. Studies have demonstrated that MAP slows color changes, maintains firmness, and reduces spoilage. For instance, MAP-packaged tomatoes stored at 6°C and 91% RH showed significantly fewer cracks and stretch marks (14.23%) than unpackaged tomatoes (42.9%) after 21 days (Bouzas et al., 2021). Additionally, MAP can extend the shelf life of tomatoes harvested at the breaker stage by up to 5 days under ambient conditions (15.5°C & 82% RH), with MAP-packaged tomatoes exhibiting less weight loss, better color, and higher quality (Gautam et al., 2017). In cold storage (5°C and 82% RH), MAP delays ripening, maintains firmness and flavor, and reduces weight loss and color degradation compared with unpackaged tomatoes (Fagundes et al., 2015). Moreover, after 30 days at 15°C, tomatoes in MAP bags experienced significantly less weight loss and spoilage than non-packaged tomatoes (Nakashi et al., 1991).

Chilli: Research indicates that MAP effectively prolongs the post-harvest shelf-life and maintains the quality of chili. For instance, during a 10-day storage period at 30°C and 65-75% relative humidity, King chili stored in passive MAP conditions experienced only 4% weight loss, compared to 18% in open storage (Malakar et al., 2020). Additionally, storing fresh green chili in MAP helps preserve quality and freshness as well as significantly extending the shelf life (Edusei et al., 2012). Studies also show that MAP significantly reduces weight loss in capsicum, with losses 200% less after 25 days and up to 400% less after 30 days compared to regular storage conditions (Nyanjage et al., 2005; Poudel et al., 2021).

Cucumber: MAP has proven effective in extending post-harvest storage life and preserving the quality of cucumbers. Research has shown that MAP can extend cucumber freshness by 5-7 days (Owoyemi et al., 2021). Cucumbers stored in MAP bags exhibit significantly reduced weight loss, up to 14-15 times less—compared to those stored under ambient conditions (Kargwal et al., 2021). Additionally, cucumbers in MAP bags maintain better firmness and experience lower weight loss than unpackaged samples (Kaur et al., 2021). Internal trials[3] has also demonstrated that by day 15, cucumbers stored in MAP bags showed minimal spoilage, whereas over 50% of cucumbers in open storage were spoiled. This underscores MAP's effectiveness of MAP for enhancing cucumber quality and longevity during storage.

[3] ***Internal trials*** *refers to a small-scale experimental evaluations conducted within the Mandala Agrifresh facility. These trials served as a preliminary assessment of new technologies or practices before their larger-scale implementation.*

3. METHODOLOGY:

3.1. Overview of the research framework:

This study employed an *'action research'* approach to evaluate the efficacy of passive Modified Atmospheric Packaging (MAP) bags in reducing post-harvest losses (PHL) and extending the shelf life of selected vegetables. A '*commercial demonstration'* model was utilized to assess the technology's performance under real-world conditions within Nepal's agricultural supply chain.

The research framework integrated both action research and commercial demonstrations to offer a comprehensive understanding of MAP technology's effectiveness in real-world conditions. This framework included a systematic approach to data collection and analysis, targeting critical points in the supply chain from harvest to market delivery. The research design incorporated a randomized controlled trial to establish a comparative framework between the treatment (MAP) and control groups.

A combination of quantitative and qualitative methods was employed, including direct measurements of post-harvest losses, shelf-life assessments, and stakeholder feedback. This mixed-methods approach ensured a robust evaluation of the technologies under investigation, providing detailed insights into their practical applications and potential benefits.

3.2. Methodology adopted for the commercial demonstrations:

To conduct the commercial demonstrations, vegetables were selected based on their economic importance, susceptibility to post-harvest losses as well as the preference of the involved stakeholders. The selected vegetables were procured from single or multiple collection centers and farms within the targeted regions. The commodities were then randomly divided into treatment and control groups. The treatment group was packaged using MAP bags (and ethylene absorbers), while the control group utilized standard packaging (or non-packaging) exisiting practices.

The methodology for the commercial demonstrations was carefully designed to ensure accurate and meaningful results. Four demonstrations were conducted, beginning at collection centers where produce is aggregated and ending at market points where the commodities are sold. Data was collected at key stages of the supply chain, as indicated in the Figure 1. The datas collected includes weight loss, and the quality parameters like freshness, firmness, physical damage, and spoilage. While weight loss was measured quantitatively, other quality parameters were assessed using the Hedonic

Scaling [4] method, a standardized approach for quantifying subjective perceptions. Standardized data collection forms were utilized to ensure consistency and reliability throughout the study. The study design incorporated multiple replications to enhance data consistency and reliability.

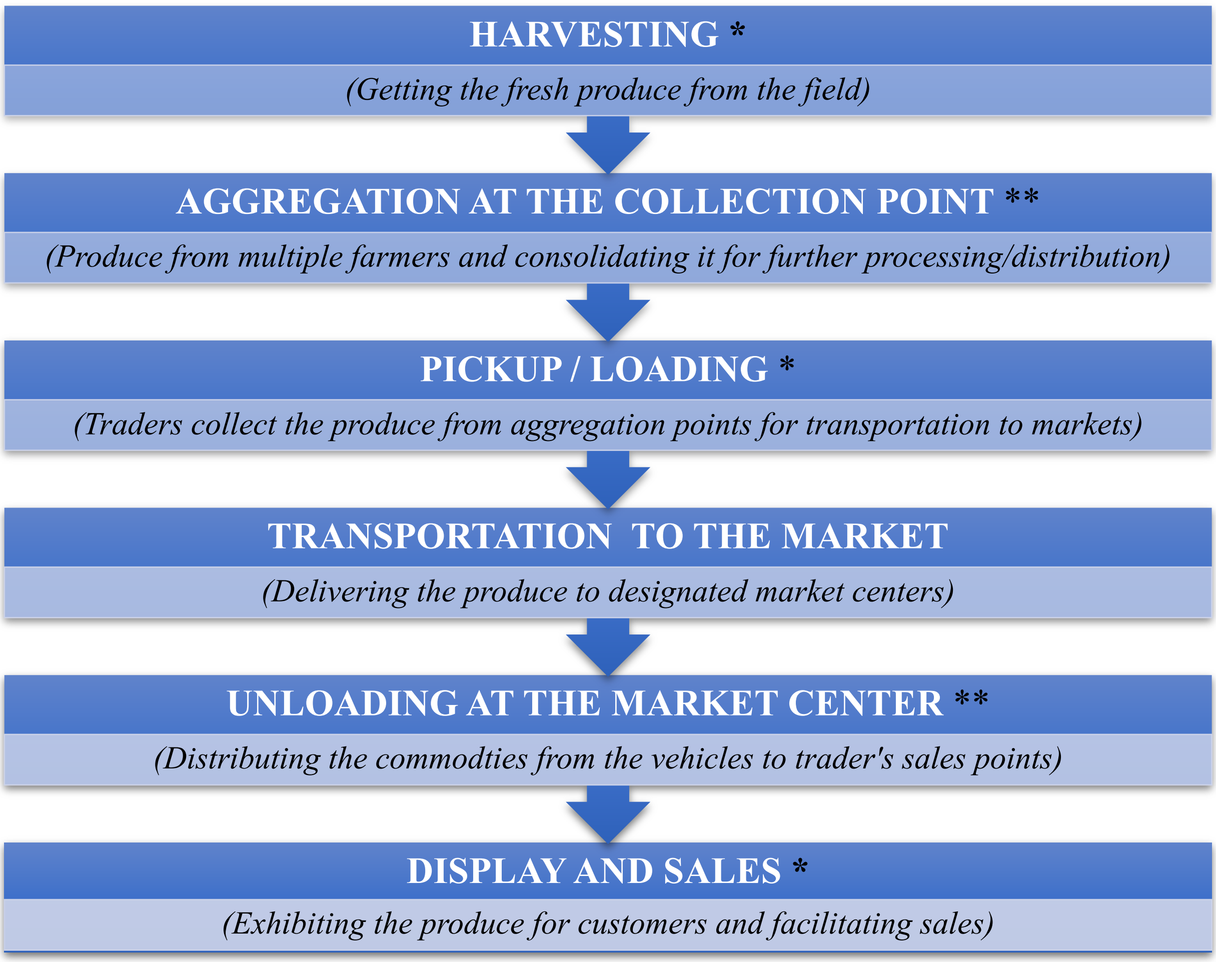

Figure 1: Key stages in the supply chain for the fresh agricultural commodities
(* *Additional observations and inquiries*, ** *Points of interventions and datas collection*)

Ideally, it was planned to have half of the procured commodities to be integrated with the MAP technology (treatment group), while the rest to be transported using existing practices (control group). However, the volume of commodities used was limited based on stakeholders' allowances, considering situational practicality and feasibility.

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[4] Hedonic scaling is a sensory evaluation method used to assess the quality attributes of products based on human perception. In this study, it was employed to measure the quality parameters of fresh vegetables, including freshness, firmness, physical damage, and spoilage. Each attributes were assesed on a 5-point scale, with 1 representing the lowest level and 5 representing the highest. To facilitate data analysis and improve graphical representation, the raw scores were later adjusted to a 1-10 scale. This approach allowed for a more intuitive interpretation of the results and enhanced the clarity of graphical representations by providing a subjective yet systematic way to capture the perceived quality of produce under different conditions.

The stakeholders involved in the study included approximately 1,000 commercial farmers, over a dozen traders, and several cooperatives. Key stakeholders were actively engaged throughout the study. Follow-up visits were conducted during peak production and trading periods to provide brief orientations and training on the use of MAP technology. Feedback was collected from stakeholders to evaluate the practicality and acceptance of the technology.

3.3. Criteria for district and commodity selection:

The selection of study sites and commodities was strategic, focusing on regions with significant agricultural production, existing post-harvest challenges, and established supply chains. Districts were chosen based on the areas with commercial vegetable production pockets, particularly those with potential for wider market reach but currently limited due to nearby markets due to the challenges like the inability to export to wider markets because of post-harvest losses, were selected. Semi-remote regions with limited access to larger markets and farmers facing significant challenges in reducing post-harvest losses were also considered to ensure the study's relevance.

For instance, Palpa Cluster (Palpa, Gulmi, Argakhachi and Rupandehi districts) was selected due to its substantial vegetable production, historical postharvest challenges, and the presence of a well defined supplu chain with processing and distribution network involving commercial farmers and traders.

Commodities were selected based on their economic importance, susceptibility to post-harvest losses, and potential benefits from MAP technology. Crops such as spinach, coriander, pumpkin leaves, tomatoes, chilies, and capsicum were included due to their high commercial value and perishability. This diverse selection allowed for a comprehensive evaluation of MAP technology's effectiveness across different horticultural product categories.

The regions and commodities chosen for this study reflect the broader challenges within Nepal's agricultural supply chain. The project aimed to provide actionable insights and practical solutions to enhance the commercial adoption of MAP technology, ultimately supporting Mandala Agrifresh's objectives of improving post-harvest management and expanding market access for Nepalese farmers.

3.4. Capacity building of the stakeholders:

One of the key aspect of this action research was also to build the capacity of the stakeholders involved reagrding the better post harverst handling and management. During the project, significant emphasis was placed on capacity building to ensure that both farmers and traders could effectively utilize MAP bags, thereby maximizing the benefits of this technology. Training sessions were conducted to familiarize participants with the proper handling, packaging, and storage techniques essential for maintaining produce quality using MAP bags. Key exercises included:

- **Hands-on Training:** Farmers and traders were guided through the entire process of using MAP bags, from selecting the right type of bag to correctly sealing and storing the produce. In addition, all the participants were provided with sample MAP bags for practical application and experimentation, reinforcing the training materials and fostering a deeper understanding of MAP technology.

- **Demonstrations of Impact:** Live demonstrations showed how MAP bags reduced weight loss and spoilage compared to traditional methods, providing tangible evidence of their effectiveness.

- **Best Practices Sharing:** Sessions focused on sharing basic guidence as well as best practices for the post-harvest management, emphasizing the importance of minimizing the damage to the fresh produce during handling and transportation.

This capacity-building initiative was pivotal in the project's success, as these training sessions played a crucial role in enabling farmers and traders to inform, encourage them for the adoption of the MAP technology effectively. By understanding the principles and techniques involved, participants were better equipped to implement MAP packaging in their operations. More information about the strucutre of training sessions and the numbers of sessions with locations is provided in the Annex 3.

4. STUDY SITE, BACKGROUND AND DEMO OVERVIEW:

Spinach, a highly perishable leafy green, was the focus of our demonstrations due to its strong market demand. Most production areas rely on nearby markets due to limited access to larger markets, with longer transport times negatively affecting quality and shelf life. The typical supply chain for spinach is short, with transportation primarily occurring at night to minimize post-harvest quality degradation.

Our demonstrations spanned various locations, including Dolakha, Palpa, Palung, and Dhankuta (as apart of other visit), each with distinct harvesting and handling practices. Approaches were customized to adapt specific regions and conditions, with necessary adjustments made throughout the study. Initial plans to use crates for packaging and treatment group division were often impractical due to local customs and resource constraints. Methods were adapted based on stakeholders' allowances and existing aggregation and packaging practices.

For example, Spinach is rarely packed and transported in crates; instead, they are typically bundled and packed in nylon sacks tied or sewn at the top. The use of MAP bags, originally designed for crate liners, required modifications to accommodate existing packaging practices. For demonstration purposes, spinach bundles were placed directly inside the MAP bags (without crates) and tied at the top as shown in the Figure 3. Care was taken not to overload the bags to prevent tearing, as the MAP bags are relatively thinner than other polythenes.

In Dhankuta, a colder region with extended spinach production, spinach is typically packed tightly into nylon sacks and transported to warmer areas like Bitratnagar. This change in ambient temperature causes rapid degradation, reducing the shelf life of the perishable vegetables. Our demonstration involved packing freshly harvested spinach without precooling, replicating common practices. The spinach was harvested, tied into bundles, and initially piled in the field before being packed and aggregated in shaded areas as shown in the Figure 2. Harvested produce was stored on-farm until evening collection by traders, who transported it to collection centers before final distribution. The produce remained in this state until evening when traders arrived with transport vehicles to collect the aggregated produce from various farms. The produce was then taken to a collection center where it stayed briefly before being transported to its final destination during nighttime to reduce the temperature impact, depending on the trader's arrangements. This process highlights the challenges posed by inadequate post-harvest handling, including exposure to varying temperatures and delayed cooling.

Figure 2: Spinach Packaging Process *(From Left to Right)* Typical bundling of fresh spinach leaves; packing of the spinach bundles into MAP bags; MAP-packaged spinach inside the nylon sacks & the packed spinach collected at the aggregation point.

In Dolakha, spinach was not packed at all; the spinach bundles were collected in local baskets, weighed, and stacked roadside, covered with a tarp. Later in the evening, they were stacked in vehicles, compacted from the top, and transported loose and exposed. This method, while raising significant safety and post-harvest quality concerns, was accepted by stakeholders due to a lack of alternatives and a focus on maintaining margins, often shifting the cost of losses to other actors in the supply chain.

Figure 3: Spinach Handling and Packaging Comparison: *(Top)* Typical bundling and handling of the fresh spinach leaves; *(Bottom)* Comparison of MAP packaging versus traditional bundling of spinach stacked at the aggregation point and while loaded in the transporation vehicle *(bottom right)*.

Our demonstrations aimed to address these issues by showing the benefits of MAP technology, even when faced with established practices under challenging conditions, challenges in the supply chain and despite economic pressures driving suboptimal practices.

5. OVERALL RESULTS & FINDINGS:

The MAP bags in general showed better results at preventing weight loss as well as maintaing the different quality parameters like freshness, turgidity, preventing damage and decay. As demonstrated by the results, MAP bags consistently outperformed traditional packaging methods in preventing weight loss. This finding highlights the effectiveness of MAP technology in preserving product weight and reducing economic losses due to spoilage. Even in the cases where the weight loss was not significant, the quality parameters were visibily maintained in the commodities packed in MAP bags as compared to control conditions.

5.1. CASE STUDIES:

5.1.1. DOLAKHA DEMO:

Given Dolakha's reputation as a major vegetable production area, a demonstration of MAP bags was conducted in collaboration with local farmers and traders within its spinach supply chain. The goal was to assess the efficacy of MAP bags in preserving produce quality during transportation.

Two spinach demonstrations were held in Makaibari, Bhimeshwor Municipality, Dolakha. Fresh spinach were harvested from a local farmer and subjected to different packaging treatments: a control group using traditional bundling, and two MAP treatments (compact packaging with four bundles per bag and loose packaging with two bundles per bag). The first demonstration involved immediate packaging and same-day transportation, while the second demo encountered overnight storage before transportation to the market due to logistical and coordination challenges. In both demonstrations, spinach was transported to the market in Kathmandu. Upon arrival, it was evaluated for weight loss and visual quality parameters, including appearance, turgidity, damage, and decay. The results were analyzed using a hedonic scale to determine the impact of MAP technology on maintaining spinach quality during transport.

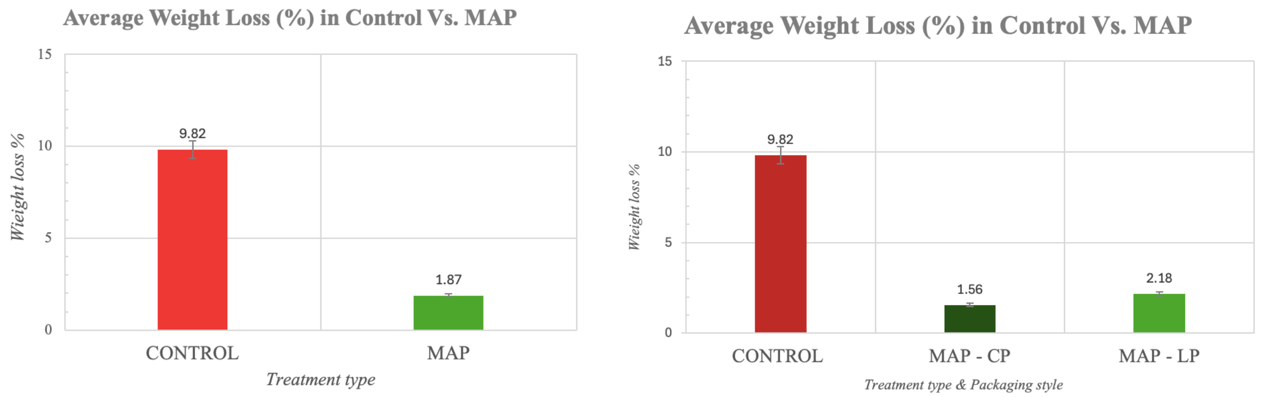

Figure 4: Dolakha Demo I: (Left) Comparison of the Average Weight Loss (%) between the spinach packed in MAP bags and in control conditions (openly stacked); **(Right)** Average Weight Loss (%) of spinach under different packaging conditions i.e. MAP-CP (Compact packaging) & MAP-LP (Loose packaging)

Initial trials in Dolakha demonstrated the efficacy of MAP bags in significantly reducing spinach weight loss compared with traditional packaging. While variations in packaging tightness within the MAP bags showed slight differences in weight loss, MAP packaging outperformed the control conditions. The control group experienced a substantial 8.02% weight loss, whereas the average weight loss of MAP-packaged spinach was considerably lower (1.67 %) (Figure 4). The reduced weight loss in the MAP-treated spinach likely results from the controlled environment inside the packaging, which helps maintain moisture levels and reduces spoilage.

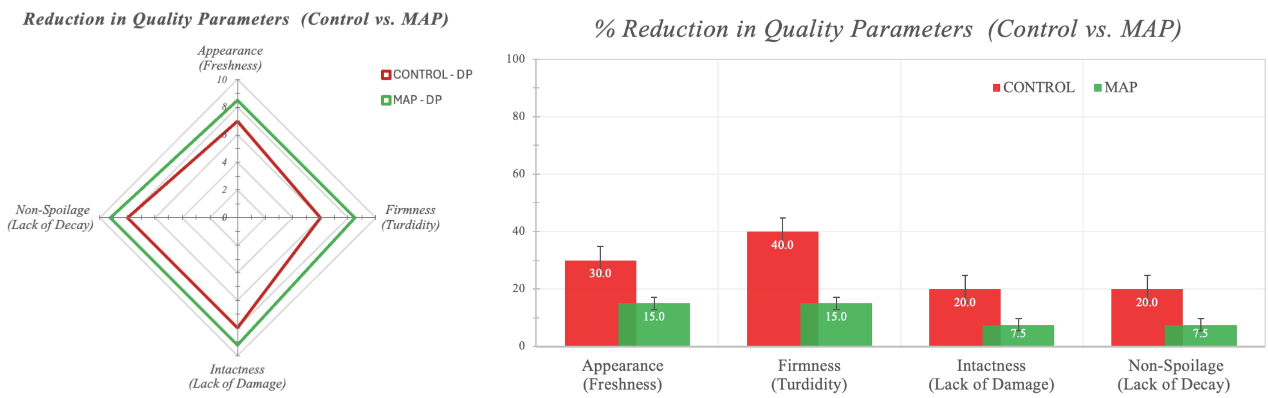

Figure 5: Dolakha Demo I: (Left) Reduction in quality parameters for control vs. MAP packaging at the point of delivery; (Right) Reduction in Quality Parameters of Spinach (Control vs. MAP)

Note: The radar chart above compares the reduction in quality parameters of the commodity at the point of delivery under control and MAP conditions. The different quality parameters are measured on a scale of 1 to 10, with 10 being the best possible score. The control group (red line) shows a significant reduction in quality parameters compared to the MAP group (green line). This suggests that MAP packaging is effective in preserving the quality of various commodities during the post-harvest period.

Weight loss data were further supported by a comparison of key quality parameters, including appearance (freshness), firmness (durability), intactness (lack of damage), and non-spoilage (absence of decay). As seen in both visual representations (Figure 5), the control group showed a significant reduction in the quality parameters compared to the MAP group. The radar chart clearly indicates that the control group experienced a noticeable decline across all quality metrics, particularly in appearance and firmness. Conversely, the MAP group maintained better preservation of most quality parameters. The bar graph further supports these findings, showing that the control group experienced higher reduction in percentage in all quality metrics as compared to MAP packaging.

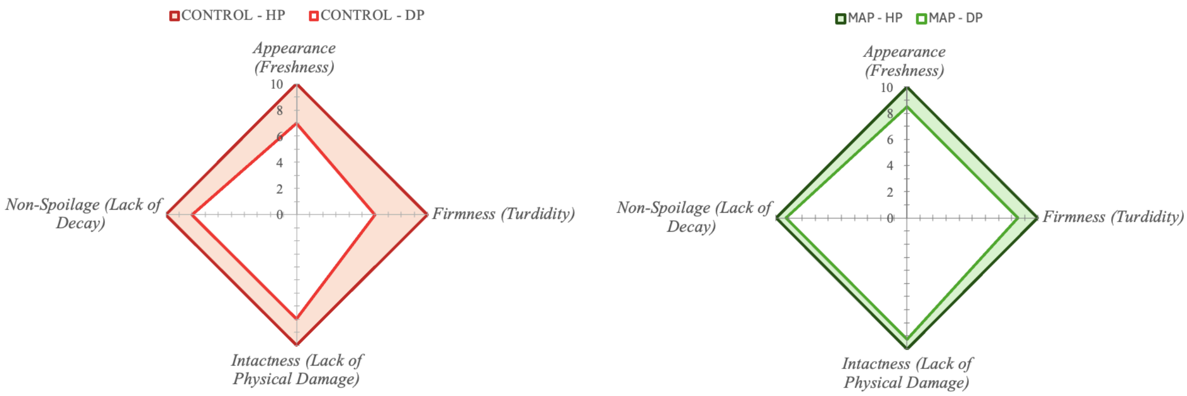

Figure 6: **Dolakha Demo I: a)** (left) Changes in the various quality parameters of spinach: (Left) Comparison between control conditions at the point of harvest (Control - HP) and at the delivery point (Control - DP); **b):** (Right) Comparison between MAP packaging conditions at the point of harvest (MAP - HP) and at the delivery point (MAP - DP).

The webbed plots for changes in spinach quality parameters under control and MAP conditions (Figures 6a and 6b) illustrates the impact of packaging on produce preservation. The control group, packaged using traditional methods, exhibited a pronounced decline in most of the quality attributes such as appearance, firmness, and non-spoilage from harvest to delivery, as indicated by the substantial shadow areas. In contrast, spinach packaged using MAP demonstrated significantly less deterioration in these parameters, as evidenced by the smaller shadow areas in the corresponding plot. These findings underscore the effectiveness of MAP packaging in mitigating post-harvest losses and preserving product quality.

These results conclusively demonstrate that MAP packaging significantly reduces postharvest losses by maintaining the freshness, firmness, and overall quality of the spinach, thereby enhancing its shelf life and marketability. While the spoilage and damage were less, the major setback was seen in degrading the quality parameters of appearance and firmness.

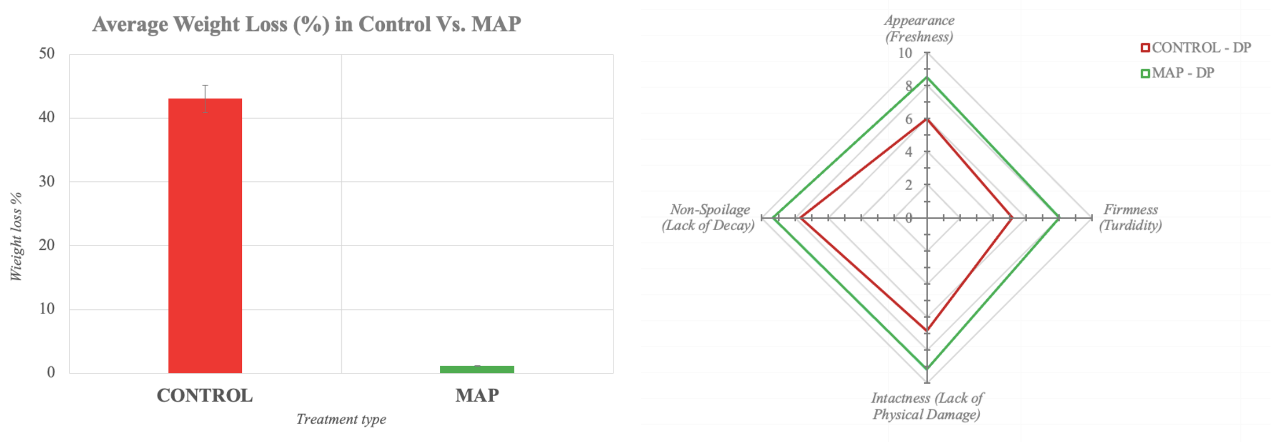

Figure 7: Dolakha Demo 2: (Left) Comparison of the average weight loss between spinach packed in MAP vs. control conditions; (Right) Radar chart illustrating the difference in quality parameters at the point of delivery for Control vs. MAP conditions

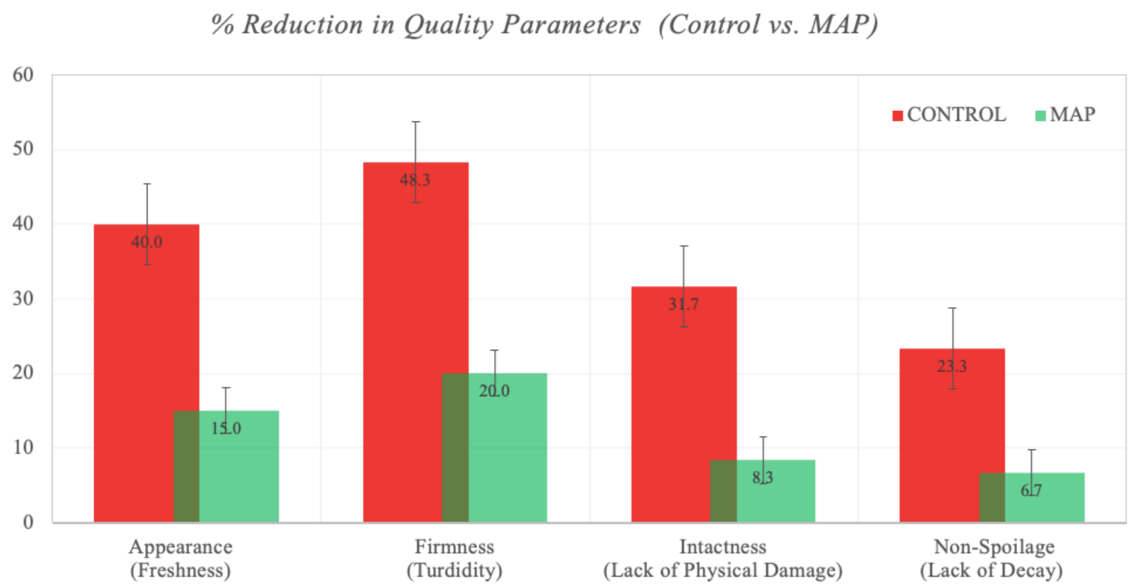

Figure 8: Dolakha Demo 2: Bar graph showing the percentage reduction in quality parameters of the spinach in Control and MAP conditions.

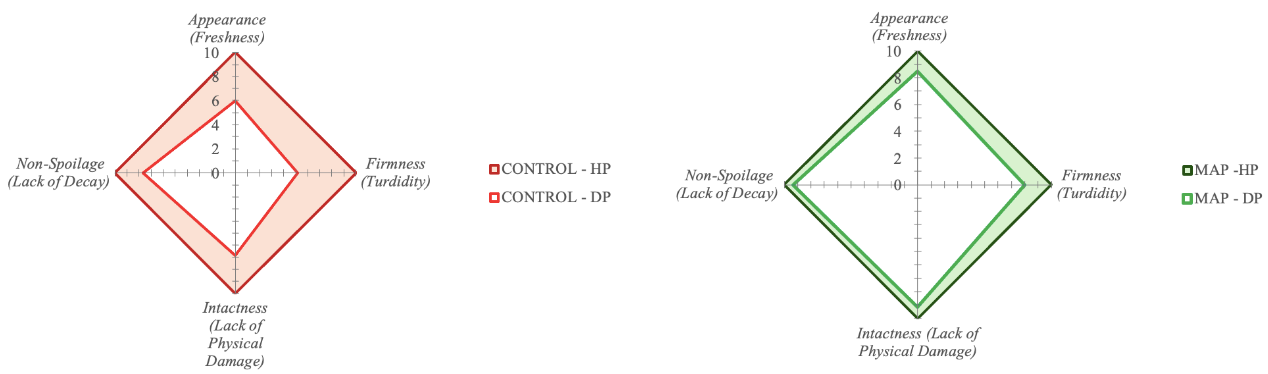

Figure 9: Dolakha Demo 2: Changes in the various quality parameters of spinach: (Left) Comparison between control conditions at the point of harvest (Control - HP) and at the delivery point (Control - DP); (Right) Comparison between MAP packaging conditions at the point of harvest (MAP - HP) and at the delivery point (MAP - DP).

In the second demonstration, harvested spinach faced overnight storage before transportation to the market due to logistical and coordination challenges. This resulted in prolonged exposure to ambient conditions, delaying its market arrival. Despite the colder climate of the region, this delay significantly increased weight loss in the control group, exceeding 40%. In contrast, MAP treatment effectively minimized weight loss, even after extended storage, with a weight loss upto 1.15% (Figure 7). This highlights the ability and importance of MAP bags to preserve the quality of fresh produce, even when transportation is delayed due to logistical or climatic factors, which is very common in Nepal.

Additionally, the radar chart (Figure 7) and bar graph (Figure 8) both clearly demonstrate the effectiveness of MAP in preserving the overall quality of the tested commodities. The bar chart (Figure 8) shows a notable reduction in quality parameters for control-packaged commodities, while MAP-packaged commodities retained significantly better quality, especially in terms of appearance and non-spoilage. Although there was a reduction in firmness and intactness for both treatments, MAP treatment outperformed the control. Similarly, when comparing changes in quality parameters from the point of harvest (HP) to the point of delivery (DP) under both control and MAP conditions, it was evident that the control conditions experienced significantly larger quality losses (Figure 9). These findings suggest that MAP packaging is highly effective in preserving the overall quality of commodities during extended storage and transportation delays.

5.1.2. DHANKUTA DEMO:

In a visit to the Sidhuwa region of Dhankuta, a demonstration was conducted to evaluate the effectiveness of MAP bags for spinach and green peas. Freshly harvested spinach was packaged in two ways: directly compacted in nylon sacks (control) and within MAP bags placed inside nylon sacks (treatment). Similarly, green peas were packaged in netted sacks (control) and within MAP bags inside netted sacks (treatment). Both commodities were transported overnight to Biratnagar and Birtamode markets, arriving in the early morning. Upon arrival, spinach samples were retained for evaluation of weight loss, appearance, turgidity, damage, and decay, while green peas were not assessed due to logistical constraints.

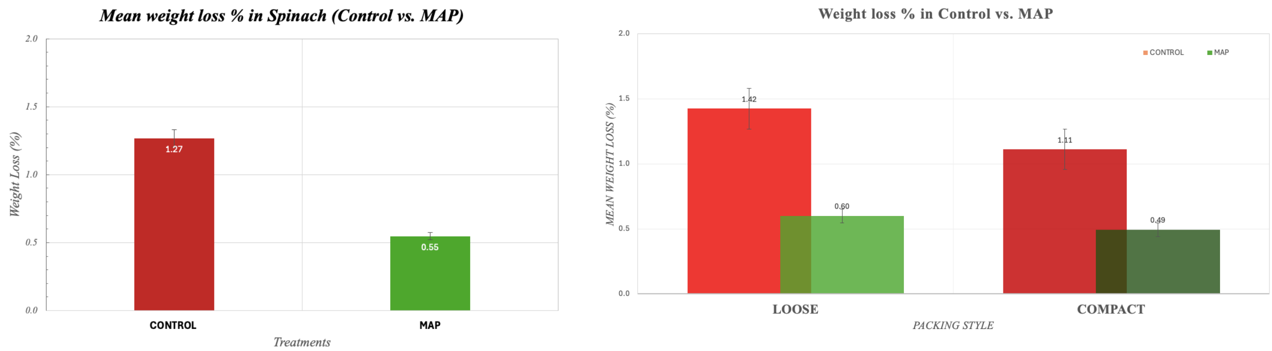

Figure 10: Dhankuta Demo: (Left) a. Mean Weight Loss (%) in Spinach for Control vs. MAP Packaging, **(Right) b.** Comparison of Weight Loss in Spinach in MAP vs. Control conditions with different packing style (density variation)

Similar to previous findings, this demonstration also indicated that spinach packed in MAP bags experienced lower weight loss compared to those packed using traditional nylon sacks. The control group showed a higher mean weight loss of 1.27%, while the MAP group exhibited a much lower weight loss of 0.5% (Figure 10a). Additionally, packaging was conducted in two styles: loose and compact. Notably, packing style had a minor impact on weight loss; in compact packaging, weight loss was slightly less in both control and MAP conditions. However, the MAP group consistently showed lower weight loss across both packing styles as compared to control conditions (Figure 10b). Overall, the results confirm that spinach packed in MAP bags experiences significantly less weight loss compared to those packed in nylon sacks.

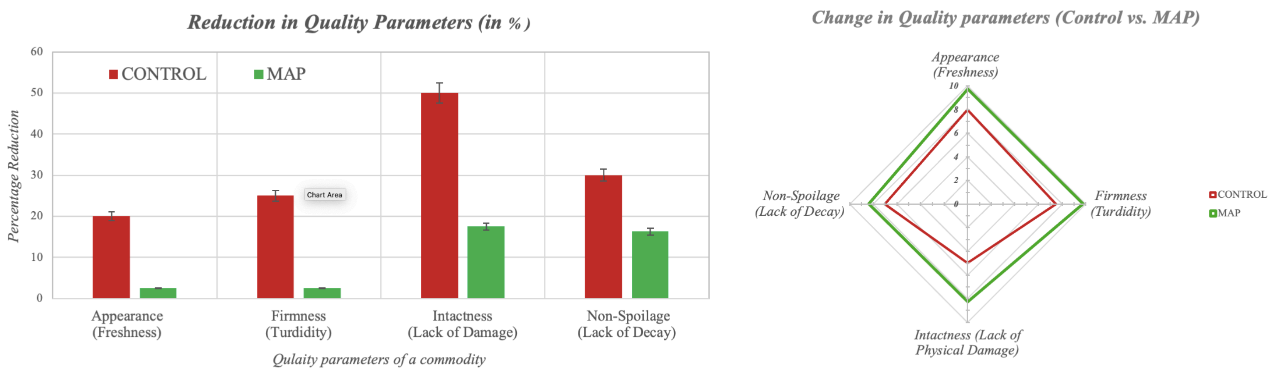

Figure 11: Dhankuta Demo: (Left) a. Bar graph showing the percentage reduction in vairous quality parameters of the spinach in Control and MAP conditions; **(Right)** b. Variations in Quality Parameters in spinach under Control vs. MAP Treatments.

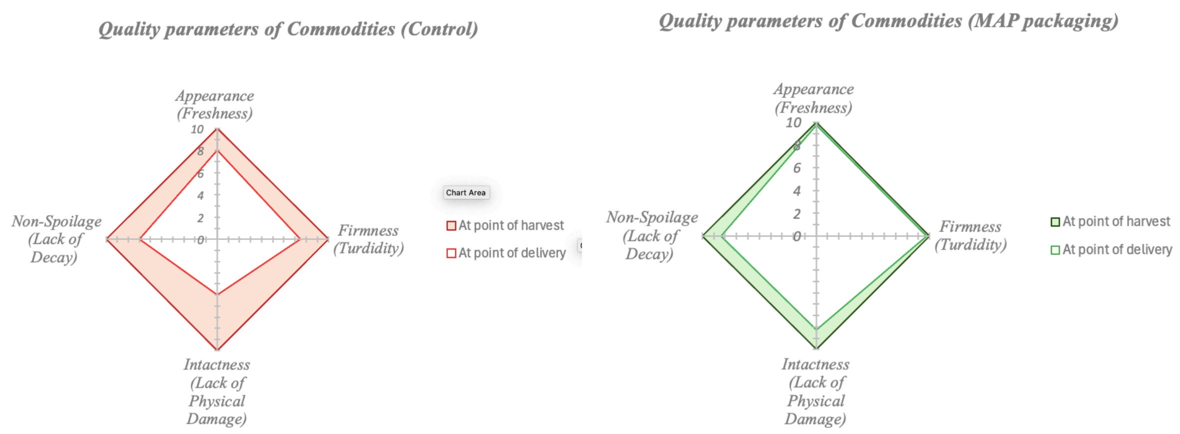

Figure 12: Dhankuta Demo: Changes in spinach quality parameters from harvest (HP) to delivery (DP) under control (left) and MAP packaging conditions (right).

Consistent with previous findings, MAP packaging demonstrated lower reductions in all tested quality parameters compared to the control group, highlighting its effectiveness in preserving spinach quality attributes such as appearance and overall conditions (Figure 11). The radar chart in Figure 11b visually supports this, with the MAP treatment (green line) showing a larger radius than the control treatment (red line), indicating better quality preservation for most commodities. Furthermore, comparing the quality parameters of spinach at the point of harvest versus delivery showed more significant changes in the control group compared to the MAP conditions (Figure 12). This demonstrates MAP's effectiveness in reducing loss and preserving overall quality during the post-harvest period, which is crucial for maintaining the marketability of fresh produce.

These findings underscore the potential of MAP technology to enhance shelf life and reduce post-harvest losses in perishable commodities like spinach, offering a valuable solution for improving supply chain efficiency.

5.1.3. PIACHO DEMO:

Paicho Pasal is a prominent player in Nepal's agribusiness sector, operating across multiple value chains. The company sources produce directly from smallholder farmers through a network of collection centers. By purchasing all produce regardless of quantity and offering a product exchange system, Paicho Pasal has cultivated strong farmer relationships. In addition to processing raw materials into value-added products, the company also sells fresh produce through its own outlets. To address post-harvest losses during transportation, a supply chain demonstration was conducted in collaboration with Paicho Pasal to evaluate the effectiveness of post-harvest technologies such as MAP bags in preserving produce quality of multiple commodities.

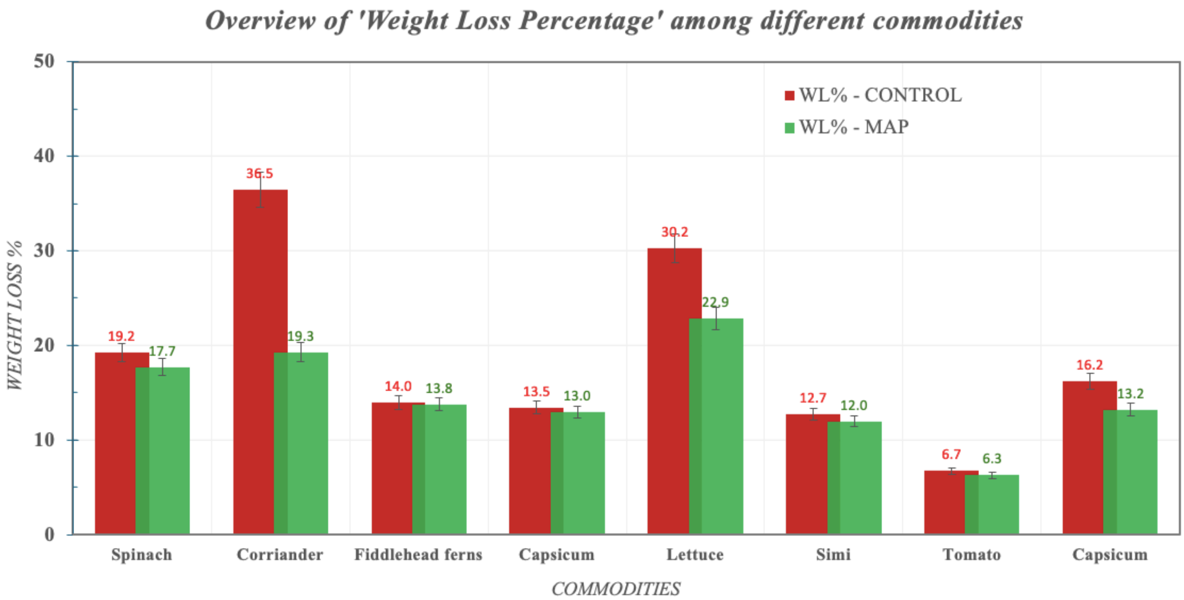

Figure 13: Paicho Demo: Comparison of the average weight loss percentage for multiple commodities packed in MAP bags and control conditions

The visual representation of weight loss data across different commodities indicated notable variations in degrees of weight loss (%) among different commodity types, suggesting that factors such as commodity type, maturity stage, and initial moisture content significantly influence the efficacy of MAP packaging. Commodities with higher respiration rates, for example, may experience greater weight loss, regardless of packaging method.

Despite these variations, a comparative analysis of weight loss percentages in various commodities consistently demonstrated the superior performance of MAP packaging in mitigating weight loss across all analyzed commodities when compared to control conditions. This suggests that MAP's ability to modify the gaseous environment within the package effectively inhibits respiration and transpiration, thereby preserving product weight.

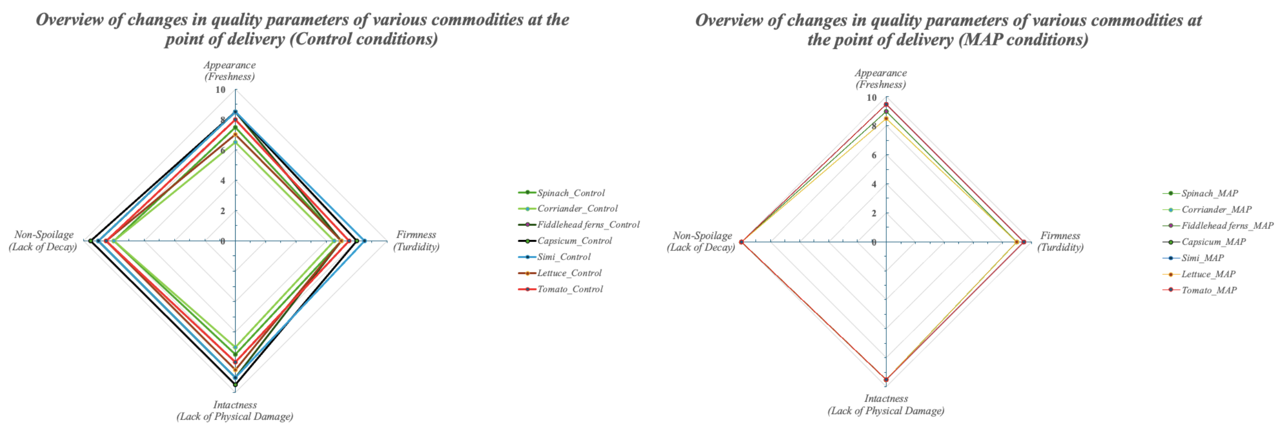

Figure 14: Paicho Demo: Radar charts representing changes in quality parameters of multiple commodities packed in MAP bags (right) and control conditions (left)

The radar charts (Figure 14) comparing quality parameters under control and MAP conditions for multiple commodities also provide valuable insights into the effectiveness of MAP packaging in preserving produce quality. Each radar plot represents a specific commodity, and the distance from the center to the polygon vertices indicates the magnitude of change in each quality parameter. On observing the general trends, the control group consistently demonstrated a decline in quality parameters at the point of delivery for all commodities, as evidenced by the inward movement of the radar plots. This indicates that traditional packaging methods are generally ineffective in maintaining product quality. In contrast, the MAP-packaged commodities exhibit greater stability in quality parameters, as shown by the outward movement or consistent position of the radar plots. This suggests that MAP packaging is effective in mitigating quality deterioration.

The combined analysis underscores the significance of MAP technology in preserving the freshness, firmness, and overall quality of various commodities during the post-harvest period. These findings support the potential of MAP packaging as a valuable tool for reducing post-harvest losses and enhancing the marketability of agricultural products.

5.1.4. MADANPOKHARA DEMO:

Madan Pokhara is a key commercial vegetable production area in Palpa district, which is known for its off-season vegetables. A leading agricicultural cooperative from the region i.e. Madanpokhara Sangam Multipurpose Cooperative Limited, a prominent agricultural cooperative formed in 2019 through the merger of two existing cooperatives, serves over 1,300 smallholder farmers in the region was selected was one of the partner organization to conduct a demo in their supply chain. This cooperative plays a crucial role in the agricultural supply chain by enhancing vegetable collection and marketing strategies while providing microfinance services to its members. It supplies vegetables to major markets in Butwal, Bhairahawa, Pokhara, and Chitwan, and operates its own wholesale and retail stall in Butwal's vegetable market, one of Nepal's largest.

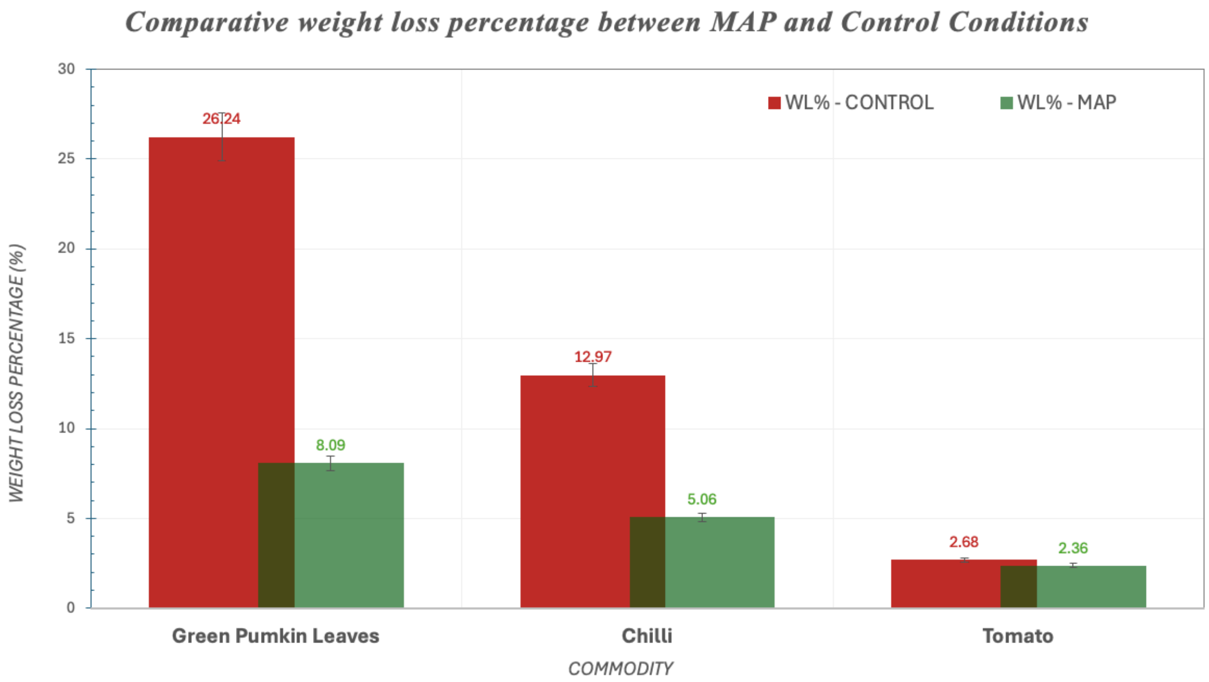

Figure 12: Madanpokhara Demo: Comparative Weight Loss Percentage of Green Pumpkin Leaves, Chili, and Tomato Under MAP and Control Conditions

The bar graph (Figure 12) demonstrates a substantial reduction in weight loss for all three commodities when packaged using MAP compared to the control group. Green pumpkin leaves had the most pronounced reduction in weight loss (by 18.15%), followed by chili (by 7.41%) and tomato (0.53%), as compared to control conditions, highlighting MAP's effectiveness, particularly for leafy vegetables prone to moisture loss. Based on the observed weight loss reduction, it is estimated that MAP can packaging preserve the weight of leafy greens nearly threefold and reduced weight loss in chili by almost half, suggesting its potential to extend the shelf life of these commodities and maintain their marketability. While precise calculations of income increase would depend on the specific market data at particular time and require economic analysis, the reduction in post-harvest losses can translate to significant economic benefits for farmers. By minimizing spoilage and extending shelf life, farmers can command higher prices and reduce the risk of unsold produce. The potential income increase would vary based on factors such as market demand, pricing structures, and the specific commodity.

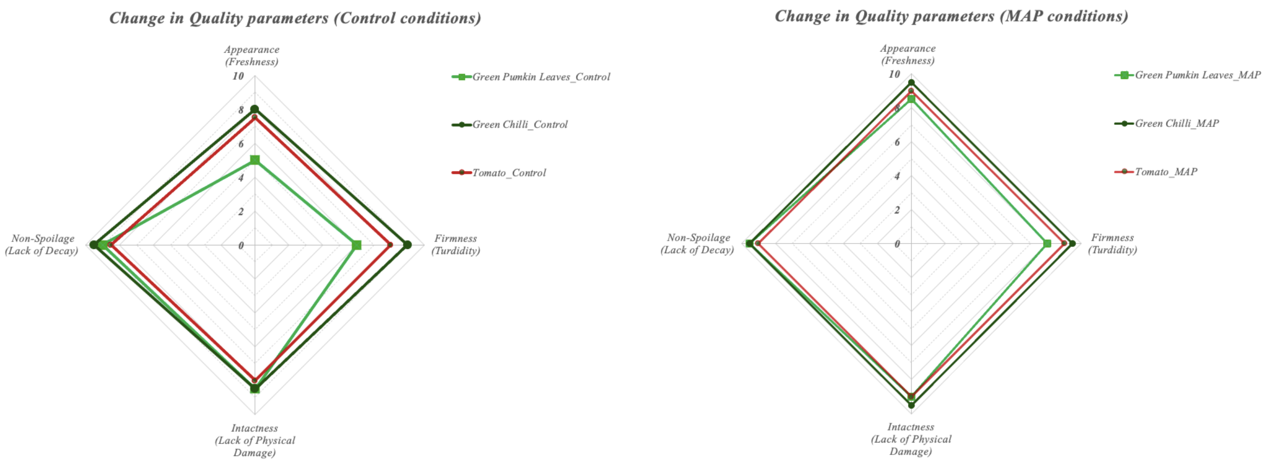

Figure 13: Madanpokhara Demo: Changes in Quality Parameters (Appearance, Firmness, Intactness, and Non-Spoilage) of Tomato, Green Pumpkin Leaves, and Green Chili Under Control Conditions (left)& MAP packaging (right)

The radar chart analysis revealed a significant difference in quality preservation between commodities packaged under control conditions and those using MAP bags. Despite a relatively short supply chain of less than 24 hours, all commodities - tomato, green pumpkin leaves, and green chili - packaged under control conditions exhibited significant quality deterioration over time (Figure 13). This is evidenced by the pronounced inward shift in the radar plots, indicating reductions in appearance, firmness, intactness, and resistance to spoilage. In contrast, commodities packaged with MAP demonstrated remarkable stability in quality attributes, with minimal degradation by the time they reached the delivery point. The radar plots for MAP-packaged commodities remained largely unchanged, signifying the effectiveness of MAP technology in maintaining quality attributes and in mitigating quality degradation. These findings underscore the potential of MAP packaging to significantly reduce post-harvest losses and enhance the value of agricultural produce.

These findings highlight the critical role of MAP packaging in maintaining quality of the fresh produce and hence increasing the consumer appeal. By preserving key quality attributes, MAP technology presents a promising solution for reducing post-harvest losses and enhancing the overall value of agricultural produce. While these visual representations offer a qualitative understanding of the comparative performance between control and MAP conditions, a quantitative analysis with specific data points and statistical measures would provide a more precise evaluation of MAP's impact on product quality.

6. DEMO RESULTS AND IMPACT:

The demonstrations underscored the need for innovative solutions to address post-harvest losses. The lack of standardized packaging and handling practices, driven by cost considerations, highlighted the necessity for adaptable, practical interventions that can be integrated into existing systems.

6.1. Result and Impact at Farmer Level:

Preliminary findings indicate that MAP packaging has the potential to significantly benefit farmers, especially those handling highly perishable vegetables like leafy greens (e.g. spinach). MAP bags consistently reduced weight loss compared to traditional methods and even in cases where weight loss was minimal, MAP packaging better preserved key quality attributes such as freshness and firmness as well as reduced spoilage rates. This will allow farmers more time to sell their produce, reducing the pressure to sell immediately after harvest. The ability to maintain quality over longer periods also means the farmers can transport their produce beyond the nearby local markets without without compromising quality, hence leading to better prices. This not only stabilized their income but also enhanced their bargaining power. While specific case studies with quantifiable income data were not available within the scope of this research, there were some anecdotal evidence suggesting that the traders often differentiate prices based on product quality, with the produce with superior quality and extended shelf life fetching higher prices. The observed price differentials ranged from 50 to 150 rupees per unit for the same commodity depending on the quality, highlighting the potential economic benefits of MAP adoption.

Figure 14: Comparative quality assessment of spinach at the point of delivery. Spinach on the left was packaged using MAP bags, while the spinach on the right was packaged using traditional methods.

Additionally, the reduced risk of damage during transportation, even under adverse conditions such as road blockages due to landslides, further mitigated potential losses, enhancing the economic resilience of farming communities.[5] In addition, the anecdotal evidences from the traders and reatailers also indicated improved produce quality and reduced wastage.

Figure 15: Discarded preishable vegetables as observed at the Butwal Vegetable Market due to the spoilage resulting from extended transportation times to reach the market center.

While MAP packaging has shown promise in preserving produce quality and extending shelf life, its direct impact on farmers is less pronounced than on traders. Farmers have limited control once their produce leaves the farm, so the benefits of improved produce quality are primarily indirect, through potential improvement in overall market prices for their produce. However, realizing the full advantages of MAP packaging requires effective supply chain management and widespread adoption by traders. Ultimately, the most significant benefits are realized further along the supply chain.

6.2. Result and Impact at Trader Level

Traders involved in the commercial demonstrations noted substantial benefits from using MAP technology, including improved product quality and reduced post-harvest losses. Firstly, MAP-packaged produce consistently arrived at market points with better visual quality and lower spoilage rates compared to non-MAP-treated produce. This improvement allowed traders to present fresher, more appealing products to buyers, leading to potential economic benefits that could trickle down to farmers, fostering a more equitable distribution of profits.

[5] Mandanpokhara Cooperative in Palpa, for example, faces significant transportation challenges due to its landslide-prone location. A few years ago, a landslide blocked the roads, causing one of their vehicles loaded with vegetables to be stuck for over 24 hours. By the time the roads reopened and the vehicle reached the market, the perishable produce had spoiled and was discarded, resulting in substantial losses for the farmers. This incident underscores the urgent need for improved infrastructure and alternative routes to mitigate the impact of natural disasters on local agriculture.

The extended shelf life of MAP-treated produce provided traders with greater flexibility in scheduling transportation and sales. This flexibility reduces the need for rush sales, allowing traders to time their market entries better and capitalize on favorable conditions. It also minimizes spoilage and quality degradation during transport, resulting in fewer losses and less waste, contributing to better margins for traders. This efficiency is crucial in Nepal, where rough roads and transportation delays can significantly impact the quality of perishable goods.

Anecdotal evidence from traders consistently indicated that MAP-packaged commodities arrived in better condition compared to those packed using traditional methods. However, despite recognizing these benefits, traders expressed reservations about fully adopting MAP technology due to perceived increased costs and additional process steps.

While traders benefit most from decreased post-harvest losses, they also bear the highest risk as they must pay farmers or cooperatives for the volume procured regardless of losses during transport. This risk makes them more cautious about investing in additional costs associated with MAP bags, which are more expensive compared to their current packaging methods that, while cheaper and sturdier, are less effective in preserving quality. This issue is exacerbated by their focus on minimizing the cost per kilogram of transported produce, which often leads to overpacking and mishandling, ultimately compromising quality. Thus, this short-term focus on immediate cost savings blinds them to the long-term value of preventing losses and gaining stronger bargaining power through better quality produce. As a result, the adoption of advanced post-harvest technologies like MAP bags is hindered by a focus on short-term costs rather than long-term benefits. The traders also noted that mismanaged supply chains and the rush to clear commodities upon delivery often prevented them from fully realizing the advantages of MAP technology.

Overall, while traders are well-positioned to integrate post-harvest technologies and benefit from reduced losses, their focus on cost reduction and perceived higher risk of loss are substantial barriers to adopting MAP technology. These insights highlight the need for strategies to address these short-term concerns and more effective communication of the long-term economic benefits of MAP technology as well as potential support mechanisms to facilitate its broader adoption. Such approach to successfully adopt post harvest technologies could significantly enhance supply chain efficiency and profitability, benefiting all stakeholders involved.

6.3. Result and Impact on Climate Adaptation:

Beyond the benefits for the various stakeholders within the agricultural supply chain, MAP packaging also offers significant potential as a climate adaptation strategy which is often overlooked but provides significant benefits.

First and foremost, by reducing post-harvest losses, maintaining produce's quality, and extending food shelf life, MAP technology contributes to a substantial reduction in spoilage and food waste, a primary source of greenhouse gas emissions. Reducing food waste also translates to lower carbon footprints as resources invested in food production, transportation, storage as well as diposal are conserved. Additionally, the use of biodegradable and potentially reusable MAP bags can further reduce packaging waste. This all contributes to overall environmental sustainability as well as more sustainable and resilient food system.

The extended shelf life enabled by MAP packaging allows also for more efficient transportation, reducing fuel consumption and emissions. Moreover, it provides a buffer against climate-related disruptions, such as extreme weather events, ensuring a more reliable food supply. MAP packaging can give added layer of protection to the food damage that can occur due to obstruction in transporation due to floods, landslides, or other climate-related hazards. The ability to store produce longer also mitigates the need for premature harvesting due to adverse weather, promoting sustainable agricultural practices. This resilience is vital in areas prone to climate variability, offering a sustainable solution to climate-induced challenges.

Moreover, MAP's integration with sustainable packaging solutions enhances food distribution efficiency and minimizes energy consumption. This holistic approach positions MAP as a key strategy in mitigating climate change through optimized food systems.

Overall, MAP packaging offers a multifaceted approach to climate adaptation by reducing food waste, improving supply chain efficiency, and enhancing agricultural resilience. Despite challenges, the substantial benefits of MAP technology in mitigating climate change impacts justify further exploration and implementation. While its potential is significant, wider adoption and integration into agricultural practices are essential to fully realize its benefits and develop as valuable tool in building climate-resilient food systems.

7. LESSON LEARNED AND RECOMMENDATIONS:

The action research project provided some valuable insights into the challenges and opportunities associated with implementing the new post-harvest technologies within Nepal's agricultural landscape. These findings offer crucial guidance for improving post-harvest practices and integrating innovative technologies into Nepal's agricultural supply chain. While the project demonstrated the effectiveness of MAP bags in preserving product quality, it also highlighted broader systemic obstacles to widespread adoption.

7.1 Key insights and learnings

- **Effectiveness of MAP Technology:** The use of MAP bags has shown to be promising technology to reduce post-harvest losses and extended the shelf-life of various horticultural commodities within Nepal's agricultural supply chain. The results were especially pronounced in leafy greens, which are highly perishable.

- **Contextual Adaptation:** Since each supply chains vary significantly based on location, commodity, and stakeholder dynamics, the successful adoption of MAP technology needs a tailored approach as well as the deep understanding of local agricultural practices, supply chain dynamics, and the specific needs of traders and farmers. A one-size-fits-all approach is ineffective in addressing the diverse challenges and opportunities within Nepal's agricultural sector, this is where Mandala Agrifresh can play a crucial role, offering customized consultancy and recommending tailored solutions and appropriate technologies.

- **Stakeholder Engagement:** Effective project implementation hinges on strong collaboration with farmers, traders, and other key stakeholders. Their active involvement is crucial for project success, fostering trust, identifying challenges, and ensuring long-term sustainability.

- **Farmer Practices and Awareness:** This remains a significant challenge to technology implementation. Inconsistent post-harvest handling, including the mixing of produce with varying quality, hindered the application of technologies requiring uniform input materials.. This inconsistency also negatively affects quality-based pricing systems, which could otherwise serve as an incentive for adoption. Raising awareness about the importance of quality and the economic implications of post-harvest losses is crucial.

- **Challenges with Handlers and Laborers**: Handlers, drivers, loaders, and laborers, who often lack education and awareness of proper post-harvest handling techniques, significantly impact the quality and systematic handling practices. These individuals are typically underpaid and prioritize completing their tasks quickly, often compromising the quality and safety of the commodities.

- **Supply Chain Bottlenecks:** Inefficient practices, poor record-keeping, rushed transportation, and lack of cold storage hinder the effective use of post-harvest technologies. In addition, limited access to cold chain facilities and efficient transportation networks further constrains the potential of MAP technology, making it essential to address these infrastructure gaps for long-term success.

- **Pricing Dynamics and Quality Differentiation:** Some traders often offer different prices to farmers based on the quality of the produce, with higher quality fetching better prices. For instance, a trader in Butwal reported offering up to 100 rupees more for the better quality produce of the same commodity. However, traders may hesitate to pay a premium for graded produce mainly to offset the risks they face, including quality deterioration, transportation damage, and market price fluctuations.

- **Trader Priorities and Practices:** Traders prioritize product quality over weight due to its direct impact on bargaining power and sale prices. To account for potential weight loss, they often deduct a percentage of the weight at procurement for example, requesting 22-23 kg of produce in a crate labeled as 20 kg to account for potential losses. While this practice complicates post-harvest loss assessments, the traders typically adjust procurement volumes or profit margins accordingly. However, since quality deterioration significantly reduces market value, it underscores the critical importance of timely and proper post-harvest handling. This emphasizes the need to encourage traders to adopt technologies that preserve produce quality.

- **Trader Behavior and Incentives:** Traders primarily have short-term focus on minimizing costs and maximizing profits, hindering the adoption of MAP technology despite its long-term benefits. Incentive structures that promote improved product quality and reduced losses that ultimately adds value to margins could encourage wider adoption. Additionally, the potential cost reductions through MAP bag reuse need to be explored.

- **Economic Feasibility and Market Dynamics:** Despite recognizing the benefits of improved produce quality, traders are hesitant to invest in MAP technology due to its higher costs compared to traditional packaging.[6] Traditional packaging is cheaper and sturdier but less effective in preserving quality. This focus on short-term cost savings, immediate margings and risk aversion hinders the adoption of this technology, despite its potential long-term benefits. While there is potential to reduce packaging costs through the reuse of MAP bags, traders have not yet explored this option. Additionally, the potential gains from preventing losses and securing better prices with MAP bags remain unrealized. Therefore, the economic feasibility of MAP technology, despite its significant benefits, requires careful consideration of initial material costs and potential increases in operational expenses.

- **Flexibility in Harvesting and Market Access:** The use of MAP bags and other postharvest technologies can provide farmers with greater flexibility in harvesting schedules and enabled access to wider markets by extending the shelf life of the produce. This flexibility also reduced dependency on weather-specific harvesting and transport patterns. Hence, promoting the adoption of technologies could be continued that offers flexibility and improve market access.

- **Capacity Building:** Empowering stakeholders through comprehensive training on post-harvest handling, technologies and their usuage, as well as business management is essential. Hence, capacity building was one of the key component of this action research, focusing on training farmers and traders in post-harvest handling and the technology usuage. These sessions were designed to raise awareness, improve practical skills, and build confidence in adopting new technologies. Training included hands-on demonstrations of MAP bag usage, emphasizing their benefits in reducing losses and maintaining produce quality. A list of capacity building activities performed during this project are highlighted in the Annex. Feedbacks indicated that these capacity-building efforts significantly boosted the acceptance and enthusiasm for MAP technology among stakeholders. However, ongoing training and follow-up support are essential to reinforce these practices and ensure long-term adoption.

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[6] Traditional packaging, typically polythene bags, costs between 10 and 20 rupees per bag, depending on it's quality. While MAP bags are slightly more expensive, costing around 30 rupees per bag, the added cost per kilogram is offset by the significant reduction in losses achieved with MAP packaging. For e.g. One of the trader reported losing approximately 5 kilograms out of a 15 kilogram bag of produce when using traditional packaging. This highlights the substantial economic impact of post-harvest losses and emphasizes the potential cost-effectiveness of MAP technology in the long run.

- **Difficulties in Reliable Data Collection**: Obtaining reliable information from stakeholders about production, procurement, and trading activities posed a significant challenge. This difficulty hindered the planning of visits for demonstrations. Frequently, during visits, the available commodities were insufficient in quantity or quality for ideal trials. Additionally, there were timing gaps between packaging and loading, leading to difficulties in tracking and assessing the commodities. At the point of delivery, commodities were often misplaced or sold rapidly, limiting proper data collection and feedback.

7.2 Recommendations, Future Considerations and Next Steps:

This action research project, while demonstrating the potential of MAP technology, also highlighted several areas for improvement.

Firstly, the study's focus on technology efficacy limited its exploration of broader supply chain dynamics and economic impacts. A more comprehensive evaluation, including pricing analysis and cost-benefit assessments, is crucial for understanding the proper value proposition of the postharvest technologies used. Such analysis will help pinpoint the exact monetary value or impact on the major stakeholders, which is crucial for broader adoption.

Secondly, the role of human factors in post-harvest management cannot be overstated. The behavior of handlers, drivers, and laborers significantly influences product quality. These individuals often lack awareness of proper post-harvest handling practices and are typically underpaid, leading to rushed and careless handling. So, in addition to the traders and farmers, investing in training and awareness programs for these individuals is essential. Additionally, establishing standardized operating procedures and quality control measures can mitigate the impact of human error.

Thirdly, the project encountered challenges in data collection and standardization due to the complex and often informal nature of Nepal's agricultural supply chains and it's actors. Developing robust data collection protocols and building strong partnerships with appropraite stakeholders will be crucial for future research. Reliable information from stakeholders regarding production, procurement, and trading activities is essential for planning demonstrations and assessing the impact of post-harvest technologies.

To address these limitations and for future considerations some recommendations are as follows:

- **Customized Approach:** While there is need of standardized data collection protocols and monitoring systems to track the performance of postharvest technologies and informed decision-making, a tailored postharvest management strategies and interventions is important. These strategies should address the specific needs of different stakeholder groups, regional constraints, supply chain dynamics, and the characteristics of various agricultural regions and commodities. Developing region-specific and commodity-specific guidelines for the use of MAP bags and other technologies will optimize their benefits under varying environmental and logistical conditions.

- **Comprehensive Evaluation:** Future studies should expand the research scope beyond technology efficacy to incorporate a comprehensive assessment of technology's economic impacts, including pricing dynamics, cost-benefit analysis, and value proposition of the technologies for the stakeholders involved.

- **Supply Chain Optimization:** Addressing the challenges posed by the informal and often inefficient supply chain is crucial. Improving handling practices, reducing losses during transportation, and ensuring proper storage conditions are essential for maximizing the benefits of MAP technology.

- **Reliable Partnerships for Data Collection**: Identify and collaborate with reliable partners who can adhere to guidelines for harvesting, procuring, and recording data. These partners should be capable of maintaining commodities for observation and data collection over time, ensuring comprehensive analysis of the impact.

- **Monitoring and Evaluation Systems:** A significant constraint in this study was the inability to reliably monitor changes in quality parameters due to factors such as stakeholder unreliability, uncertain procurement volumes, and and insufficient time and conditions for scientific data collection in real field environments. To address this, it is essential to involve reliable supply chain actors and implement robust monitoring and evaluation systems. There should be a mechanism for the the stakeholders involved to do the regular data collection, analysis, and feedback mechanisms will help identify areas for improvement and ensure that the technological interventions deliver their intended benefits.

- **Financial Incentive Mechanisms:** In order to encourage the stakeholder and getting them onboard as early adopters of innovative postharvest echnologies, options for providing financial incentives has to be explored, such as subsidies or rebates, low-interest loans, etc that could offset their initial costs.

- **Enhanced Training Programs:** Strengthening human capital couldn't be stressed enough. Comprehensive training programs on the use of new postharvest technologies like MAP technology should be developed for farmers, traders, as well as all other stakeholders. Investing in training programs for relevant supply chain actors will improve post-harvest practices and also the technology adoption. Such programs should include practical demonstrations, hands-on sessions, and easy-to-understand materials to ensure effective knowledge transfer. In addition, a series of follow-up training sessions could be implimented and create a platform for continuous learning and knowledge sharing among stakeholders. Peer-to-peer learning networks could be established where farmers and traders can share experiences and solutions, fostering a community of practice that supports ongoing improvement in postharvest management.

- **Strengthened Extension Services:** Investment in capacity building programs esp. for the extension workers has to be done to provide ongoing support and guidance to farmers and traders.

- **Public-Private Partnerships:** Building strong collaborations between government agencies at all levels, agricultural cooperatives as well as the stakeholders from the private sector involved in agricultural supply chain, and civil society organizations is essential for promoting MAP technology adoption. Strengthening stakeholder partnerships will be necesasary to build strong collaboration between farmers, traders, and government agencies to facilitate knowledge sharing, data collection, and technology adoption. Also creating successful case studies demonstrating the technology's impact on reducing post-harvest losses and improving economic conditions for all stakeholders will encourage wider adoption of innovative post-harvest solutions like MAP bags.

- **Policy and Financial Support:** Government policies and financial support, such as subsidies for technologies like MAP bags and ethylene absorbers, and grants for infrastructure improvements, can significantly encourage the for commercialization and adoption of post-harvest technologies. Additionally, supportive policies including subsidies, incentives, and extension services can create a favorable environment for farmers and traders to implement better post-harvest management practices.

ADDITIONAL CONSIDERATIONS:

Pilot Implementation: A pilot projects in selected regions could be condcuted to test and refine different implementation models, identify best practices for scaling up post harvest technologies, demonstrate the economic viability of MAP technology and build trust among stakeholders. For e.g. in Gulmi *'Paicho'* given its strong presence in agriculture sector appears to be a ideal parther to collaborate for the sucessful demo, while in Palpa region, *Madanpokhara Sangam Coopeartive*, *Milansar Cooperative*, are the potential candiates to start commodity-specific pilot projects. Also given the previous extensive previous works in the region, *'Ribikot Rural Muncipality'* positions itself as a potential local govermental partner to support and systemize the postharvest technological interventions in supply chain of fresh produce in the region.

The successful demo with the priority commodities of Milansar and Madanpokhara Sangam Cooperative followed by the advocacy in the local government have the potential for the integration of the postharvest technologies within their supply chain. Some of the advocay activities conducted and the efforts made during this project are detailed in Annex 2. Also, the partnership with the local organizations (REDA) in Palpa, could be the key to successfully integrating the postharvest technologies via their partner cooperatives like Milansar. In addition, there are multiple avenues of partnership and collaboration with REDA / Hefer International for the future pilot works in Palpa cluster.

Similarly, the '*Paicho'* has huge potential to be a model agricultural stakeholder by implementing appropriate postharvest technologies within the supply chain to not only reduce the losses but also to preserve the marketable quality of the procured commodities. However, for more efficient and effective supply chain management some issues need to be addressed mainly regarding the collection, handling and management of the harvested produce.

Scaling-Up Strategies: To maximize the impact of MAP technology, after pilot studies strategies for scaling up the shoud be developed beyond the initial demonstration sites. This could involve identifying new districts and commodities that could benefit from the technology, fostering partnerships with private sector players, and leveraging existing agricultural networks for wider dissemination. Additionally, consumer awareness campaigns can be launched to stimulate demand for high-quality, sustainably produced agricultural products. As the scaling process progresses, robust data collection systems should be established to monitor the technology's economic, environmental, and social impacts.

Economic and Environmental Sustainability: The reduction of postharvest losses not only improves economic outcomes for farmers and traders but also has a positive environmental impact by reducing waste and resource use. However, these benefits are often overlooked in favor of immediate economic gains. Hence, the economic and environmental benefits of post-harvest technologies could be further promoted by highlighting the role of MAP technology in reducing food waste, conserving resources, contribution to sustainbililty golas and enhancing the economic viability of farming operations through better market access and reduced losses. Additionally, environmental impact assessments could be integrated into project evaluations to provide a more comprehensive view of the benefits of postharvest technologies.

Potential for Future Research:

Given the study's limitations, particularly the absence of detailed pricing data and the challenges in isolating the specific impact of MAP technology within complex supply chain dynamics, underscore the need for further research and monitoring. Some of the themes could include but not limited to:

- Conducting in-depth economic analysis to quantify the cost-benefit ratio of MAP technology adoption
- Investigating the role of post-harvest technological interventions on accessing wider markets for fresh produce currently limited to local or nearby markets.
- Exploring the potential of integrating MAP technology with other post-harvest interventions, such as grading, sorting, and/or other complementary postharvest technologies like ethylene absorbers, etc.
- Investigation on the effect of postharvest packaging technologies on food safety, nutrition, and consumer acceptance.
- Assessing the environmental impact and sustainability of MAP technology compared to traditional packaging methods.

8 CONCLUSION:

This action research highlights the transformative potential of Modified Atmosphere Packaging (MAP) technology in reducing Nepal's significant post-harvest losses and improving the agricultural supply chain. By preserving produce quality and extending shelf life, MAP technology offers a promising solution to the challenges faced by farmers and traders.

To maximize the impact of MAP and other post-harvest technologies, a multi-faceted approach is essential. Partnering with the right stakeholders and conducting real-world demonstrations with priority commodities will create compelling case studies that showcase the benefits of these technologies. Continuous monitoring and multiple rounds of integration examples are crucial for market acceptance and visibility to boost the integration rates.

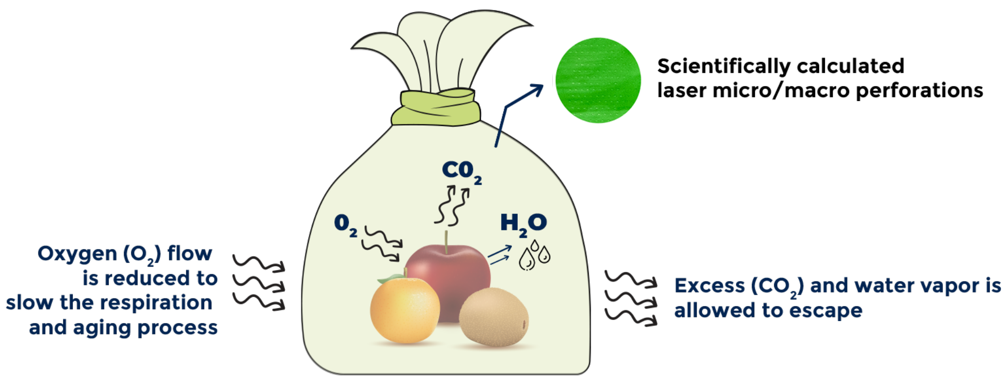
Collaboration with local governments is vital, especially in the early stages of introducing post-harvest technologies. Subsidy programs can facilitate early adoption, and policy-level support can integrate these technologies into the broader agricultural supply chain.

Awareness and capacity-building programs for supply chain actors, coupled with improved post-harvest handling, stricter food safety guidelines, and waste reduction efforts, are critical. Creating impactful case studies through collaboration with local stakeholders will further enhance the integration of post-harvest technologies, benefiting farmers, traders, and consumers alike.

The lessons learned and recommendations provided in this report offer a clear roadmap for future initiatives, ensuring that these innovations are effectively integrated into Nepal's agricultural landscape, contributing to a more sustainable and efficient supply chain.

ANNEX 1: POST-HARVEST TECHNOLOGIES USED

Modified Atmospheric Pacakaging (MAP) bags	Ethylene Absorbers (Sachets, Tubes, and Paper)	Germination Sheets
• Creates a modified atmosphere inside the packaging to extend the shelf life of fresh produce and keeps them fresh for longer. • Decreases respiration and slows ripening. • Maintains ideal humidity to prevent weight loss and wilting.	• Effectively absorb ethylene gas and excess moisture, extending the shelf life of fruits, vegetables, and flowers during storage, transportation, distribution, and retailing	• Absorbs excess moisture and condensation inside packaging, preventing fungal growth. • Has a high water-absorbing capacity, doesn't easily disintegrate when wet, hence making it ideal for maintaining freshness in packaging boxes.



Source: Mandala Agrifresh *(https://www.mandalaagrifresh.com/product-detail/modified-atmosphere-packaging-map-bags)*

MAP works by reducing the concentration of oxygen (O_2) and increasing the concentration of carbon dioxide (CO_2) levels inside the package. This is achieved through the natural respiration of the fresh produce, which consumes (O_2) and produces (CO_2) to reach equilibrium, which slows down the respiration of the fresh produce, therefore extending the shelf life. Furthermore, MAP also helps to maintain ideal relative humidity inside the package, which prevents weight loss, wilting and shriveling of harvested produce.

Features of MAP bags:

- Slows down the ripening process.
- Reduces moisture loss, wilting and dehydration.
- Blocks the mode of action and biosynthesis of ethylene.
- Reduces decay and rotting by directly inhibiting the growth of pathogens.
- Slows the yellowing of green tissues by preventing chlorophyll degradation.
- Nature-friendly, made up of natural minerals, chemically inert and non-toxic.
- Biodegradable and can be disposed as normal waste.
- Suitable for fruits, vegetables, and flowers

Packaging fresh produce in a MAP bag can increase the shelf life of fresh produce and reduce weight loss by up to five times (depending of produce).

Image: Informative brochure on the postharvest technologies avaibale at Mandala Agrifresh

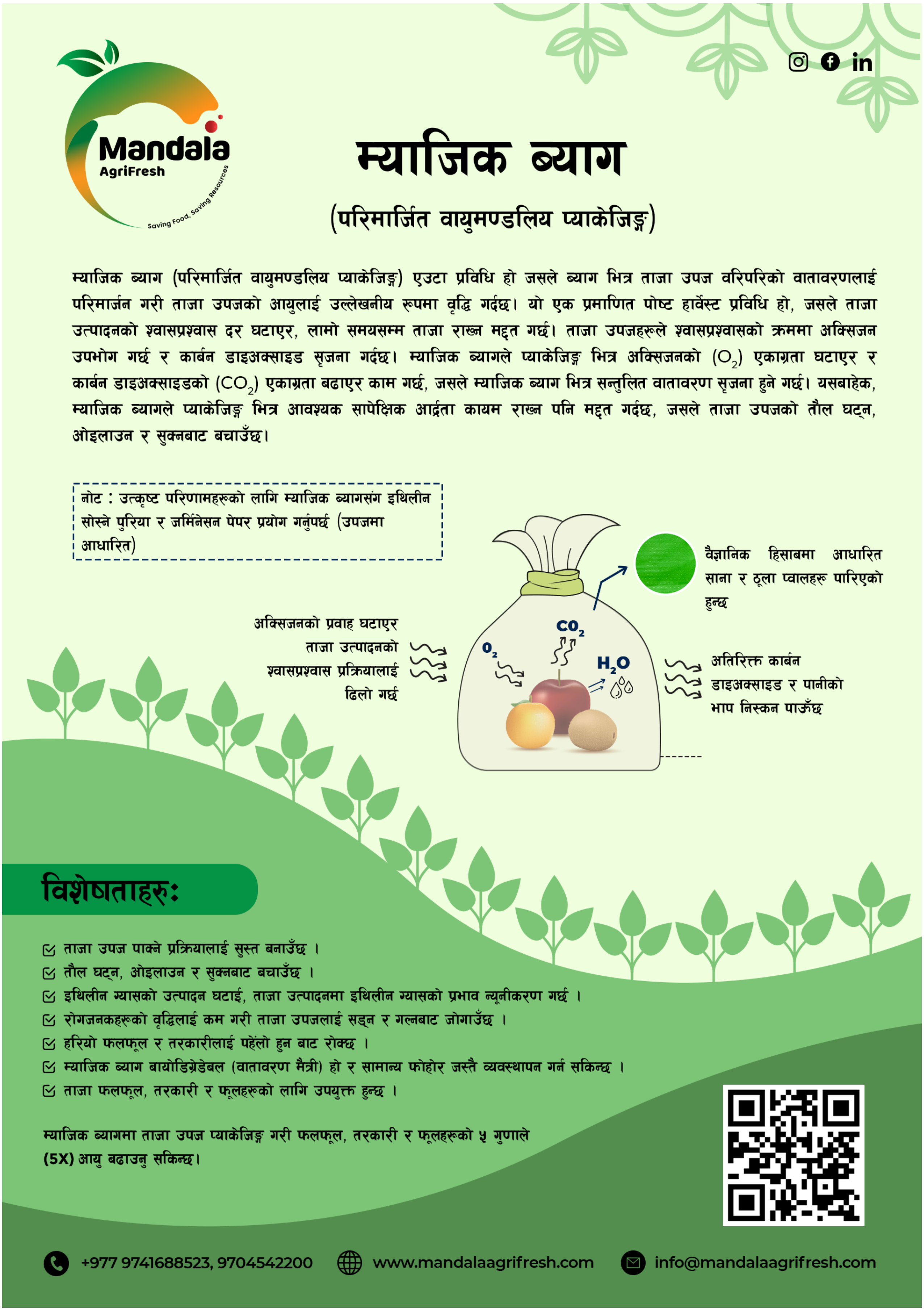


Image: Informative brochure about Modified Atmospheric Packaging (MAP) Bags

ANNEX 2: ADVOCACY EFFORTS DURING THE PROJECT DURATION

The project successfully engaged with various government entities and stakeholders to promote the adoption of MAP technology and address post-harvest challenges. Key collaborations included:

S.N.	ORGANISATION / GOVERNMENT ENTITY	DISTRICT	REMARKS
1	Ribdikot Rural Municipality	Palpa	Multiple meetings were held with key officials, including the Chairman, Administrative Head, and Agriculture Officers, to discuss post-harvest management (PHM) and explore collaboration opportunities. Successfully organized orientation sessions on PHM for local farmers, submitted a proposal for a post-harvest program emphasizing MAP bag adoption, and discussed about potential technical support for cold storage management in the region.
	Agriculture Knowledge Centre (AKC) & Prime Minister Agriculture Modernization Project (PMAMP)	Tansen, Palpa	Met with organizational heads to discuss post-harvest technologies. Received valuable insights on the region's challenges and were invited to contribute to training sessions for commercial farmers. PMAMP has shown interest in integrating post-harvest technologies and coordinating future collaborations
2	AKC Rupandeni & PIU Rupandehi	Siddharthanagar, Rupandehi	Engaged with heads of organizations to discuss post-harvest technologies and collaboration. With their positive interest and invitation, delivered an orientation session on PHM to agriculture technicians from all municipalities in Rupandehi.
3	Sandhikharkha Municipality	Arghakhanchi	Met with municipal officials to discuss PHM technologies and explore potential future collaborations
4	Bhimeshwor Municipality	Dolakha	Met with the Mayor and officials to explore future PHM program collaborations. Organized an orientation on PHM in collaboration with municipal agriculture officers. The Ward Chairman of Makaibari expressed interest in conducting a program for commercial farmers and hinted at potential budget allocation following a successful demonstration.
5	Agriculture Knowledge Centre (AKC)	Arghakhanchi	Engaged with organization heads to discuss adoption of post-harvest technologies to reduce losses in Mandarin and explore tehnical support on citrus in cold storage. A PHM orientation session for commercial vegetable farmers was conducted in collaboration with AKC. Plans for further action research together with AKC in progress.

7	Taha Municipality	Makawanpur	Introduced post-harvest technologies and discussed the potential demonstrations in the vegetable supply chain. The Mayor expressed interest in conducting PHM programs and integrating in the future programs of plaika, conditional on positive demonstration outcomes.
8	Chakraghatta Rural Municipality	Sarlahi	The Chairman showed interest in PHM technologies and committed to supporting future PHM programs to reduce post-harvest losses in the upcoming fiscal year.
9	Directorate of Agriculture Development, Hetauda, Bagmati Province	Makawanpur	Met with representatives to introduce PHM technologies and discuss potential collaborations. Positive feedback received with a commitment to explore integration in upcoming programs. Follow-up required.
10	Directorate of Agriculture Development, Butwal, Lumbini Province	Rupandehi	Met with organization heads and other officials and introduced about the postharvest technologies. Discussed potential action research on PHM technologies and agreed to support extension efforts. Assistance offered for training and orientation sessions.
11	Gaidahawa Rural Municipality	Rupandehi	Met with the Mayor and Administrative Head to introduce the postharvest technologies and discuss the potential future collaborations. After postive response from the meeting submitted a proposal for the conductin PHM programs. Follow-up required to finalize the joint efforts.
12	Tansen-9, Ward Office Madanpokhara	Palpa	Engaged in discussions on PHM technologies and potential collaboration. Positive feedback received, with assurances of support for future programs following successful demonstrations.
14	Tansen Municipality	Palpa	Productive meeting with the Agriculture Department and connected partners, including HEIFER and REDA. Discussions focused on packaging, branding, and support for cold storage operations, with strong commitment to collaborative efforts.

ANNEX 3: CAPACITY BUILDING ACTIVITIES

S.N.	DATE	TRAINING LOCATION	DISTRICT	NO. OF PARTICIPANTS
1	13-Jan-24	AKC, Arghakhanchi	Arghakhanchi	19
2	04-Feb-24	Samaj Sewa Sana kisan Krishi Sahakari, Makaibari	Bhimeshwor, Dolakha	43
3	17-Feb-24	Madan Pokhara Sangam Multipurpose Cooperative	MadanPokhara, Palpa	247
4	18-Feb-24	Purbakhola Women Cooperative (Purbakhola Rural municipality)	Purbakhola, Palpa	43
5	18-Feb-24	Purbakhola Women Cooperative (Purbakhola Rural municipality)	Purbakhola, Palpa	34
6	19-Feb-24	Ruru Sana Kisan Sahakari	Baletaksar, Gulmi	65
7	19-Feb-24	Nawaratna Krishi Sahakari	Birbas, Gulmi	47
8	20-Feb-24	Mathi Rukhse, Paicho	Gulmi	18
9	20-Feb-24	Tallo Rukhse, Paicho	Gulmi	14
10	20-Feb-24	MaitriDevi Multipurpose Cooperative	Dhurkot, Gulmi	40
11	20-Feb-24	MaitriDevi Multipurpose Cooperative	Jaishithok, Gulmi	39
12	21-Feb-24	MaitriDevi Multipurpose Cooperative	Madane, Gulmi	49
13	21-Feb-24	MaitriDevi Multipurpose Cooperative	Purkotdaha, Gulmi	45
14	21-Feb-24	Fruits Trading Associaton	Tamghas, Gulmi	19
15	17-Mar-24	Shree Bhanjyangpokhara Krishi Sahakari Sanstha Ltd.	Bhutuke, Bhanjyang, Gorkha	36
16	15-May-24	Palung	Taha, Makawanpur	38
17	31-May-24	Chakraghatta	Sarlahi	19
18	02-Jun-24	Palung Multipurpose Sahakari Sanstha	Palung, Makawanpur	25
19	13-Jun-24	REDA, Tansen	Tansen, Palpa	33
20	14-Jun-24	Paicho, Tallo Guwaga	Chhatrakot, Gulmi	34
21	14-Jun-24	Paicho, Mathillo Guwaga	Chhatrakot, Gulmi	17
22	15-Jun-24	Shree Baragdahiya, Aathgharwa, Thulo Yechawal (Smart Krishi Gaun Karyakaram)	Gaidahawa, Rupandehi	39

Note: *Informal meetings with stakeholders, as well as orientation sessions (e.g., information sharing, discussions, sample distributions, personal trials), are not listed here. Follow-up meetings during the demo and additional orientation sessions and briefings for farmers and stakeholders are also excluded. These activities, while valuable and also part of capacity building activities, were not formally documented as part of the project's data collection.*

ANNEX 4: VISUAL IMPRESSIONS FROM THE FIELD VISITS AND ACTIVITIES

Images 1: *Spinach production and harvesting in the farm of Mr. Gyan B. Tamang*

Images 2: *(Left) Bundled spinach after harvesting, (Middle) Collecting the spinach bundles in the local basket (doko) & the spinach finally carried to the collection site (Right)*

Images 3: *Weighing and recording the weight of the freshly harvested spinach bundles (Left), stacking the spinach on the farm side road which was then covered with a thick tarp to avoid the direct sun exposure*

Images 4: *Aggregated spinach covered in thick tarp under the sun/shade, where it remains exposed till later in the evening when the vehicle arrives to load commodities for transport*

Images 5: *Glimpses during the demo of MAP bags for the harvested spinach*

Image 6: *MAP packaged Spinach alongside the normally staked ones during the first demo*

Images 7: *Glimpse of spinach aggreagation practices (Top) and using MAP bags during the second demo*

Images 8: *General aggregation, handling and loading practices of the fresh vegetables by the vendors as observed during the second demo in Dolakha*

Images 9: *MAP bags interventions during the second demo*

Images 10: *Loading of the commodities (spinach) in the vehicle for the transport*

***Images 11:** The spinach upon reaching the market after the trasnport*

***Images 12:** Quality observations of the spinach packaged in MAP bags*

***Images 13:** Spinach upon reaching Kathmandu in normal bags (left) vs. with MAP bag (right)*

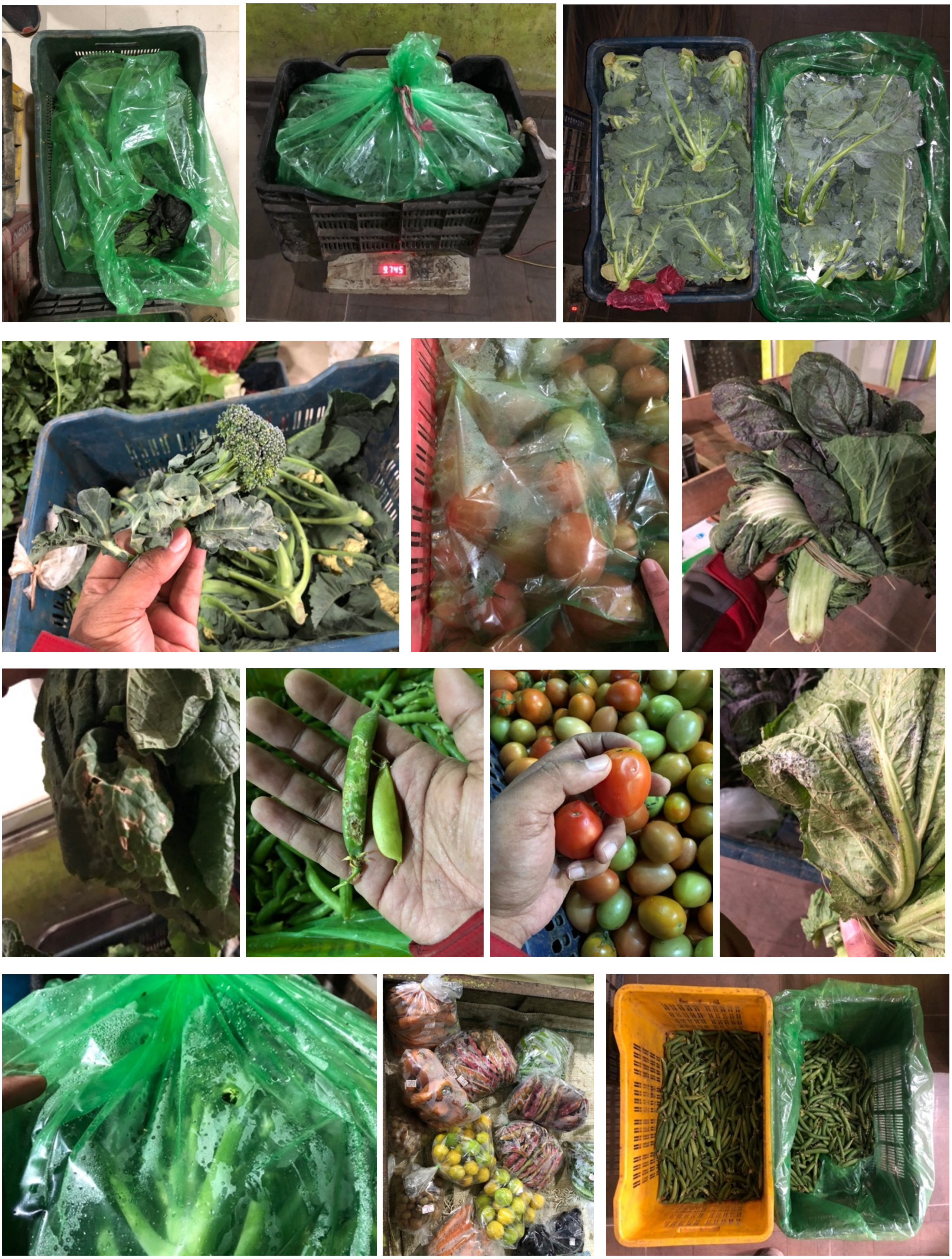
Images 14: *Observations and impressions from the visit, orientation and demonstration in one of the Paicho's collection center at Mathillo Rukse, Gulmi*

Images 15: *Photos during the orientation & demo in another collection center (Tallo Rukse, Gulmi)*

Images 16: *Photos of packaging and treatments sample during the demo in Paicho's supply chain*

Images 17: *Photos of sample treatment during the demo (left) & interaction with farmers in the field*

***Images:** Observations during visit to Paicho Butwal outlet and observation of the procurement delivery and the unloading process*



Images: *Observation and assessment of quality parameter during the data collection and inspection of the packaged commodities sent from Gulmi as a part of commercial demonstration.*

Images 10: *Impressions during demo at Madanpokhara Sangam Cooperative*

Images 11: *Impressions during assessment of demo commodities at the Butwal outlet*

ANNEX 5: ADDITIONAL GRAPHICAL REPRESENATIONS OF RESULTS

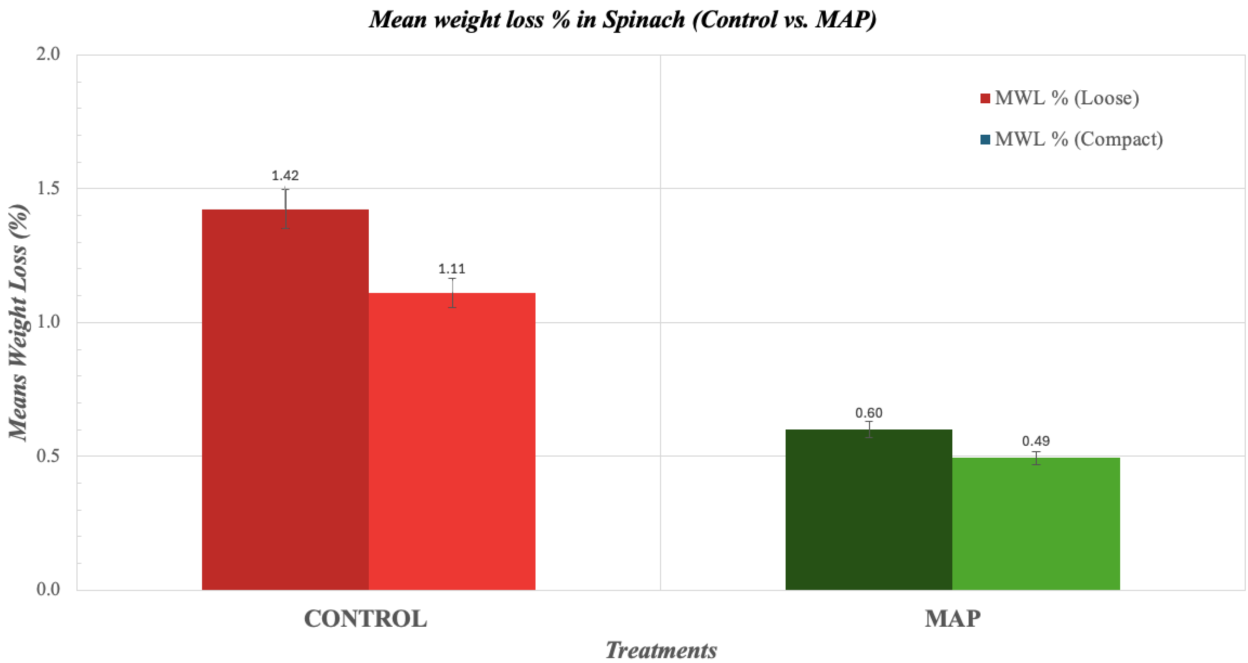


Figure: Dhankuta Demo: Comparison of Weight Loss in Spinach in MAP vs. Control conditions with different packing style (density variation)

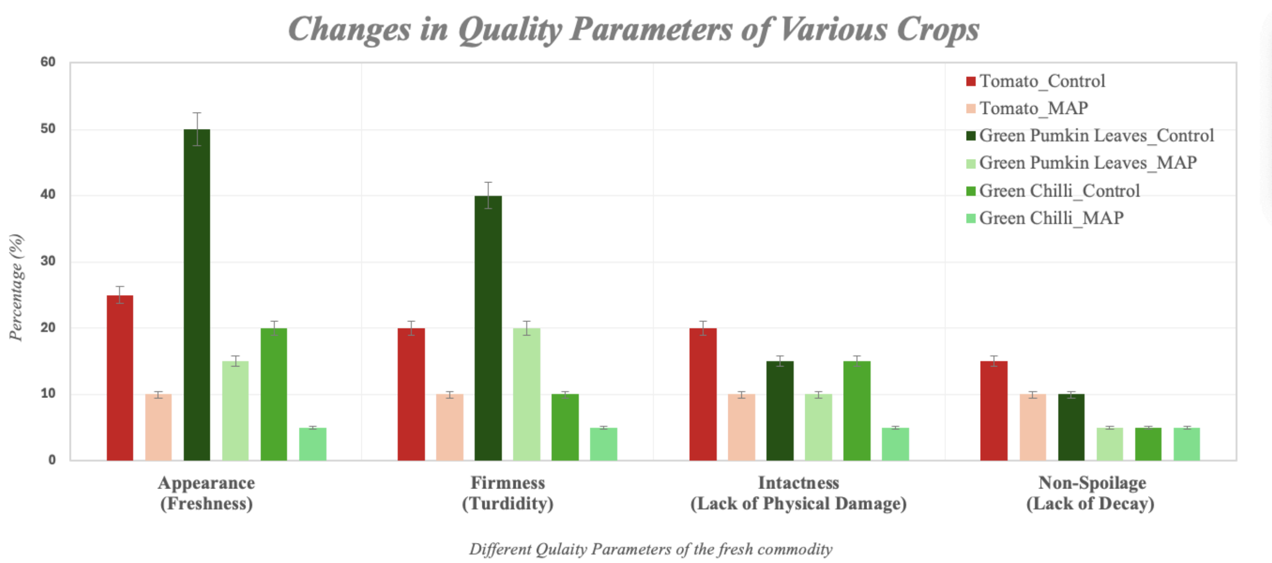


Figure : Madanpokhara Demo: Changes in the Quality Parameters (Appearance, Firmness, Intactness, and Non-Spoilage) of Tomato, Green Pumpkin Leaves, and Green Chili Under MAP and Control Conditions

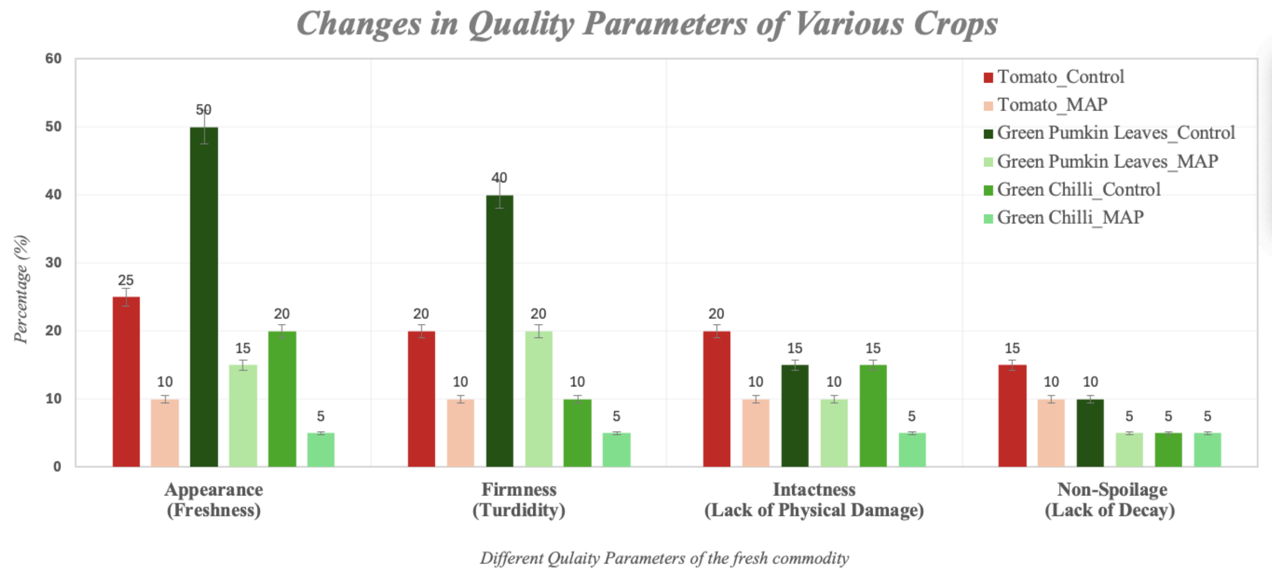


Figure : Madanpokhara Demo: Changes in the Quality Parameters (Appearance, Firmness, Intactness, and Non-Spoilage) of Tomato, Green Pumpkin Leaves, and Green Chili Under MAP and Control Conditions

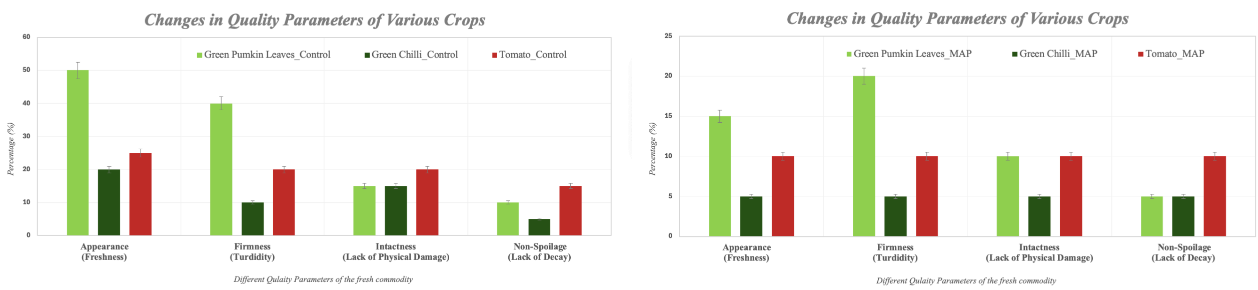


Figure : Madanpokhara Demo: Reduction of different quality parameters for various commodities in Control (left) vs. MAP conditions (right)

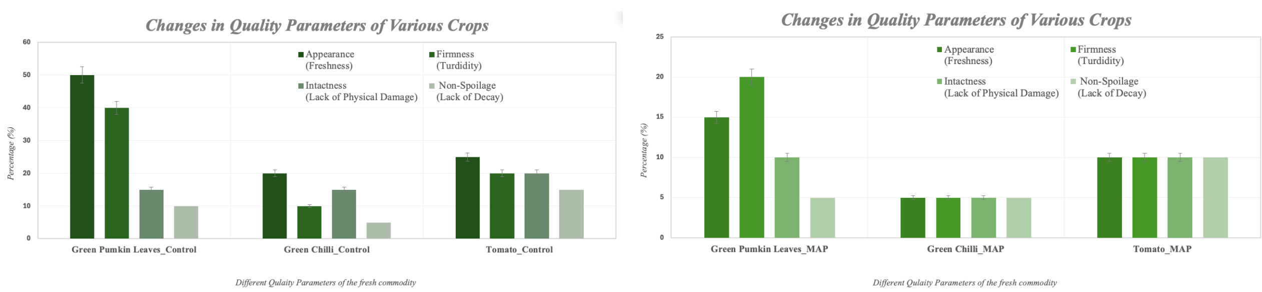


Figure : Madanpokhara Demo: Reduction of different quality parameters for three different commodities i.e. Green pumpkin leaves, Green chilli and Tomato in Control (left) vs. MAP conditions (right)

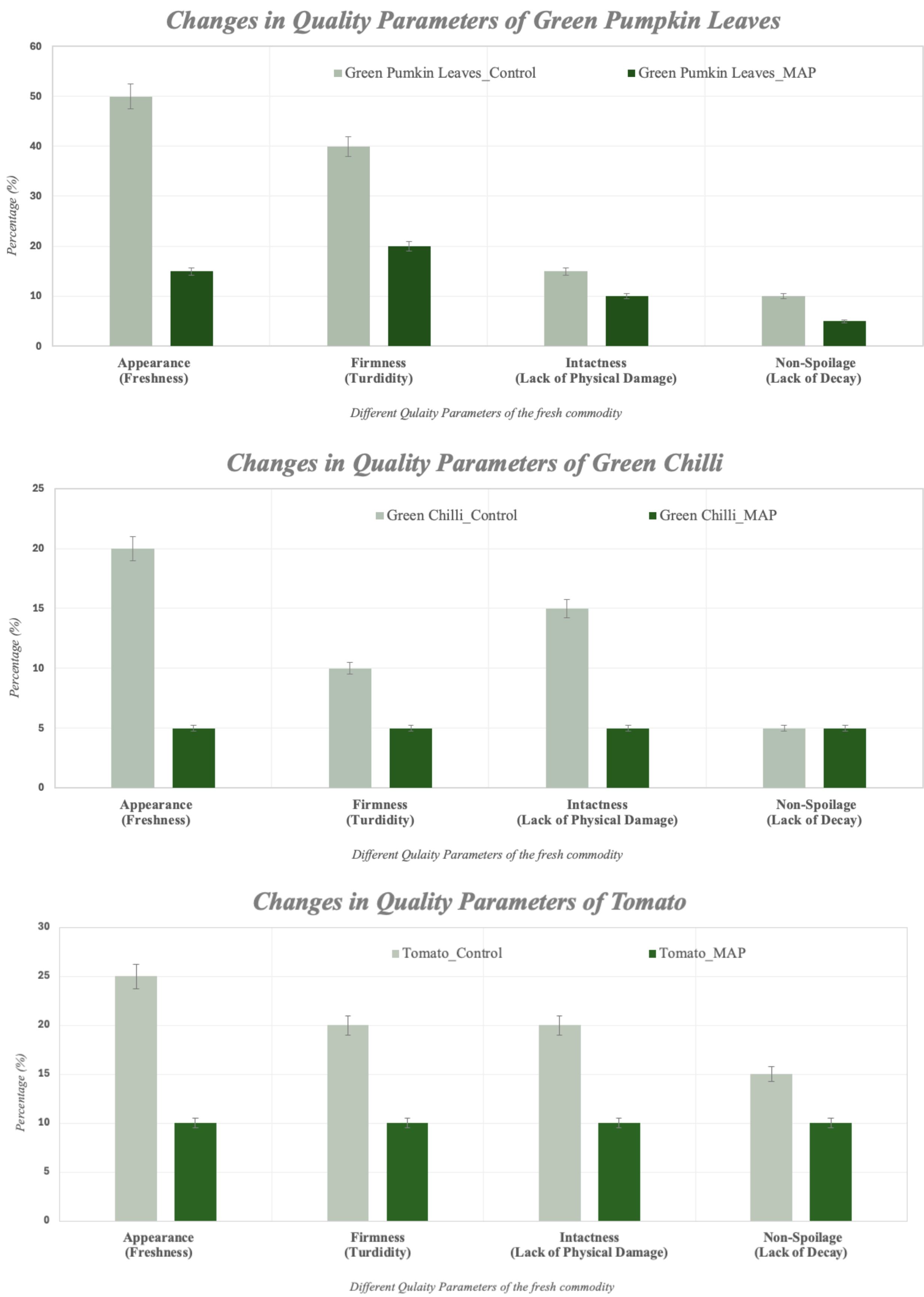


Figure : Madanpokhara Demo: Comparison of the reduction of quality parameters in MAP vs. Control conditions for Green pumpkin leaves (Top), Green chilli (Middle) and Tomato (Bottom)

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