

# UNIVERSITY OF PETROLEUM & ENERGY STUDIES

College of Management & Economic Studies, Dehradun



Dissertation Report

## Methods to Reduce Post-Harvest Losses of Perishable Fruits and Vegetables in India

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## Declaration

I, P. Rahul, MBA-L&SCM (SEM 4), College of Management & Economic Studies, University of Petroleum & Energy Studies, hereby declare that the Dissertation Report titled “Methods to Reduce Post-Harvest Losses of Perishable Fruits and Vegetables in India” is a thesis report submitted in partial fulfillment of Masters of Business Administration (Logistics & Supply Chain), and an original work carried out by me availing the guidance of my mentor.

This report has no resemblance with any other report to any University or Institute published Earlier.

Dated:

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## Acknowledgement

At the very outset of this report, I would like to extend my sincere & heartfelt obligation towards all who have helped me in this endeavor.

Without their active guidance, help, cooperation & encouragement, I would not have made headway in the project.

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Any omission in this brief acknowledgement does not mean lack of gratitude

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## Executive Summary

In a vastly growing world, it becomes a basic essential to provide food security to all. In the world scenario, the produce should statistically be adequate to meet the basic demand of everybody. In reality, about half the population is malnourished and in India, a common man is facing difficulty in feeding his/her dependents with adequate quantity.

Total vegetables and fruits production in the world is estimated 1, 042 million and 900 million tons. India is 2<sup>nd</sup> leading F & V producing nation of the world with 76.4 and 156.3 million metric tons, respectively. The PHL losses in India account for 40% of the average produce which may continue to rise if left unattended. PHL has various implications apart from availability such as cost implication, waste of resources and greenhouse emissions. Large amount of resources of water, arable land and fertilizers gets wasted annually.

This report identifies the loss % across types of fruits and vegetables and the causes of these losses. It is not possible to reduce the loss without identifying the reason for the losses. Various types of injuries are caused through the supply chain of the produce resulting in such majestic losses.

The major one identified is the inadequate cold chain infrastructure in the country. Cold chain includes transport and storage facilities. Lack of such options at the right places and cost imperative utilities make it inaccessible for large section of farmers in the country. It was also found that the traditional practices of harvesting cause high level of damage to the produce.

To develop a good plan to reduce major losses at these two sections of supply chain, it requires the study of loss patterns in developed/more-efficient countries in the world. It can be found through this comparison that human resource, quality and safety standards, handling and marketing knowledge has an impact on the level of losses.

The scenario with current level of facilities provides little guarantee to reduce losses in the future. The report concludes with suggestion that will enable India to reduce the post-harvest losses by considerable margins.

## Literature Review

Authors	Context	Inferences/ Parameters
<p>Office of Agriculture, Biotechnology, and Textile Trade Affairs</p> <p>Bureau of Economic and Business Affairs</p>	<p><b>Postharvest Loss Challenges</b></p>	<p>Practices and loss saving techniques used in US</p>
<p>Jaspreet Aulakh and Anita Regmi (FAO)</p>	<p>POST-HARVEST FOOD LOSSES ESTIMATION- DEVELOPMENT OF CONSISTENT METHODOLOGY</p>	<p>Category wise loss estimation and the possible measures to mitigate them with reference to perishable goods.</p>
<p>Renie Subin</p>	<p>India's Cold Chain Industry</p>	<p>Currently persistent problems with the cold chain industry in India and related issues faced in the use of reefer trucks and what are the challenges faced in the development of this industry in India</p>
<p>National Cold Chain Development</p>	<p>Comprehensive report on creation and management of cold chain infrastructure for agriculture and allied services.</p>	<p>A statistical report on the development of infrastructure in the country and the current capacity available state-wise. Losses are elaborately explained through inadequacy.</p>
<p>Jaspreet Aulakh, Anita Regmi, Joan Fulton, and Corinne Alexander</p>	<p>Estimating Post-Harvest Food Losses: Developing a Consistent Global Estimation Framework</p>	<p>Factors contributing to losses across various stages of supply chain in agriculture.</p>
<p>Thomas Reardon &amp; Bart Minten</p>	<p>The Quiet Revolution in India's Food Supply Chains</p>	<p>Traditional practices prevalent with the farmers and their accessibility to the market and their storage facilities available.</p>
<p>Sunil Bhardwaj and Indrani Palaparthy</p>	<p>Factors affecting Indian Supply Chains of Fruits and Vegetables</p>	<p>Current practices and supply chain followed by the farmers and the reason why farmers prefer the inefficient channels are identified.</p>

DECLARATION

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## INTRODUCTION

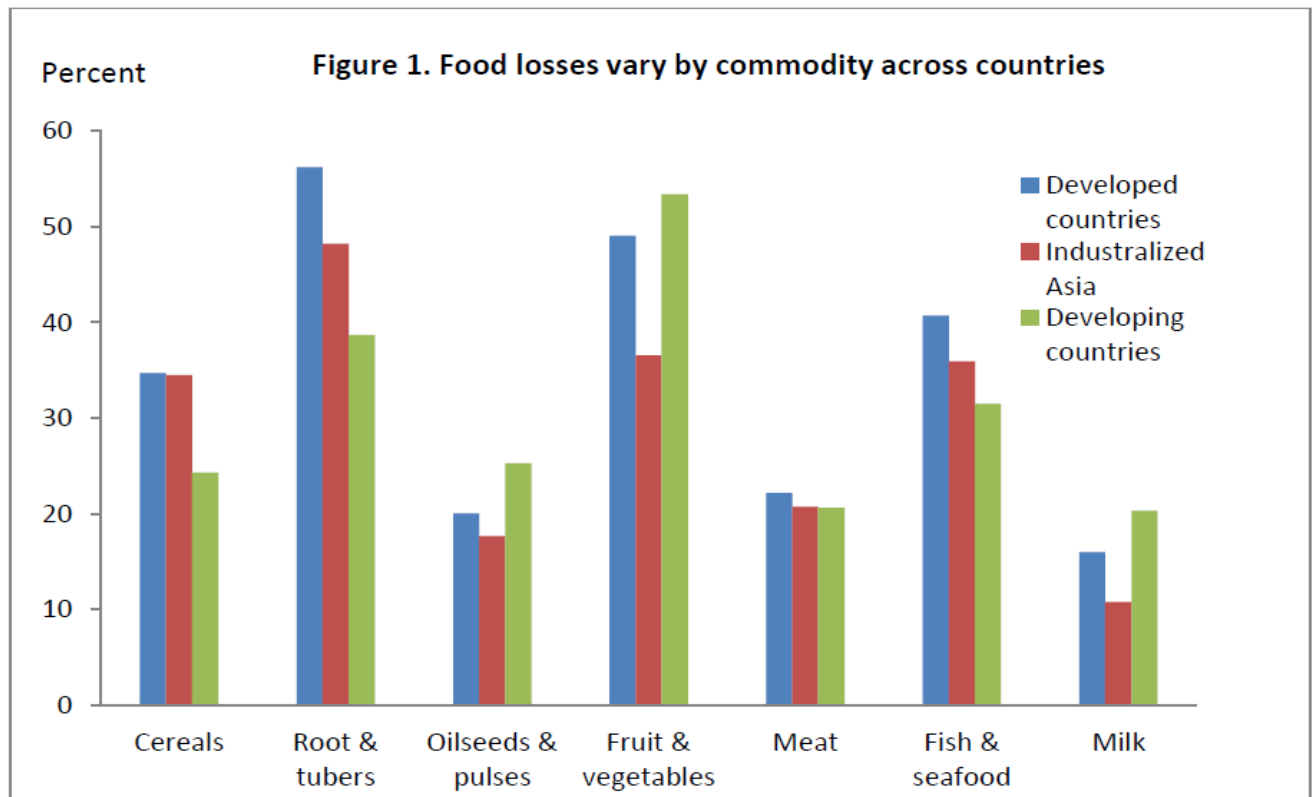
Total vegetables and fruits production in the world is estimated 1, 042 million and 900 million tons, respectively and 20-30% of the total production in developed nation is damaged due to inappropriate post-harvest handling up to consumption. India is the second largest producer of F & V with first rank in production of ginger and okra, bananas, mangoes etc. But in the case of developing nation like India, the PHL are estimated close to 40% of the total F & V production which affects the availability of F & V to the consumers. Perishable F & V (F & V with more water content) become easy to attack for the micro-organism due to high water activity and damaged rapidly. Inappropriate handling, storage, preservation techniques and microorganism damage increase the PHL in F & V up to 40%. The microbial effect plays a vital role in damage of F & V due to some extensive heat or cold resistance micro-organism, the processed or canned product also can be damaged. Practices of post-harvest technologies can reduce the quantitative and qualitative losses of fresh F & V and also maintain the product quality up to final consumption.

Post-harvest quality and timeframe of realistic usability of the products of the soil related with the development rehears assortments of the cultivar and natural viewpoints. The dirt and climatic attributes and incorporated administration rehearse additionally influence the PHL and post-harvest stockpiling span. Because of high water movement, products of the soil are viewed as more perishable. Absolute 30-40% verdant foods wastage happens from collecting to utilization. On account of developed and developing nations, the losses of foods grown from the ground Estimated around 5-30% and 20-50% individually. Lessening in the quality, stockpiling span and timeframe of realistic usability can be minimized with the assistance of sufficient stockpiling, transportation and environment conditions. A few situation components like temperature, moistness and vaporous climate are in charge of PHL s.

UN estimates show that about 1.3 billion tons of sustenance gets lost all inclusive consistently. The current world populace is required to achieve 10.5 billion people by 2050, and



the nourishment misfortune, if oversaw and avoided, can encourage in the coming decade.



As per 2011 data released by FAO

Over the earlier decades, huge focus and resources have been circulated to fabricate sustenance era. As indicated by a report disseminated by UN's cultivating wing, FAO, 95% of the investigation wanders some place around 1970 and 2000 were represented to have focused on growing produce and only 5% composed towards decreasing PHL . Growing agrarian benefit is segregating for ensuring overall sustenance security; however this may not be sufficient. Nourishment creation is at this time being tried via compelled land, water and extended atmosphere variability due to ecological change. To sensibly achieve the destinations of nourishment security, sustenance availability needs to be also extended through diminishment in the post-harvest technique at property, retail and buyer levels.

Perishable verdant foods experience the best extent of PHL in developing nations. Losses are a presumable impression of immature way of the ranch to-retail inventory network.

Conversely, sustenance losses are generally high cross-wise over numerous items for developed nations.

Food losses in developed nations happen essentially at the customer level, albeit a few losses happen on the fields or at different phases of the inventory network. Field losses happen as a result of ranchers' choices to forego reaping because of intense business norms. Losses in developing nations, conversely, happen basically amid the field-to-market stages, with the littlest offer of losses caused at the customer level. Untimely collecting, poor storerooms, absence of framework, absence of handling offices, and insufficient business sector offices cause high PHL in developing nations along the whole Food Supply Chain.

## Agricultural Scenario in India

India is a major F & V producing nation of the world with 76.4 and 156.3 million metric tons, respectively. Productivity of the Fruits varies within 4-34 tons per hectare and productivity of vegetables varies within 5-15 tons per hectare. India produced 8% and 15% of the total world F & V production respectively. After China, India is the world's largest producer of total F & V but due to unavailability of appropriate cold storage, refrigerated transportation facilities, the F & V of Rs. 212552 Cr. damaged every year. Diversified climate of India helps to produce most of all varieties of F & V. In the different steps of post-harvest handling nearly 20-30% of the produced fruits of the total produced vegetables were damaged and decreased the 100 g (Based on total produced fruits ) to 60 - 70 g per capita per day (based on consumable produces after losses reduction). Production level of the fruits increased by 3.9% annually and processing sector for fruits strengthen by 20% per year. In the case of vegetables 30-35% of the total produced vegetables were lost and only 2% of the total produced vegetables undergo for processing and marketed only 0.15 million tons of processed vegetables. Export market of vegetables also expanded and noticed 16% in volume and 25% in value of the total produced vegetables (2009-10 value Estimates). Generally, India exported the vegetables to the Asian Region (Sri Lanka, Malaysia, Gulf and Singapore) and Europe (United Kingdom).

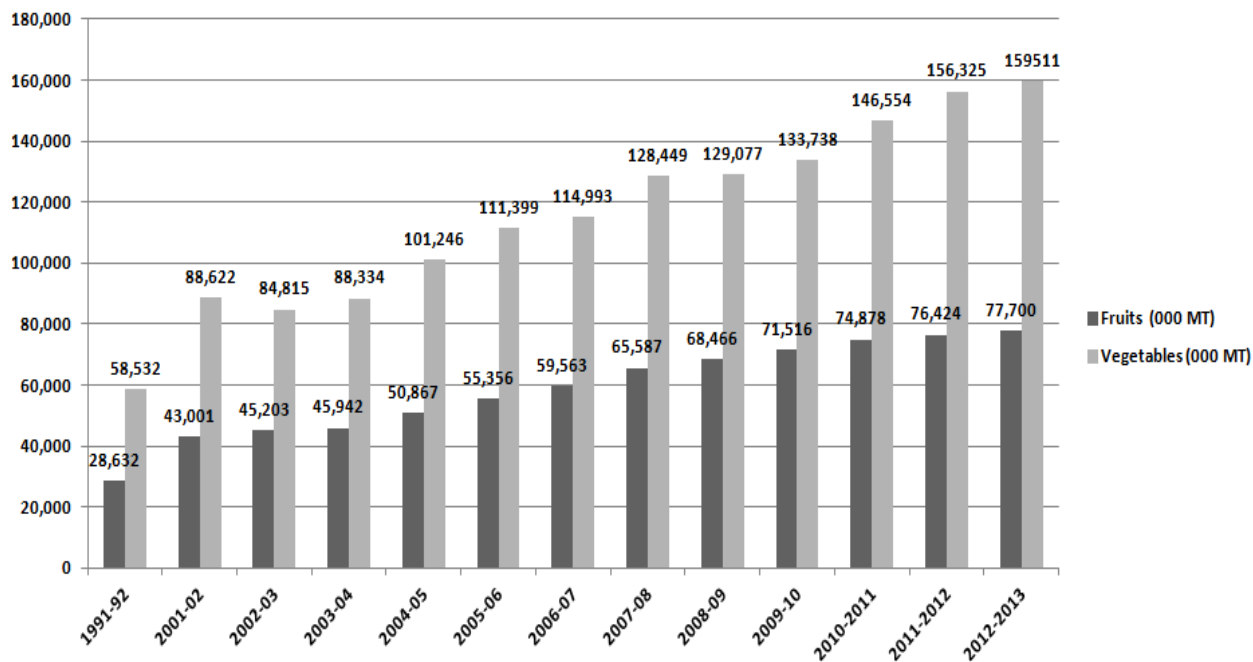
### Per Capita Availability of F & V

F & V are important supplements to the human diet. As per the specifications of National Institute of Nutrition at least 300g of F & Vs are to be consumed by an individual for a balanced diet.

**FRUITS: 76,424,000 tons with a per capita consumption of 79 grams**

**VEGETABLES: 156,325,000 tons with a per capita consumption of 176 grams**

(After deducting for wastage and food processing industry. Includes export value.)



### F & V Production in India

Source: National Horticulture Board, Govt. of India (Advance estimate 2013)

The offer has expanded from 28.63 million metric tons to 77.70 million metric tons in products of the soil million metric tons to 159.51million metric tons in vegetables from the year 1991-2013. A substantial mixed bag of F & V are developed in India like Mango, Banana, Papaya, Apple, Citrus, Sapota, Grapes, Pine apple & Guava and so on in Fruits and Onion, Tomato, Potato, Brinjal and so on in vegetables.

**Table2. F & V Losses among the major producing state**

State	Total Loss (Rs. Cr.)
1. West Bengal	13657
2. Gujarat	11398
3. Bihar	10744
4. Uttar Pradesh	10312
5. Maharashtra	10100
6. Tamil Nadu	8170
7. Karnataka	7415
8. Andhra Pradesh	5633
9. Madhya Pradesh	5332
<b>All India</b>	<b>212552</b>

Source: ASSOCHAM India

In a 2003-04 estimation, about 30 – 40% of total production of fresh F & V, was wasted in India, which is equal to the total production of the UK. Even at current levels of production, wastage of INR 2, 12,552 Cr. is mainly caused by inadequate facilities of storage, transportation and network, cold chain facilities and other infrastructural supports.

On August 6, 2013, D S Rawat, ASSOCHAM Secretary General, said "...lack of appropriate storage facilities is primarily responsible for wastage of substantial quantities of F & V produced in the nation which could be prevented otherwise."

The magnitude of PHL in F & V can be minimized by fitting taking care of operations, reaping, transportation, stockpiling, pre and post-harvest medications and other such critical measures.

Besides, the storage and handling conditions need some enhancing to bring down PHL and increase productivity.

#### **Estimated Loss of Fruits**

<b>Crop</b>	<b>Estimated Loss (In %)</b>
Papaya	40-100
Grapes	27
Banana	20-28
Citrus	20-95
Avocado	43
Apple	14-25

CIPHET Report, 2012

### Estimated Loss in Vegetables (2012 Figures)

Crop	Estimated Loss (in %)
Onion	25-40
Garlic	8-22
Potato	30-40
Tomato	5-34
Cabbage & Cauliflower	7-25
Chili	4-30
Radish	3-5
Carrot	5-9

CIPHET Report

### Important sites of PHLs

The break-up of these Losses which occur due to poor Post-harvest Management facilities and practices is as follows:

Poor handling	30%
Poor Storage Facilities	30%
Poor Transportation	30%
Presence of Large Number of Middlemen	5%
Lack of Knowledge amongst farmers about harvesting techniques	5%

Source: [Globalfoodchainpartnerships.org](http://Globalfoodchainpartnerships.org)

## F & V Supply Chain in India

Store network Management is characterized as a situated of methodologies used to effectively incorporate suppliers, makers, distribution centers, and stores, so stock is delivered and appropriated at the right amounts, to one side areas, and at the correct time, so as to minimize framework wide expenses while fulfilling administration level necessities.

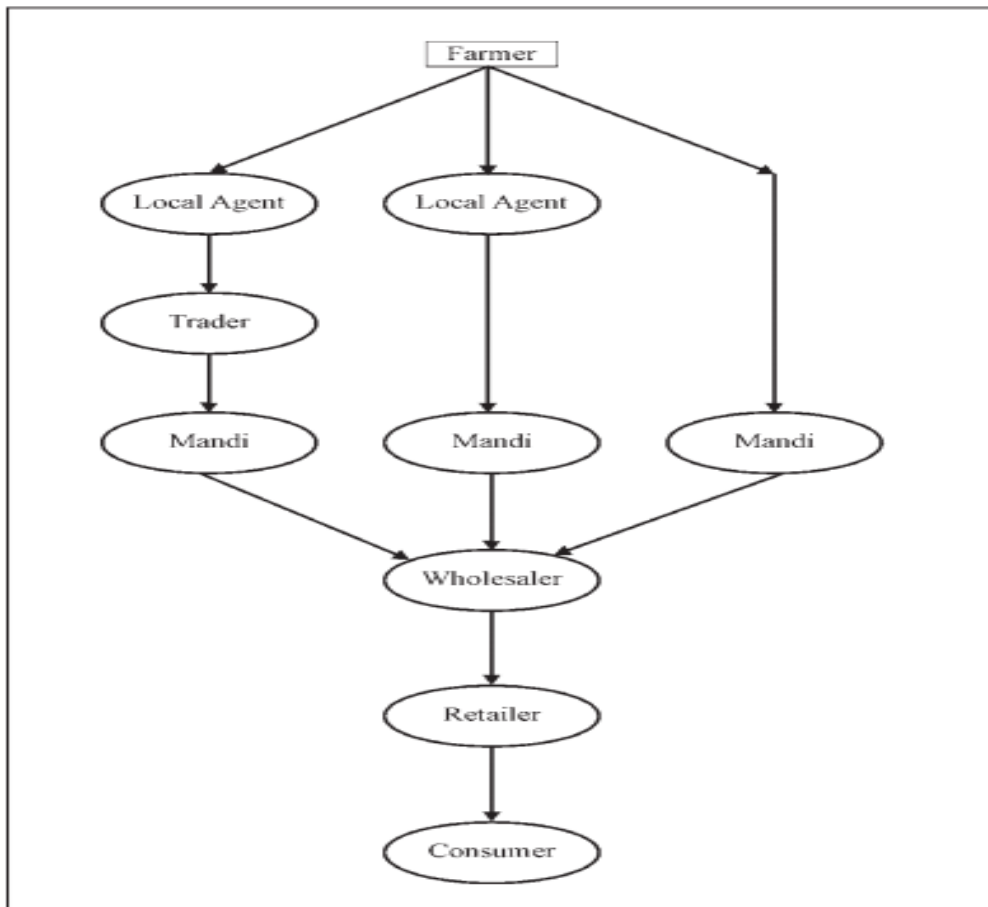
The Supply Chain Management of F & V (F & V) constitutes the methodologies from creation to conveyance of the crisp produce, i.e. from the rancher to the client and is complex in examination to other Supply Chains because of the perishable way of the produce, higher variances popular and costs, expanding purchaser attentiveness toward nourishment security and quality, and reliance on atmosphere conditions. Because of the perishable nature these commodities require appropriate cold storage and transportation throughout the chain to keep the freshness and quality of the fresh produce.

The Supply Chain Management for F & V in India is still in a very pitiful state and troubled with various issues like

- Inadequate cold chain management,
- Fragmented and long supply chain,
- High cost of packaging,
- Poor distribution.

Large share of a farmer's realisable value is lost as commission, supply chain mishandling and losses. On its way to market, a lack of appropriate cold chain results in greater wastage of produce. This results in immense loss in the quantity and quality of the produce, giving rise to the 40 % value loss in Indian supply chain for F & V. The extent of loss of F & V ranges from 10 and 80 % in some of the most perishable F & V. Inappropriate management of cold chains are leading to loss in quality of the vegetables and fruits which in turn is leading to loss of profits and business opportunity. In the absence of an efficient supply chain, the risk of wastage of is very high. The existing supply chain for the F & V involves many intermediaries

who eat up into the share of about 75 percent of the total net margin accumulating in the entire supply chain. The commission agents and local traders act as aggregators who procure the fresh produce from the small growers on behalf of big traders. Some farmers with large land size holding are able to sell their produce directly to the local mandis, but usually, farmers prefer to sell their produce to local agents or trader rather than adopting the direct channels. More than 90 percent of the produce in the country is disposed through commission agents/wholesalers and a small proportion is sold through retailers directly to consumers.



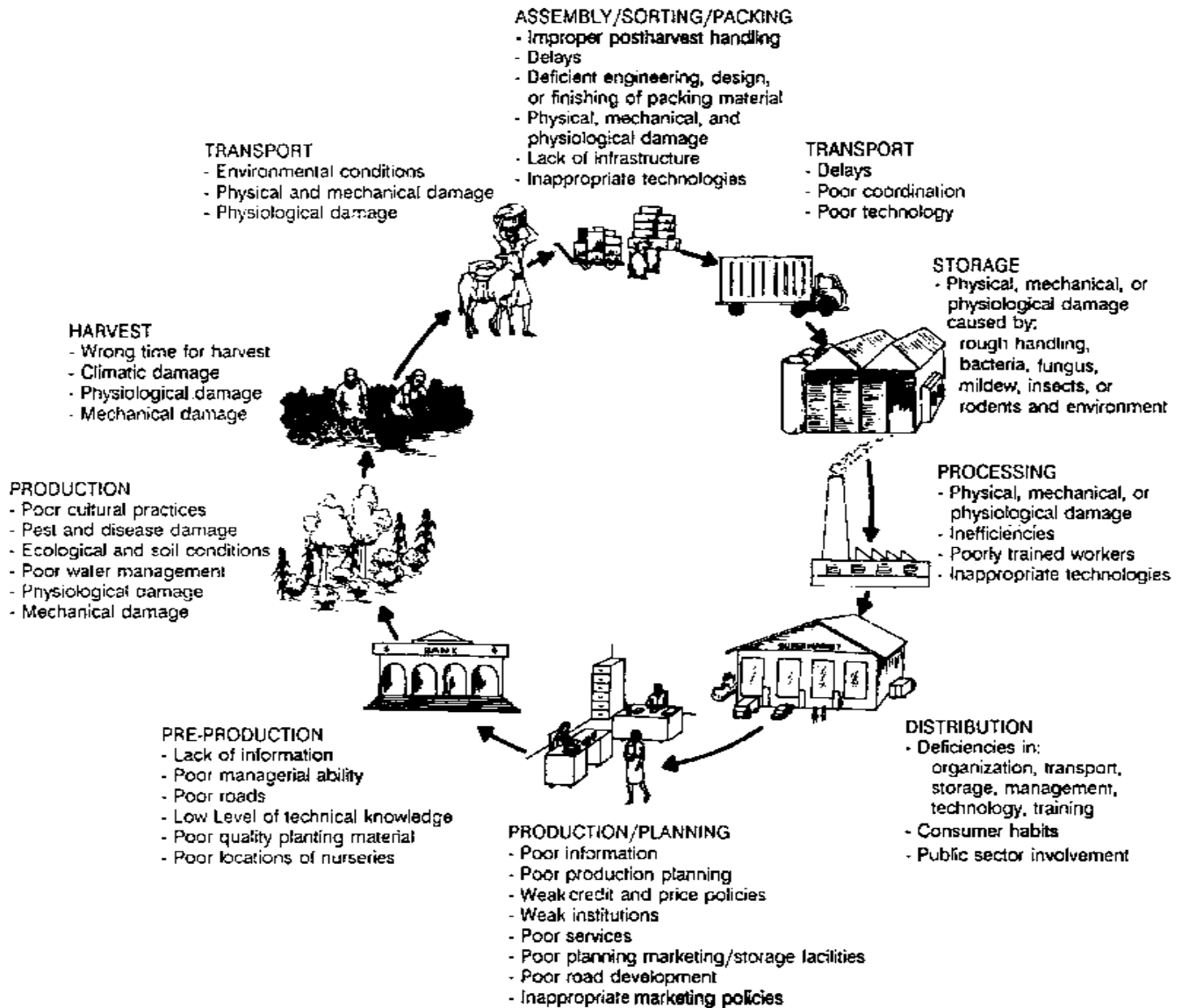
**Supply Chain for F & V in India**

*Source: Modi, P et al, 2009*



The presence of large intermediaries and highly inefficient supply chain leads to instability in prices, farmers not getting deserving prices. The differential between farmer's realisation and the final consumer price is the highest in India in the fresh produce (National Food Processing Policy) causing rural impoverishment resulting in farmers' frustrations and suicides and increased additional costs in the supply chain which ultimately is passed onto the final consumers to pay higher charges.

## Challenges in the Supply Chain



The focus of this study in the above figure is strictly from the time of harvest to distribution. Types of injuries caused to F & V at each of level of the cycle is specified in the table below:

Process in the Cycle	Type of Injuries
Harvest	Mechanical, Premature Harvesting
Transport	Temperature, Disease, Mechanical & Physical
Packaging & Storage	Temperature, Disease, Mechanical & Physical

Farmers in India are not highly educated and lack the information to utilize the best of available technologies to optimize their agricultural produce. Even with available information majority of the farmers are comfortable using their old, even if inefficient, methods. Their lack of willingness to accept new technologies and methodologies to minimize the harvesting loss can be identified in many regions across India. However, a few groups of farmers in various regions have taken the initiatives to accept the modern methods of farming.

Many farmers restrain due to financial constraints in adopting the new technologies which are expensive in comparison to the traditional methods which do not require any new investments. Farmers need to be educated or oriented with the methods so they could comfortably practice new methods and reap higher benefits of their harvest.

In less developed nations where the supply chain is less mechanized, larger losses are incurred during drying, storage, processing and in transportation.

## Comparison of Supply Chains: Developed Vs. Developing Nations

The fundamental prerequisites for keeping up quality and wellbeing of agricultural perishables (organic products , vegetables, herbs, ornamentals) in the middle of harvest and utilization destinations are the same around the world. Nonetheless, the level of appropriation of the particular gathering and post-harvest taking care of systems and advancements differs significantly among countries and inside every country, contingent upon size of operation, proposed markets, and the arrival on venture (expense/advantage proportion) of every method or innovation.

It is assessed around 1/3rd of all F & V delivered are never devoured by people. The general contrast in the middle of created and creating countries is that a greater amount of the misfortunes happening in the middle of generation and retail destinations in creating than in created countries. On the other hand, more can and ought to be done to decrease PHL in all countries. It is not conservative or down to earth to go for 0% misfortunes, yet a worthy misfortune level for every product generation zone and season mix can be distinguished on the premise of expense advantage investigation. Further in this segment, the similitudes and contrasts in the middle of created and creating countries in different parts of the taking care of frameworks used to keep up quality and wellbeing and lessen misfortunes of crisp agricultural products will be talked about.

3 Key center zones to enhance the circumstances of creating countries are:

- (1) Application of current information to enhance the taking care of frameworks of agricultural perishables and guarantee their quality and security;
- (2) Removing the financial limitations, for example, deficiencies of framework, poor advertising frameworks, and feeble innovative work limit; and
- (3) Overcoming the impediments of little scale operations by reassuring union and vertical combination among makers and advertisers of every product or gathering of wares.

## HUMAN RESOURCES

The human component in post-harvest treatment of green products is amazingly imperative. Despite the fact that work expenses are lower in creating countries, work preparing, profit, and administration are for the most part better in created countries. Compelling preparing of laborers and their directors alongside designation of obligation and power to the managers are more regular in created countries than in creating countries. The inclination in numerous operations in creating countries to cutoff power for rolling out any improvements in the strategies to the proprietor or not very many trusted persons regularly prompts poor administration and critical thinking aptitude among the chiefs and lessened profit of the specialists.

Numerous pressing houses and storerooms for taking care of crisp deliver in creating countries have poor logistics and item stream as a consequence of poor outline and/or stage-wise development with deficient anticipating future extension. Problematic item stream brings about diminished productivity of the specialists and may expand the open doors for cross-pollution with microorganisms when approaching items are taken care of in the same region as last items.

Most handlers included in collecting, bundling, transporting, and showcasing in creating countries have constrained or no gratefulness for the requirement for, or how, to keep up quality and security of produce.

## MAINTAINING THE COLD CHAIN

Despite developing district or size of operation, temperature and muggy administration techniques to keep up nature of new create include: collecting amid the coolest piece of the day conceivable, and keeping deliver in the shade while gathering it in the plantation or field; transporting produce to pressing house and/or direct-advertising outlet at the earliest opportunity after harvest; shielding deliver in plain view from introduction to direct daylight; delivery stuffed produce to the business in refrigerated travel vehicles, and keeping up suitable temperature and relative moistness in showcase cases and cool storage spaces.

Accessibility and effective utilization of the icy chain is substantially more apparent in created countries than in creating countries. Inconsistency of the force supply, absence of suitable upkeep, and wastefulness of use of chilly stockpiling and refrigerated transport offices are among the explanations behind disappointment of the cool chain in numerous creating countries. Expense of giving the icy chain every ton of produce relies on upon vitality costs in addition to use proficiency of the offices as the year progressed.

In numerous creating countries, some great offices that were manufactured a couple of years prior are as of now "out of request" or not working fittingly on account of absence of upkeep and inaccessibility of extra parts. This issue is particularly valid for open division offices. Any new venture ought to incorporate in its arrangement sufficient stores for support to guarantee its prosperity and developed helpfulness.

Proper post-harvest innovations when utilized viably can extraordinarily improve productivity; however no single innovation is a substitute for the numerous incorporated steps included in fitting post-harvest administration for guaranteeing quality and wellbeing of plant yields.

## **QUALITY AND SAFETY STANDARDS**

Grade norms distinguish the degrees of value in a product that are the premise of its convenience and quality. Such principles, if implemented fittingly, are vital instruments of value affirmation amid showcasing and give a typical dialect to exchange among producers, handlers, processors, and beneficiaries at terminal markets. Some creation territories uphold least gauges concerning produce quality, development, holder checking, size and pressing prerequisites. This gives systematic advertising and value in the commercial center and shields shoppers from unappetizing and low quality produce.

Principles of value and buyer inclination and acquiring force fluctuate extraordinarily among countries and societies. Case in point, end of deformities from a given thing before promoting is significantly less thorough in creating countries than in created countries. This, nonetheless, is not so much terrible, on the grounds that appearance quality is regularly overstressed in created countries. Another distinction is the consistency of value inside a bundle;

setting great quality units on top and lower quality units beneath is significantly more basic in creating countries than in created countries. Disheartening extortion in pressing produce by means of creating and upholding obligatory, straightforward least quality norms can enormously enhance nature of F & V coming to the shoppers and expand trust in the middle of purchasers and merchants in creating countries.

The level of administrative controls, particularly on wholesale and retail costs of crisp F & V, fluctuates starting with one country then onto the next. Much of the time, value controls are counter-gainful. Albeit proposed for buyer security, such regulations energize misrepresentation and give no impetus to delivering superb produce or for post-harvest quality support. Then again, regulations covering proper taking care of methods and general wellbeing angles (nourishment security issues) amid advertising are, if authorized suitably, imperative to the shopper.

### **Improving Handling Strategies**

Suggested techniques in regards to development and quality include: reaping at the suitable development stage with respect to planned utilize and promoting practices and periods; wiping out produce with genuine deserts, and reviewing produce quality and condition when it is gotten; dividing out deliver that must be sold instantly, and putting it in plain view first; and turning produce when renewing presentations.

- Procedures for minimizing mechanical injury include:
- Handling produce with consideration amid gathering and pulling to the business sector or produce stand;
- Using suitable materials-taking care of gear;
- Avoiding drops, effects, vibrations, and surface wounds of produce all through the taking care of framework;
- Using delivery holders that will give satisfactory security to the merchandise from physical wounds; and
- Stacking holders so that the weight goes ahead the structure of the bundle, not on the produce.

In most creating nations, avenues are not sufficient for the recompense of transport of green items. In like manner, transport vehicles and diverse modes, especially those suited for new green perishables, are difficult to find. This is veritable whether for neighborhood elevating or toll to distinctive nations. Bigger piece of creators have little belonging and can't remain to have their own particular vehicle vehicles. In several cases, promoting affiliations and cooperatives have had the ability to get transport vehicles, yet they can't do much about poor road conditions

The expressions "value chain" and "inventory network" are utilized conversely to incorporate creation, accumulation, transforming, wholesaling, and retailing and bolster capacities, for example, enter supply, monetary administrations, transport, bundling, and promoting. A deliberate examination of every merchandise generation and taking care of framework is the sensible initial phase in distinguishing a suitable procedure for diminishing PHL s. Additionally, an expense advantage investigation to focus the arrival on interest in the suggested post-harvest innovations is crucial. It is critical to choose the innovations that are suitable for the measure of every post-harvest.

## **MARKETING SYSTEMS**

Cultivators can create substantial amounts of great quality natural products , ornamentals, and vegetables, at the same time, on the off chance that they don't have a tried and true, quick, and impartial method for getting such wares to the buyer, misfortunes will be broad. This issue exists in numerous areas inside creating countries and is accentuated by absence of correspondence in the middle of makers and collectors, and absence of business sector data. Business sector access for little makers relies on upon comprehension the business sector, association of the firm or operations, correspondence and transport connections, and a proper arrangement environment. As a rule, the quantity of go-betweens in the middle of makers and customers is much bigger in creating countries than in created countries; this circumstance frequently brings about lower costs to the makers.

Advertising cooperatives ought to be supported among makers of real things in critical development zones. Such associations are particularly required in creating countries as a result of the moderately little ranch size. Favorable circumstances of promoting cooperatives include:



giving focal gathering focuses to the collected thing, obtaining reaping and pressing supplies and materials in amount, accommodating suitable planning for business sector and capacity when required, encouraging transportation to the businesses, and going about as a typical offering unit for the individuals, facilitating the showcasing program, and conveying benefits among individuals

Aggregate activity in farming markets is encouraged by institutional plans that viably resolve the natural pressure inside gatherings and additionally in the middle of ranchers and other monetary operators. Methods of maker associations are to by-pass go between, to meet quality necessities in cutting edge markets and to adequately utilize post-harvest innovations.

Elective conveyance frameworks, for example, direct offering to the buyer (roadside stands, produce advertises in urban areas, nearby ranchers' business in the countryside, and so on.) ought to be energized. Generation ought to be kept up as near to the real populace focuses as could be expected under the circumstances to minimize transportation costs.

## Post-harvest food loss (PHL ) : Indian Scenario

### What is PHL ?

Post-harvest sustenance misfortune is nourishment lost along the production network from harvest until utilization (or flip side employments). PHL can happen because of sustenance waste or incidental nourishment misfortunes along the way.

- Food waste is the loss of eatable nourishment because of human activity or inaction, for example, not expending sustenance before its termination date or discarding withered produce.

- Food misfortune is the incidental misfortune in nourishment amount due to the base and administration limits of a given sustenance quality chain. Nourishment misfortunes can be the consequence of a quantitative misfortune or a subjective misfortune.

Damage of F & V depends upon several factors which can be defined as intrinsic factors like oxidation-reduction capacity, maturity level, cultivar, nutrient level and some exterior factors like:

- Storage temperature,
- Produce handling, and
- Availability of oxygen.

If at the time of harvesting the F & V are not so dirty they can be stored without washing because moisture addition enhances the chances of damage, while some F & V are very dirty just after harvesting. Such types of produces must be washed and appropriately dried up to optimum moisture level before storage. Generally, the shelf life of fresh cut fruits or vegetables is less than the same without cutting as a whole and for preventing the vitamins and minerals losses the several F & V needs appropriate temperature and relative humidity during storage.

Shelf life and post-harvest preservation temperature range varied for different types of F & V. Some can be stored at temperature slightly more than freezing but others need to be stored safely at 45-55F. Some F & V like pumpkin, okra, sweet potatoes and cucumber are highly

sensitive to chilling injury but at the same time tomatoes, watermelon, muskmelon and peppers have moderate chilling injuries.

Quantitative loss of sustenance infers a diminishment in the accessible amount as an aftereffect of:

- Infestation by irritations at harvest or stockpiling,
- Physical misfortune amid taking care of, or
- Reduction in amount due to changes in temperature, dampness substance, or concoction structure.

Subjective loss of nourishment results in changes which bring down its financial or supplement esteem, regularly obliging that it be disposed of (i.e., bringing about quantitative misfortune).

This can happen because of:

- Damage because of bugs or maladies,
- Physical or synthetic changes because of an absence of atmosphere controlled stockpiling and taking care of offices,
- Food debased with nonfood material, or
- Adverse taste, surface, or different changes because of improper handling

## **Indian Scenario**

While PHL could be of various types and India is not isolated from these problems. India faces the highest degree of necessity to reduce these damages for various reasons which will be discussed in the sections followed. To be able to reduce PHL, it is important to understand the types of injuries and what are the causes for them individually. This will enable the development of better techniques or improve technological penetration to alleviate the current conditions.

## **Transportation Injury**

The transportation of perishables agricultural commodities with the help of road transported vehicles hamper the quality of commodities and basically caused the significant textural damages (higher in the case of perishable commodities) due to the irregular and unsmooth roads. The different F & V absorbs vibration and collapse with each other during road transportation, handling, loading and unloading which causes mechanical damage. Different types of citrus fruits contains different amount of vitamin C and minerals, which can be lost in high temperature storage.

Exposure of F & V to the sun in open body trucks, which are often used for transportation of agricultural produce in India, further lose their qualitative value leading to overall quantitative loss. Dust accumulation is very high on Indian roads which cause damage to the freshness of the produce. In a study conducted by FAO in India in 2011, it was found that the use of temperature controlled trucks can reduce the loss caused by various factors in transportation by 15% which is substantial in volume.

## **Temperature Injury**

Sensitivity changes with the ware, yet with each there is a temperature underneath which injury happens: the lowest safe temperature (LST). Inside a solitary item sort, the LST may shift between mixtures. Natural products is by and large less delicate when ready.

Manifestations of chilling damage may not create until the produce is expelled from cool stockpiling to typical business (i.e. encompassing) temperatures. At the point when vulnerable produce must be held for quite a while away, it must be kept at a temperature just over its LST. This implies that such yields will have a shorter promoting life than non-delicate products on the grounds that breath has proceeded at a generally quick level amid capacity at higher than typical chilly stockpiling temperatures.

Chilling injury was a physiological issue subjected to the subtropical and tropical natural products beneath the temperature 12-14 C. Capacity of organic products harvests like banana, pineapple and sweet potatoes at low temperature hamper the amount of ascorbic corrosive and quicken the chilling wounds on account of pulverization in the ascorbic corrosive substance bringing on chilling. The temperature of F & V amid whole preparing impacted the ascorbic corrosive substance and brought on chilling harm. Measure of ascorbic corrosive diminished at the lower temperature (5 C) yet not influenced at higher temperature (20°C) on account of cucumber. Amid the capacity and saving methodology of F & V the dampness and relative moistness likewise influence the timeframe of realistic usability, quality and different attributes in light of the fact that basically F & V has demonstrated better quality perspectives at higher relative stickiness.

All new convey is obligated to damage when displayed to extremes of temperature. Items change fundamentally in their temperature strength. Their levels of flexibility to low temperatures are of staggering criticalness where cool stockpiling is concerned:

- Freezing damage - All produce is obligated to cementing at temperatures some place around 0 and -2 degrees Celsius. Hardened produce has a water-sprinkled or glossy appearance. Despite the way that a few items are tolerant of slight hardening, it is reasonable to keep up a key separation from such temperatures because following stockpiling life is short. Produce which has recovered from setting is significantly helpless to decay.

- Chilling harm - Few sorts of new convey are defenseless against damage at low however non-setting temperatures. Such items are essentially of tropical or subtropical root, yet two or three mellow reaps may be affected.

- High temperature harm - if new make is displayed to high temperatures brought on by sun arranged radiation, it will go to pieces rapidly. Convey left in the sun after harvest may attain to temperatures as high as 50 degrees Celsius. It will fulfill a strange condition of breath and, if squeezed and transported without cooling or acceptable ventilation, will get the chance to be unusable. Long prologue to tropical sun will achieve great water adversity from extremely touchy root harvests, for instance, carrots and turnips and from verdant vegetables

<b>Effect of chilling injury</b>	<b>Symptom</b>
Discoloration	Internal or external or both, usually brown or black
Skin piking	Sunken spots, especially under dry conditions
Abnormal ripening (fruits )	Ripening is uneven or fails; off-flavours
Increase in decay	Activity of micro-organisms

### Incompatibility

A single facility cannot be utilized to store various produce together. There is a possibility of odor change if two incompatible fruits or vegetables are stored together. The table below shows the compatibility of few F & V.

Table shows the more important incompatibilities.

	<b>Apples</b>	<b>Bananas</b>	<b>Cabbage</b>	<b>Grapes</b>	<b>Oranges</b>	<b>Potatoes</b>	<b>Vegetables</b>
<b>Apples</b>	-	N	SR	Y	Y	SR	Y
<b>Bananas</b>	N	-	N	Y	N	N	Y2
<b>Cabbage</b>	SR	Y	-	SR	N	SR	SR
<b>Grapes</b>	Y	Y	SR	-	Y	Y	Y
<b>Oranges</b>	Y	N	N	Y	-	Y	Y
<b>Potatoes</b>	SR	N	SR	Y	Y	-	Y

Y = No cross action SR = Slight danger BR = Danger N = Cross action will take place

Source: NCCD, 2011

## Mechanical injury

The high dampness content and delicate composition of organic product, vegetables and root products make them helpless to mechanical harm, which can happen at any stage from creation to retail advertising on account of:

- poor collecting practices;
- unsuitable field or promoting holders and cases, which may have chipped wood, sharp edges, poor nailing or stapling;
- over-pressing or under-pressing of field or promoting holders;
- careless taking care of, for example, dropping or tossing or strolling on produce and pressed compartments amid the procedure of evaluating, transport or promoting.

Wounds brought about can take numerous structures:

- splitting of natural products or roots and tubers from the effect when they are dropped;
- internal wounding, not obvious remotely, brought about by effect;
- superficial brushing or scratches influencing the skins and external layer of cells;
- crushing of verdant vegetables and other delicate produce.

Wounds removing through or scratching the external skin of produce will:

- Provide entrance focuses for molds and microscopic organisms creating rot;
- Increase water misfortune from the harmed range;
- Cause an increment in breath level and therefore warm generation.

Wounding wounds, which leave the skin in place and may not be obvious remotely

Causes:

- Increased breath level and warmth generation;
- Internal staining in light of harmed tissues;
- Off-flavors in light of unusual physiological conditions

## Diseases

Misfortunes from post-harvest malady in new deliver fall into two fundamental classifications:

- Misfortune in amount, the more genuine, happens where profound infiltration of rot makes the tainted produce unusable. This is regularly the consequence of disease of the produce in the field before harvest.
- Misfortune in quality happens when the sickness influences just the surface of produce. It may bring about skin imperfections that can bring down the estimation of a business crop. In yields developed for neighborhood utilization, the outcome is less genuine since the influenced skin can regularly be uprooted and the undamaged inside can be utilized.

Contagious and bacterial sicknesses are spread generally by tiny spores, which are broadly disseminated noticeable all around and soil and on dead and rotting plant material. Produce can get to be tainted:

- through wounds created via thoughtless taking care of, by creepy crawly or other creature harm, or through development breaks
- through regular pores in the above- and subterranean parts of plants, which permit the development of air, carbon dioxide and water vapor into and out of the plant;
- by direct infiltration of the in place skin of the plant. The time of disease changes with the product and with distinctive infections. It can happen in the field before harvest or whenever subsequently.



Field contaminations before harvest may not get to be unmistakable until after harvest. For instance, rot of root products brought about by soil molds will create amid capacity. Likewise, tropical natural products tainted whenever amid their improvement may show rot just amid maturing.

Disease after harvest can happen whenever between the field and the last customer. It is generally the aftereffect of intrusion of reaping or taking care of wounds by molds or microscopic organisms.

Post-harvest sicknesses may be spread in the field before harvest by the utilization of tainted seed or other planting material. Numerous maladies can make due by utilizing weed plants or different harvests as substitute or option has. They are additionally spread by method for contaminated soil carried on homestead actualizes, vehicles, boots, and so on and from product deposits or rejected create left rotting in improper storage conditions.

## Why should we reduce PHL?

There is have to have a solid post-harvest base for post-harvest administration of these perishables. Post-harvest innovation (PHT) is between disciplinary "Science and Technique" connected to agrarian deliver after harvest for its assurance, protection, handling, bundling, dispersion, advertising, and usage to meet the nourishment and dietary prerequisites of the individuals in connection to their needs. Utilization of fitting PHT decreases the post-harvest and stockpiling misfortunes; increases the value of the item, produces vocation in the town and re-creates agro-commercial enterprises in rustic area.

### Food Security

Current world populace is required to achieve 10.5 billion by 2050 (UN March, 2013), further adding to worldwide nourishment security concerns. This increment deciphers into 33% more human mouths to nourish, with the best request development in the poor groups of the world. Nourishment supplies would need to increment by 60% (Estimated at 2005 sustenance creation levels) to take care of the sustenance demand in 2050. Sustenance accessibility and availability can be expanded by expanding creation, enhancing circulation, and diminishing the misfortunes. Accordingly, diminishment of post-harvest nourishment misfortunes is a discriminating part of guaranteeing future worldwide sustenance security.

F & V are important supplements to the human diet. As per the specifications of National Institute of Nutrition at least 300gms of F & Vs are to be consumed by an individual for a balanced diet. By calculations with the record from 2011, per capita availability of F & V remarkably fell short by the above standards and would require additional 50 million tons to statistically feed the population of the nation with the basic requirements.

### Affordability

Nourishment and Agriculture Organization of U.N. predicts that around 1.3 billion tons of nourishment are comprehensively squandered or lost every year. Decrease in these misfortunes would build the measure of sustenance accessible for human utilization and

upgrade worldwide nourishment security, a developing concern with rising nourishment costs because of developing shopper interest, expanding interest for biofuel and other modern uses, and expanded climate variability. A diminishment in nourishment misfortune likewise enhances sustenance security by expanding the genuine pay for all the buyers (World Bank, 2011). In addition, crop production contributes significant proportion of typical incomes in certain regions of the world (70 percent in Sub-Saharan Africa) and reducing food loss can directly increase the real incomes of the producers (World Bank, 2011).

## **Environmental Concern**

Food losses do not merely reduce food available for human consumption but also cause negative externalities to society through costs of waste management, greenhouse gas production, and loss of scarce resources used in their production. Food loss is estimated to be equivalent to 6-10 percent of human-generated greenhouse gas. A significant contributor of this problem is through methane gas generation in landfills where food waste decomposes anaerobically.

A study by Institute of Mechanical Engineers demonstrates that current horticultural practices utilize 4.9 Global hectares (4931 million hectares) of the aggregate 14.8 Global hectares (14894 million hectares) of area surface on the earth. Rural creation also utilizes 2.5 trillion m<sup>3</sup> of water every year and more than 3% of the aggregate worldwide vitality utilization. With assessed sustenance misfortunes of around 30-50 % of aggregate generation, this means 1.47-1.95 Global hectares of arable area, 0.745-1.25 trillion m<sup>3</sup> of water and 1% to 1.5% of worldwide vitality.

## Cold Storage and Transportation

A cold chain protects a wide variety of food produce to get deteriorate in the whole supply chain by providing temperature controlled facility. It is a logistic system that provides a series of controlled temperature storage and transport conditions from the point of origin to the point of consumption, i.e. from farm to fork. It saves fresh produce from degradation, humidity, inappropriate exposure to temperature and keeps them frozen, fresh and chilled. Any disorder in temperature or time-distance in the cold chain could hamper the net present value and their added value. The cold chain starts at farm level and covers up to the consumer level in a temperature controlled practices and behavior. Cold chain infrastructure generally consists of grading, sorting, packing, storage, processing and transportation facilities.



### The Cold Supply Chain Infrastructure

*Source: Sapra & Joshi (2011)*

### Cold Storage

Cooling of F & V is necessary at different stages:

- after harvesting (pre cooling),
- during storage (cold storage), and
- during transportation (vehicles with freezer)

for controlling the wastage and degradation in the quality aspects of the produces. The numbers and capacity of cold storage increased in India during last few years but still not sufficient for handling the production. Appropriately controlled storage temperature up to 70F minimizes the

respiration rate, excess moisture loss and textural shrinkage which reduce the weight loss of the potatoes and prevents browning.

Commodities condition, packaging process, and storage system of the agricultural products are affected by implemented cooling methods. Different kinds of cooling:

- room cooling,
- hydro cooling (Evaporative), and
- forced air cooling

have been used in which room cooling decreased the temperature of the produces slowly in the comparison of hydro cooling as well as forced air cooling.

Great nature of the F & V relies on temperature in light of the fact that stockpiling at ideal temperature limitations over aging, softening, expanded breath level and harm. Higher capacity temperature builds the breath level and results in fast harm and quick corruption of the timeframe of realistic usability of F & V. Ingestion of the warmth by means of encompassing temperature causes the high breath and resulting decay of the crisp items. Precooling declines the temperature up to imperative level before handling or stockpiling and retards the synthetic and changes of F & V amid transforming or stockpiling. Timeframe of realistic usability of F & V has been expanded with the assistance of diverse precooling techniques.

Cold storage facilities were available for only 10-11% of the produce, resulting in 18-40% of the produce being lost, said the study that was released at a conference organized by the PHD Chamber of Commerce in New Delhi in 2010.

In the present situation, India has the capacity store just 2% of its homestead create in temperature-controlled environment as against 8% for the Asia-Pacific segment and 85% for Europe and North America. Punjab was the main state in India with surplus storeroom. Among all expresses, the biggest crevices exist in Tamil Nadu, took after by Maharashtra and West Bengal.

India's chilly chain industry is as yet developing, not all around sorted out and working underneath limit. Most hardware being used is obsolete and single ware based. India has 5,400 cool storage spaces, of which 4,875 are in the private division, 400 in the agreeable part and 125 in general society area. In spite of the fact that the joined limit of the chilly storerooms is 23.66 million metric tons, India can store under 11% of what is delivered. A large portion of the base utilized as a part of the chilly chain segment is obsolete innovation and is single ware based. Numerous are intended for putting away potatoes. The vast majority of these offices are situated in the conditions of Uttar Pradesh, Uttaranchal, Punjab, Maharashtra, and West Bengal.

Industry specialists accept that controlled air storage spaces and other cool storerooms with the innovation for putting away and taking care of distinctive sorts of F & V at variation temperatures would have a decent potential market in India.

The gap between demand and supply of cold storage facilities in India, the world's second largest producer of F & Vs, was 36.832 million tons (mt) in 2010, according to a Yes Bank study.

<b>State</b>	<b>Cold Storage Requirement (Lakh MT)</b>	<b>Present Capacity</b>	<b>Gap</b>
Tamil Nadu	79.06	2.39	76.67
Maharashtra	62.73	5.47	57.26
West Bengal	105.66	56.82	48.84
Bihar	42.41	11.47	30.94
Kerala	27.71	0.58	27.13
UP & Uttaranchal	122.28	101.87	20.41
Karnataka	24.04	4.07	19.97
Orissa	18.35	2.91	15.44
Gujarat	27.48	12.67	14.81
Andhra Pradesh	23.24	9.01	14.23
Assam	9.19	0.88	8.31
Jammu & Kashmir	7.37	0.43	6.94

Jharkhand	7.96	1.7	6.26
Himachal Pradesh	4.87	0.2	4.67
Haryana	8.04	3.93	4.11
Madhya Pradesh	12.13	8.08	4.05
Meghalaya	2.39	0.03	2.36
Chhattisgarh	5.43	3.42	2.01
Tripura	1.63	0.3	1.33
Manipur	0.8	0	0.8
Mizoram	0.74	0	0.74
Rajasthan	3.91	3.24	0.67
Nagaland	0.7	0.06	0.64
Punjab	13.18	13.45	0
<b>Total</b>	<b>611.3</b>	<b>242.98</b>	<b>368.32</b>

Source: NCCD, 2011

Above table breaks down the large figure of requirement into state wise requirement of the cold storage facilities in the nation.

## Transportation

As per industry estimates, pretty nearly 104 million metric huge amounts of perishable produce is transported between urban areas every year. Of this figure, around 100 million metric tons moves by means of non-reefer mode and just four million metric tons is transported by reefer. Albeit there are right now more than 25,000 vehicles and 250 administrators included in refrigerated transport, 80% of this limit is committed to transporting milk. At the point when contrasted and world principles for load development through frosty chain, India is still a long ways behind. The rate of development of F & V through icy chain in U.S. is around 80 to 85 percent, Thailand is 30 to 40 percent and India is insignificant. Right now, the greater part of the refrigerated transport in India is worked by little, non-incorporated firms that don't make utilization of state-of-the-art innovation.

There are around 7,000-8,000 refrigerated vans or trucks having an aggregate conveying limit of 3.6 million tons in India, as indicated by authority records. In any case, this is far underneath the necessity, given that India is the world's second biggest maker of F & V after China and creates around 266 million tons of these things in a year.

### **Bottlenecks in Cold Chain**

The major bottlenecks which are found from the literature in the cold supply chain are:

- Lack of cold storage and warehousing facilities,
- Inadequate capacities to serve the needs,
- Inadequate usage/inappropriate management of cold storage,
- Irregular supply of power or shortage of power to run cold chain; and
- Poor post-harvest cold chain technology etc.

Also found the various gaps in cold chain such as:

- Poor infrastructure,
- Unavailability of cold storage in close proximity to farms,
- Insufficient cold storage capacity,
- Poor transportation infrastructure etc.
- Waiting time at Toll Booths for reefer trucks

Because of these bottlenecks in cold supply chain this sector is suffering from maximum inefficiency and decreases the returns of F & V which affect the income of the farmers and their livelihood. It plays a very vital role and is the backbone for the supply chain of F & V industry but due to the bottlenecks it becomes a very weak link and one of the main reason for Supply chain losses in food.

Around 95 % of the cool stockpiles are in private hands and due to high charges, a normal Indian rancher is not ready to profit the offices of chilly stockpiling. There is an absence of possession inside the chain and all the players are concerned with their own particular income amplification with constrained consideration towards the general benefit of the chain. The absence of an all-encompassing perspective of an inventory network is prompting the post-



harvest waste. The size of misfortunes is additionally relies on upon the base, for example, street integration and system.

In India the greater parts of the northern and eastern district is secured with bumpy territory regions and are the real wellsprings of F & V. The street integration for cool chain and system framework in such territories are extremely poor which takes quite a while to take the new F & V item to the business sector and disintegrate the quality and state of the produce which brings about wastage. The towns, homesteads and the businesses in the Uttarakhand state (Hilly district) are not all around associated and there is absence of icy chain offices and the ranchers needed to by one means or another convey their harvests to the adjacent street for transportation, which expanded the wastage of their produce. On its approach to market, an absence of fitting chilly chain offices brings about more noteworthy wastage of the crisp produce. Brief measures are needed by the administration and different partners in India to enhance the condition of frosty binds and to decrease the immense misfortunes of F & V and expansive measure of cash.

## Few Government Initiatives and Case

### Introduction of Horti-Train

Introduction of dedicated train and reefer van is also expected to bridge the gap between the producers and consumers thereby ensuring remunerative prices to the farmers.

- The first Horticulture Train, nonstop trail run was conducted between Bhusawal – Azadpur (New Delhi) sector in the month of January, 2012 which carried about 1100 MT of banana from Bhusawal to Azadpur market yard in 26 hours.
- Another round of Train run with potato was successfully conducted between Agra – Turbhe (New Bombay) sector on 12th June, 2012. The Train reached its destination in a record time with extremely good condition of produce at APMC Turbhe, Vasi Market.
- Another round of trail run of full rake load of onion from Khedwadi (Niphad, Distt. Nashik) to Chitpur, Kolkatta (West Bengal) was done in June, 2012.

After conducting trial run on various sectors and with different commodities, service of Horticulture Train is proposed to be formally launched on viable origin – destination (OD) pairs; i. e. is Agra – Turbhe – Tulgalabad/Azadpur – Agra.

### Installation of Controlled Atmosphere facility for 1000 MT of Apple

*“...the apple project of Uttarakhand, which is a unique kind of an initiative, has succeeded in empowering the small farmers of Uttarakhand and Himachal Pradesh by enabling them to move up the value chain.*

*A joint initiative by Fresh food Technology (FFT), Stichting Het Groene woudt (SHGW) and Shri Jagdamba Samiti (SJS), has constructed a Controlled Atmosphere (CA) storage facility in Naogoan to store up to 1,000 MT apples for off-season sales.*

*This long-term storage facility has relieved the apple growers of the pressure of hunting for markets for their apples. The cold storage facility has taken care of the post-harvest responsibilities of apple growers, especially the marginalised farmers and has brought a sense of security to them by selling their produce at an optimum cost...”*

Earlier, individual farmers had to manage the transportation and marketing of apples, especially in the rainy season when the produce would be ready for the markets but could not be transported due to bad weather.

### **Toll Free Access to Reefer Trucks**

The government is working on a proposal to allow refrigerated trucks and vans toll-free access across all states. The vans, mainly used to transport perishable commodities, suffer valuable loss of time when stuck in toll booths for mandatory clearances.

The proposal, mooted by the National Centre for Cold Chain Development (NCCD), received the backing of ministry of road transport as well. NCCD is an umbrella organization to develop policies, promote and lay down guidelines for growth of cold chains in the country.

### **Year For Agriculture Development (2014-15)**

“...with Gujarat witnessing fast growth in the agriculture sector, owing to water from the Narmada now reaching farmlands and also due to other irrigation facilities being made available through a variety of water conservation projects, the state government has specially focused on creation of sufficient storage facilities for agriculture produce. The government has allocated Rs 4,624 crore for agriculture in its 2014-15 budget.

To make its focus on agriculture clearer, the state government has also declared 2014-15 as ‘Year for Agriculture Development’...”

Gujarat, since 2013, has known to be receiving investments in cold storage facilities as well. This initiative from the government will further boost the developments in an attempt to reduce the losses and provide farmers with advanced and appropriate facilities.

## Case 1

*“A study conducted in Punjab (India) provides an example of postharvest loss estimation for a perishable product. The study was conducted for kinnow (citrus fruit) using random sampling technique in the largest production region of the state in 2004-05. After selection of the region, four villages were randomly chosen and the kinnow growers were grouped into three categories depending upon the size of their orchards:*

- (1) less than 2 ha;*
- (2) 2-5 ha; and*
- (3) Above 5 ha.*

*Data were gathered during the fruit harvesting and marketing seasons through pre-tested questionnaire by personal interview method. Simple averages and percentages were used to calculate the post-harvest losses at different stages identified in the kinnow supply chain.*

*In the kinnow study, two methods of harvesting were adopted. The first method involves just dropping them on the ground and the second one uses clippers, followed by the collection of fruits in crates or bags. In the first method PHL at the harvesting level were recorded to be 10.63 % compared to only 2.51 % in the second method. PHL also varied depending upon the distance to the market. When they are marketed to medium-distance markets, PHL were 5.15% whereas for long-distance markets they were 8.17 %. Overall losses were 14.47 % for the Delhi market and 21.91% for the Bangalore market.”*

## Inference

In the Punjab citrus case, two stages appear to be critical, harvesting and transportation. Significant losses could be prevented by using harvesting techniques which prevent damage to the fruit. Similarly, losses could also be minimized by either reducing the distance to markets, or likely by using climate-controlled transportation with proper packaging of fruit.

## Potential Solutions to Reduce PHL in India

F & V should be harvested very carefully after observing the appropriate maturity level and quality because lower or upper maturity level of produce reduces the storage life and enhances the damage. Single bruising of apple increases the moisture losses up to 40%. Good methods of harvesting, handling, transportation and storage extend the shelf life and maintain the qualitative characteristics of the harvested produce. Sterilized or appropriately cleaned packaging also helps to enhance the quality and prevents excessive respiration of packed F & V. Several preservation technologies like cold storage, modified atmosphere packaging and edible coating can be used for keeping the F & V safe and hygienic.

From the above theory and statistical analysis, the importance of a well-established cold chain network can easily be understood. Lack of an appropriate and technologically upgraded infrastructure to store and transport the perishable commodities in the nation over short as well as long distances. A loss of Rs. 2 Lakh Cr is an extremely high figure to be ignored in the current conditions of Indian and the World economy, where in many nations are struggling to achieve food security, the waste in India alone is sufficient to feed the larger populations of the world living in poverty.

From this study it is important to approach this problem by identifying ways to reduce the injuries to F & V in the process of harvesting, storage and transportation where largest of losses occur.

Mechanical Injury caused during harvesting and handling of the produce can be reduced by using latest methods and techniques with adoption of less expensive technology. In the Punjab case, use of clipper to harvest Kinnow reduced the loss at that stage by 8%. Such significant reductions can be achieved by simply using the right technology and other appropriate techniques in packaging and storage which will have a direct impact on PHL.

The solution will be divided into 2 segments:

- Appropriate Post-harvesting techniques
- Efficient Cold Chain

### **Appropriate Post-Harvesting Techniques**

Minimization of PHL from harvest to utilization relies on the few specialized, natural, ecological angles which can be controlled with the utilization of fitting post-harvest innovation. Accessibility of perishable delivers up to long time in the wake of collecting is conceivable just with gifted and exploratory preparing ways to deal with save the items with minimum decay.

F & V are perishable in nature. Logical collecting and taking care of are the handy approach to decrease the misfortunes because of physical harm, harms, because of bug harms and microbial development. Different conventions are institutionalized and accessible for appropriation to get the best result, which will give financial advantages. Essentially, suitable capacity conditions, with suitable temperature and mugginess are expected to stretch the stockpiling life and keep up quality once the yield has been cooled to the ideal stockpiling tempera Lure. More noteworthy accentuation need to be given on the preparation of agriculturists, making of foundation for frosty chain with basic offices for sorting, reviewing, pressing and post-harvest medications in all significant markets. A few advancements for augmentation of time span of usability of F & V are:

#### **Waxing**

It is used as protective coating for F & V and help in reduction in loss in moisture and level of respiration and ultimately results in prolonged storage life.

#### **Evaporative cool storage**

It is the best short-term storage of F & V at farm level. It helps the farmers to get better returns for their produce. In this structure, horticultural crops reduce shriveling and extend their storage life.

## **Pre-packaging**

This technology controls the level of transpiration and respiration and hence keeps the commodity in fresh condition both at ambient and low temperature. It can able to bring revolutionary progress in our trade practice and also benefit the consumer and the producer because of its low cost and ready availability.

## **Modified atmosphere packaging (MAP)**

These packaging modify the atmosphere composition inside the package by respiration. This technology is successful to extend the shelf life of (Cavendish banana, carrots capsicum, green chilli and tomatoes by 15, 14, 13, 8 and 15 clays as against 5, 7, 8, 4 and 7 days in control respectively, under ambient conditions. Storage of Papaya can be extended 4 weeks when stored at 10 - 12 °C under modified atmosphere (MA) conditions by wrapping them in low density polyethylene (LDPE) bag. Using this technique, the Fruits can be transported to different markets in refrigerated sea containers with Temperature Sea at 10-12 °C. Fruits ripen within 3-4 days after arrival when placed at ambient temperature. While using optimum low temperature, storage life of Cavendish banana, capsicum, green chili and tomato can be extended to 42,21,28 and 30 days in comparison to 21, 10,21 and 15 days respectively.

## **Irradiation**

It is the newer technology that can be gainfully employed during storage to reduce PHL and extend storage life of fruits and vegetable. When F & V expose to ionizing radiation (such as gamma-rays) at optimum dosage delays ripening minimizes insect infestation, retards microbial damages, control sprouting, and rotting of onion, garlic and potato during storage. It is also used as a disinfection treatment and controls Fruits fly on citrus, mango seed weevil and papaya Fruits fly.

## Edible coatings

These are continuous matrices prepared from edible materials such as proteins, polysaccharides and lipids. They can be used as film wraps and when consumed with the food, become an ingredient of the food. They not only minimize the PHL but also need for energy intensive operations and controlled atmosphere storage. They can control migration of gases, moisture, oil, fat, and solutes, as well as retain volatile flavouring compounds. An edible coating improves structural integrity and mechanical handling and carry product so that they help to maintain quality and inhibit microbial growth causing deterioration of the product.

## Modern Post-Harvesting Techniques

Several significant technologies developed by CFTRI, DFRL, IIHR, IARI, GBPUAT and HPKV include the process of ripening of fruits , optimum harvesting time, pre-cooling of freshly harvested produce, cold storing of the raw F & V, sorting, cleaning, waxing, packaging technology for fruits .

India is an overwhelmingly a horticultural economy and 65-75% of its populace live in towns and gain their vocation through farming. For rustic treatment of ranch inputs and yields, Horticulture Mission has encouraged the advancement and made accessible homestead and town level innovations furthermore accentuates opportunities grew through specific motorization of horticulture and proper post-harvest administration and worth expansion to the collected biomass in the generation catchments. All the AICRP communities for PHT, CFTRI and a few different associations included for PHM plans to create area and yield particular post-harvest advances and hardware to minimize quantitative and subjective PHL furthermore to create advancements for making accessible essential handled materials in the country territories at less expensive levels and guarantee better financial comes back to the agriculturists from their attractive surpluses and by-items and produce work in the provincial ranges commitment to the general monetary improvement and upgrades in personal satisfaction. A few homestead level cleaners, graders, dryers, decorticators and so forth were created for agriculturists by different associations and some of field level fruitful advances for country segments are highlighted below.

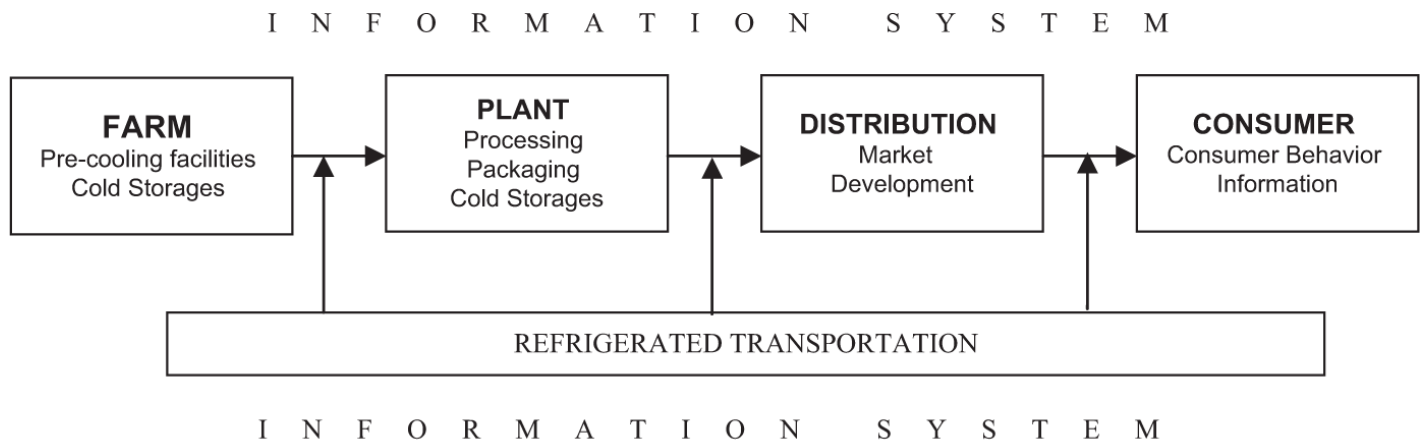


<b>Name of the Technology/Equipment</b>	<b>Working Organizations</b>
Threshers	Tami Nadu Agriculture University (TNAU)
Storage structures for Onion	Central Institute of Agriculture Industry (CIAE)
Solar Drier	CIAEI
Decorticators	TNAU, CIAE
Ginger and Turmeric Polisher	Rajasthan Agriculture University (RAU)
Pea Peeling and Punching	Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV)
Extraction of Chilies' Seed	Dr. Panjabrao Deshmukh Vishwa Vidyapeeth (PDKV)
Garlic Bulb Breaker	Maharana Prathap University of Agriculture and University (MPUAT)
Mango Grader	Govindh Ballabh Pant University of Agriculture and Tech. (GBPUAT)
Atmosphere packaging of vegetables	Central Food Technological Research Institute (CFTRI)
Papain	CFTRI
Wax emulsion for F & V	CFTRI
Zero Energy Cool Chamber	Indian Council of Agri. Research (ICAR)
Strawberry Clipper	Central Institute of Post-Harvest Engg. Tech

	(CIPHET)
Banana Comb Cutter	CIPHET
Pomogranate Aril Extractor	CIPHET
Tomato Grader	CIPHET
Groundnut Pod Grader	CIPHET
Pilot Plant for Kinnow Processing	CIPHET
Chili Processing Plant	CIPHET
Tomato Processing Plant	CIPHET
Fibers from banana plants for ropes	RRL, Jorhat
PKV chili seed extractor	PDKV
Pedal operated coconut dehusker	University of Agricultural Sciences (UAS)
Cardamom dryer	UAS
Solar cabinet dryer for vegetables	CIAE
On-farm Fruits grader	JAU
Tender coconut punch and cutter	CPCRI
Pomegranate seed extractor	RS&JRS (CIPHET)
Mechanical Fruits washer	RS&JRS (CIPHET)
Farm level washing machine	PAU (Punjab Agricultural University)

## Appropriate Cold Storage Facilities

It has become increasingly evident that the capacity of cold chain in India falls much behind the requirement. But increasing the number of facilities alone won't answer to this rising problem. Infrastructure needs to be supported with adequate cold supply chain that will enable optimum utilization of the facilities. The figure below depicts the use of Information System across the cold chain.



**Sources:** Montanari (2008), Viswanandham (2006)

The presence of cold storage and transportation at every level of this supply chain is essential to keep the quality and freshness of the produce at its best. In a hot and humid country like India it is one of the most essential need to save the F & V from direct exposure to heat and pollution by regulation and controlling temperature at the optimum levels as will be shown in the tables below.

By identifying the most favorable temperatures that each variety of fruits and vegetables can be stored in, waste in energy can also be reduced by keeping the temperature at optimum level rather than freezing the produce and increasing the risks of freezing or chilling injury.

Simultaneously cleaning and cooling of the fruits and vegetables named as hydro cooling considered as efficient method of cooling as well as reduce the temperature five times faster than air. Dense kept and high respiration agriculture produces (like sweet corn and broccoli) were cooled with top or liquid icing. Research has found that 0.453 kg of ice

decreased the temperature of 1.36 kg fruits and vegetables from 85 F to 40 F. Generally, for decreasing the temperature of leafy fruits and vegetables, vacuum cooling is preferred because with the help of this method the heat removal from the tissues takes place with the application of vacuum pressure. Fresh and hygienic characteristics of the fruits and vegetables can be maintained with the help of adequate cooling system during storage.

<b>Commodity</b>	<b>Estimate safe temperature °C</b>	<b>Chilling injury symptoms</b>
Aubergines	7	Surface scald, <i>Alternaria</i> rot
Avocados	5-13	Grey discoloration of flesh
Bananas (green/ripe)	12-14	Dull, gray-brown skin color
Beans (green)	7	Pitting, russeting
Cucumbers	7	Pitting water-soaked spots, decay
Grapefruit	10	Brown scald, piking, watery breakdown
Lemons	13-15	Pitting, membrane stain, red blotch
Limes	7-10	Pitting
Mangoes	10-13	Grey skin scald, uneven ripening
Melons: Honeydew	7-10	Pitting failure to ripen, decay
Watermelon	5	Pitting, bitter flavor
Okra	7	Discoloration, water-soaked areas, piking
Oranges	7	Pitting brown stain, watery breakdown
Papaya	7	Pitting failure to ripen, off-flavour, decay
Pineapples	7-10	Dull green colour, poor flavor
Potatoes	4	Internal discoloration, sweetening
Pumpkins	10	Decay
Sweet peppers	7	Pitting <i>Alternaria</i> rot

Sweet potato	13	Internal discoloration, piking, decay
Tomatoes: Mature green	13	Water-soaked softening, decay

Source: Emerson Climate Technologies

While the above table specifies the safe temperature to avoid temperature injuries, the table below includes what is the maximum storage time and in tropical conditions as well. Making available such important and enabling information with the farmers and those providing the cold storage facilities will improve the shelf life of the produce.

	Temperature °C	Relative humidity %	Maximum storage time recommended	Storage time in cold stores for vegetables in tropical countries
Apple	0-4	90-95	2-6m	-
Beetroot	0	95-99	-	-
Cabbage	0	95-99	5-6m	2m
Carrots	0	98-99	5-9m	2m
Cauliflower	0	95	2-4w	1w
Cucumber	10-13	90-95		
Eggplant	8-10	90-95		
Lettuce	1	95-99		
Leeks	0	95	1-3m	1m
Oranges	0-4	85-90	3-4m	

Source: Emerson Climate Technologies

The same time cleaning and cooling of the foods grown from the ground named as hydro cooling considered as productive strategy for cooling and in addition diminish the temperature five times speedier than air. Thick kept and high breath agribusiness produces (like sweet corn and broccoli) were cooled with top or fluid icing. Examination have discovered that

0.453 kg of ice diminished the temperature of 1.36 kg foods grown from the ground from 85 F to 40 F. By and large, for diminishing the temperature of verdant leafy foods, vacuum cooling is favored in light of the fact that with the assistance of this strategy the warmth expulsion from the tissues happens with the use of vacuum weight. New and hygienic qualities of the products of the soil can be kept up with the assistance of satisfactory cooling framework amid capacity.

### **Strong Cold Transportation Network**

According to an official estimate, around 20,000-25,000 refrigerated trucks are needed to ensure that fruits, vegetables and other perishable items are transported efficiently across the country. Not, only refrigerated vans, which are just one part of the whole eco-system of cold storages, a lot more needs to be done for the cold chain network itself.

Excise duty on local freezer cabinets should be reduced from 18 percent to 3 percent. This will have a direct impact on the cost of procurement of a reefer truck. A reduced cost will enable more people to invest in the use of this vehicle for transportation of perishable goods.

An infrastructure should be developed for the use of reefer containers for the purpose of domestic movements of cargo. Use of this transportation within the country will increase the quality of the available produce throughout the nation and just in the region of produce.

## Suggestions

### Cold Chain Storage

- Increasing the capacity of cold storages across the country for storing horticultural produce.
- Using the right method of cooling that is cheap and quick in the objective at the right levels of supply chain.
- Analyzing the compatibility of products to create multi product storage facilities.
- Orienting farmers on the use of cold chain and the benefits that could be derived.
- Creating cooperative societies for the development of cold storages to make it cost attractive for small and fragmented farmers.

### Cold Chain Transport

- Educating the service providers on safe temperatures and temperature injury, product wise.
- Quick implementation of horti-trains for long distance transportation.
- Connecting high producing states with other states through horti-trains to enable efficient network of transportation of goods to all parts of the country. (Page 56: reference to high producing states of various F & V)
- Removing toll tax on reefer trucks to fast track their movements.
- Reducing excise duties on products produced to be used in the cold chain like reefer containers, vehicles etc.

### Supply Chain

- Integrating the supply chain to consolidate the volumes of produce from small farmers.
- Introduction of pre-coolers and pack houses in India.
- Shortening the supply chain and providing farmers with direct access to the markets to reduce material handling and increase the margin for farmers.
- Improving packaging of the produce and providing financial assistance for the same.

### Harvesting and Post-Harvesting

- Use of harvesting and handling technology by the smallest of farmers to prevent mechanical injury resulting in additional qualitative loss of 8%.

<b>Fruit</b>	<b>Producing States</b>
Apple	J & K, Himachal Pradesh, Uttarakhand
Banana	TN, Maharashtra, Karnataka, Gujarat, Andhra Pradesh, Assam & Madhya Pradesh
Citrus	J & K, Himachal Pradesh, Uttarakhand, Punjab, Haryana, Rajasthan, WB, Sikkim, Arunachal Pradesh, Assam, MP, Maharashtra, AP & TN.
Sapota	Karnataka, Gujarat, AP, Maharashtra, Odisha.
Guava	Bihar, UP, MP, AP, Karnataka, Gujarat, Maharashtra
Mango	AP, UP, TN, Maharashtra, Karnataka, WB, Odisha
Litchi	Bihar, Tripura, WB, Uttarakhand, Assam & Punjab
Papaya	Karnataka, Gujarat, Odisha, WB, Assam, Kerala, MP & Maharashtra
Pineapple	WB, Assam, Karnataka, Meghalaya, Manipur, Bihar & Kerala

<b>Vegetable</b>	<b>Producing States</b>
Brinjal	Odisha, Bihar, Karnataka, WB, AP, Maharashtra & UP
Cabbage	UP, Odisha, Bihar, Assam, WB, Maharashtra & Karnataka
Cauliflower	Bihar, UP, Odisha, WB, Assam, Haryana & Maharashtra
Okra	UP, Bihar, Odisha, WB, AP, Karnataka & Assam
Onion	Maharashtra, Gujarat, AP, UP, Odisha & MP
Peas	UP, Bihar, Haryana, Punjab, Himachal Pradesh, Odisha & Karnataka
Tomato	Bihar, Karnataka, UP, Odisha, AP, Maharashtra, MP & Assam