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REVIEW ARTICLE



Post-harvest practices of horticultural crops in Nepal: Issues and management

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ABSTRACT

Fruits and vegetables are highly perishable in nature and have a very short shelf-life. During different handling and marketing procedures, there is massive post-harvest loss of horticulture produce, either or both qualitative and quantitative, between harvest and consumption. Factors affecting post-harvest losses differ with topography, varieties of crops, climate, etc. and are difficult to understand. Considering the fact, the present study aims to describe the status of post-harvest losses of horticultural produce and their potential management techniques. Secondary data is used to collect the related information. The demand of high-quality horticulture produce is increasing due to its healthy nutrition. Post-harvest management of the produce includes pre- and post-harvest practices, their handling, packaging, storage, distribution, and marketing. The storage life and marketable quality of the produce can be maximized by limiting (not stopping) the respiration and transpiration through proper control of temperature and relative humidity of the produce. The right selection of packaging materials and technologies play vital role in maintaining product quality and freshness during storage and distribution. Moreover, the innovative techniques like modified active packaging, active and intelligent packaging, controlled atmospheric storage, and use of antimicrobial could extend the shelf life of produce to a significant time. This review mainly focuses on the causes of qualitative and quantitative losses of horticulture produce along with the effective measures to control the losses in Nepalese context. It emphasized on the adoption of innovative technologies to improve the storage life, marketable quality and freshness of the produce.

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INTRODUCTION

Post-harvest loss is defined as a “measurable quantitative and qualitative loss of a given product at any point along the post-harvest chain” (De Lucia and Assennato, 2006) and includes the change in the availability, edibility and wholesomeness of the food that prevents it from being consumed (FAO, 1989). Post-harvest management of fruits and vegetables include pre- and post-harvest practices, their harvesting, handling, packaging, storage, distribution, marketing etc. (Yadav *et al.*, 2014). Quality of fruits and vegetables produce plays an important role in healthy nutrition and its demand is increasing day by day. Most of the fresh are highly perishable in nature due to the presence of high moisture content (75-95%) and high equilibrium relative humidity (95%) (Norman *et al.*, 1984). Although, Nepal produces

huge number of fruits and vegetables but still post-harvest losses in them is high ranging from 20-50% (Bhattarai *et al.*, 2017). It is estimated that about one-third of the fresh produce harvested worldwide is lost at some point between harvest and consumption (Kitinoja and Kader, 2002). As we know, fruits and vegetables are living organisms that can respire even after harvesting and can remain fresh only till normal metabolites continue. This makes them more susceptible to spoilage caused by mould, yeasts and bacteria, thus shelf life of fresh fruits and vegetables is limited at such ambient condition (Devon, 2018). These losses can be minimized to a considerable surplus with timely and safe management of post-harvest produce. Various studies shows that post-harvest losses have been estimated from 20-30% for fresh fruits and vegetables and could exceed 50% under adverse conditions. Losses were reported to vary

Table 1. Post-harvest losses of fruits in Nepal.

Fruits	Yield loss in percentage
Grapes	27%
Banana	11-14%
Citrus	8-31%
Apple	12-20%

Source: (Udas *et al.*, 2005).

Table 2. Post-harvest losses of vegetables in Nepal (reports based on sampling).

Vegetable	Yield loss in percentage
Cauliflower	47%
Cabbage	43%
Tomato	10%
Radish	10.5%

Source: (Udas *et al.*, 2005).

between 20 and 30% for apple, between 15 and 20% for citrus, between 10 and 15% for tomatoes and between 10 and 15% for cauliflower (Adhikari, 2006). Major causes of post-harvest losses in fruits and vegetables are improper stage of maturity, direct packing and shipping without the removal of field heat, improper packaging and insufficient grading and sorting, poor transportation and handling and poor storage facilities. However, the majority of losses occur during transportation from the yard to the collection center and thereafter to the wholesale market and retail outlets.

METHODOLOGY

This study is based on the secondary information collected by reviewing various articles, proceeding, newspapers and books. Pieces of literature were collected from different journal articles, Government institutions and other relevant reports. The papers were mainly based on the impacts of remittance earning and outmigration on socio-economic condition of Nepal and developing countries. The adoption of technology and strategy is lacking and consequences the huge loss. The highly perishable commodity demands more attention and strategy to ensure the minimum loss.

Causes of post-harvest quality losses

The quality of horticultural product is a key concern for the consumers as the consumers considers good quality produce that look good, that are firm and that possess good flavor and nutritive value. In contrast, producers and handlers are concerned with textural and appearance quality along with long post-harvest shelf life of fruits. There are many factors that influence the shelf life of fruits and vegetables like external factors i.e., stage of harvesting, handling, sorting, packaging and transporting and internal factors i.e., respiration rate, temperature, oxygen, Carbon dioxide and ethylene.

Respiration

Respiration is considered to be one of the major metabolic processes which brings about natural ageing and subsequent deterioration of fruits and vegetables. In the process of respiration,

Table 3. Storage temperature for common fruits and vegetables.

Produce	Storage temperature (°C)
Apples	32
Cabbage	32
Potatoes	38-40
Tomatoes	55-60

Source: (Khan *et al.*, 2017).

O₂ from the surrounding atmosphere is taken by the fruits for oxidative reduction of respiratory substrates (*viz.*, carbohydrates, organic acid etc.) to carbon dioxide, water and heat (Guilbert *et al.*, 1996). The heat produced as a byproduct during respiration results in higher temperature around fruits and vegetables which should be removed by refrigeration or ventilation. If ventilation is inadequate, CO₂ being another product of respiration can build up around the product resulting in the process of fermentation. However, if the availability of oxygen is depleted, it results in changes in chemical reactions, breakdown of cells, production of small quantities of alcohol, off odors, off flavor finally bringing about decay and spoilage of fresh produce (Han, 2004).

Ethylene

Ethylene is a naturally occurring plant growth substance that has numerous effects on the growth, development and storage life of many fruits and vegetables. The effect of ethylene is commodity dependent but also dependent on temperature, exposure time and concentration. Many commodities if exposed for a maximum period of time are sensitive to ethylene concentration as low as 0.1 ppm. (Ozdemir and Floros, 2004). Climacteric fruits such as apples, avocados and melons are sensitive to ethylene while fruit like strawberry can have low rate of ethylene production but are highly sensitive to ethylene. Most non climacteric fruits such as, cherries, grapes and berries have low ethylene production and low sensitivity to ethylene (Robertson, 2016). Increased ethylene production can occur as a result of disease or decay, exposure to very low temperature and physical injury.

Storage temperature

Proper temperature management between the period of harvesting and consumption has been found to be the most effective way to maintain quality of fresh produce (Table 3). Keeping the harvested fresh produce cool at low temperatures of about 2-4 degree Celsius will slow down any metabolic activities which lead to ripening, hence allowing more time for the post-harvest handling of the produce. Generally, one hour of delay between harvesting the produce and cooling will lead to one day loss of shelf life (Cantwell, 1997). There is an optimum storage temperature for all products. Tropical plants that grow in warmer climate cannot tolerate low temperature during storage so they must be stored above 8-12 degree Celsius. High temperature can hasten the rate of respiration (CO₂ production), water loss, sensitivity to ethylene and increase susceptibility of commodities to decay in stored or harvested food products. Low storage temperature can protect nonappearance quality attributes like texture, nutrition, aroma and flavor (Paull, 1999).

Handling

Proper handling of fruits and vegetables is necessary to avoid skinning and friction damage that occurs due to friction damage. In Nepal, fruits are generally harvested by shaking trees or hitting with a stick so, workers should be trained to harvest the horticulture produce well without causing damage. Injuries to the horticulture produce includes finger bruises, inappropriate removal of plant parts e.g., stems from the fruit, impact bruising. It was found that single bruising of apple increases the moisture losses up to 400% (Bachmann and Earles, 2000). It was reported that, most horticulture produce are damaged by heat and sunlight after harvest when possible, highly perishable produce should be harvested during the morning time when the temperature is lowest.

Post-harvest management practices in Nepal

Harvesting: Fruits and vegetables 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 enhanced the spoilage (Ahmad and Siddiqui, 2015). Therefore, care must be taken as to when to harvest the horticulture produce in order to maintain the best quality. The shelf life of fruits and vegetables is described by postharvest physiologists in three stages; the maturation, ripening and senescence stages. The maturation stage gives an indication of the produce being ready for harvest (FAO, 2008). Climacteric fruits can be harvested in either matured green, partially ripe or ripe stage. Producers targeting the distant markets must have harvested their produce in matured green stage allowing the ripening and senescence to occur during the post harvest period of the produce (Moneruzzaman *et al.*, 2009) This not only give producers ample time to prepare fruits and vegetables for market but also prevents mechanical injury during harvesting. Also, harvesting of fruits should be done in either early or late hours of the day to avoid excessive field heat generation (Table 1 and 2).

Pre-cooling after the harvest: Harvested fruits and vegetables must be pre cooled to remove excessive field heat. Field heat is usually high and undesirable at harvesting stage of many fruits and vegetables and should be removed as quickly as possible before any postharvest handling activity (Bachmann and Earles, 2000). Shahi *et al.* (2012) reported that, pre cooling minimizes the effect of microbial activity, metabolic activity, respiration rate, and ethylene production and reducing the ripening rate, water loss, and decay, thereby preserving quality and extending shelf life of harvested horticultural product (Ferreira *et al.*, 1994). A cheap but effective way of precooling harvested produce is dipping them in cold water (hydro-cooling) mixed with disinfectant such as sodium hypochlorite. Research stated that for maintaining the temperature of previously cooled fruits and vegetables, well ventilated room cooling is suitable, for storing the packed produce the forced convection method was found to be suitable because it removes the heat 75 to 90%

faster than room cooling. Commodities condition, packaging process, and storage system of the horticulture products are affected by implementing cooling methods. Different kinds of cooling like thatch/ roof house cooling, room cooling, hydro cooling and forced air cooling have been used in which room cooling was found to decrease the temperature of the produce slowly in the comparison of hydro cooling as well as forced air cooling.

Packaging: Fruits and vegetables require good packaging, which can prevent the physical and chemical damage (Bachmann and Earles, 2000). Improper way of packaging of fruits and vegetables increased the losses during handling and transportation that is why detailed study of packaging technologies were required to overcome from the losses of packaged fruits and vegetables (Idah *et al.*, 2007). Different kinds of materials are used for the packing of perishable commodities. They can be classified on the basis of stages of distribution system and it may be;

Types of packaging

Consumer packaging: Polythene bags (Frozen fresh peas), ventilated pouch (grapes), net bags (Citrus fruits, onions, potatoes), tray (baby corn, tamarind, brinjal), sleeve packs.

Transport packaging: Wooden boxes i.e., corrugated fiberboard boxes, plastic corrugated boxes, plastic crates, sacks, palletization, unitization etc.

Use of packaging materials varies according to the goods. Some common packaging materials used in most developing countries like Nepal includes wooden crates, cardboard boxes, woven palm baskets, plastic crates, nylon sacks, jute sacks and polythene bags. Most of the above-mentioned traditional packaging doesn't give all the protection needed by the commodity. While the majority of the packaging materials like nylon sacks don't allow good aeration within the packaged commodity causing a build-up of heat due to respiration, others like wooden baskets have rough surfaces and edges which can cause mechanical injuries to the produce (Hurst *et al.*, 2010). Several packaging techniques have been developed in this modern age for protecting the fruits and vegetables which have high moisture content (perishable product) and high respiration rate.

Methods of packaging

Active packaging: Active packaging which is sometimes referred as interactive packaging is defined as the packaging system in which some additives are added in or on the packaging material to enhance the shelf life, improved safety, sensory attributes and the maintenance of product quality (Rhim *et al.*, 2007). The use of active packaging is increasingly becoming popular and many new opportunities will open up for utilizing this technology in the future (Ščetar and Galić, 2017). It interacts with the internal gas environment to extend the shelf life of a food. It includes oxygen scavengers, carbon dioxide emitter, ethanol emitter, ethylene absorbers, and humidity absorbers.

Intelligent packaging: Intelligent packaging, sometimes called as smart packaging is defined as the packaging system which exists as a monitoring system to monitor some properties of the food it encloses that is able to inform the manufacturer, retailer and consumer of the state of these properties (Robertson, 2016). Intelligent packaging can change color to let the customer know how fresh the food is and show if the food has been spoiled because of a change in temperature during storage or a leak in the packaging. It includes Time Temperature Indicators (TTI's), i.e., Oxygen and carbon-dioxide Indicators. They are proved to be an effective tool for maintaining freshness and safety of produces than traditional systems (Nayik and Muzaffar, 2014).

Modified atmospheric packaging: MAP of products refers to the technique of sealing actively respiring produce in polymeric film packages to modify the O₂ and CO₂ levels within the package atmosphere. It not only improves moisture retention but also helps to ensure conditions that if not sterile, at least reduce exposure to pathogens and contaminants that extend the shelf life of the produce (Mangaraj and Goswami, 2009). Harmful effects of film packaging include enhancement of decay due to excess humidity; initiation and /or aggravation of physiological disorders, irregular ripening in inappropriate conditions of CO₂/O₂ off flavors and off-odors and increased susceptibility to decay (Irtwange, 2006). Some of permeable films used for packaging of fresh fruits and vegetables are low density polyethylene, polypropylene and polyvinyl chloride with different permeability for gases and water vapor as well (Schlimme and Rooney, 1994). Chamara *et al.* (2000) reported that packaging of a banana cultivar called 'Kolikuttu' as individual hands in low density polyethylene (LDPE) bags with a wrapped ethylene absorber could be recommended to extend their shelf life at ambient temperature. This could be of considerable economic importance in countries where cold storage is not readily available or expensive.

Storage

Research concluded that 10-12°C temperature and 90-95% relative humidity is required for the storage of cucumber because low temperature less than 10 °C enhances the chance of chilling injury and above 16°C color of cucumber turns to yellow and accelerate more rapidly in case of multi fruits and vegetables are stored at the same place (Tan, 1996). Storage facilities

affect the physiochemical quality of fruits and vegetables and proper care of maturity level in the storage minimized the decay, storage and total sugar level. In the context of Nepal, fresh fruits and vegetables are stored in zero-energy storage structures which are constructed using local materials such as brick and sand. The structure is double walled with a 10 cm between two walls which encloses a central storage space having dimension 75cm *50cm *75 cm. The sand is kept moist by sprinkling water to reduce temperature and increase humidity (DFQTC, Annual report 2010/11). Similarly, the temperature within the cellar stores should be maintained between 4 and 12 °C, while the humidity is maintained between 75 and 90%. Cellars are generally used for the storage of apples and citrus fruits. A number of storage techniques (ground storage, ambient storage, refrigerated storage, air cooled storage, zero energy storage, modified atmospheric storage, hypobaric storage, and controlled atmospheric storage) are being used for fruits and vegetables depending upon the nature of commodity and the storage period intended.

Controlled atmosphere storage (CAS): Controlled-atmosphere storage (CAS) is one of the most important innovations in fruit and vegetable storage systems as the composition of gas in the storage affects their storage life. The CAS technology involves reduction of oxygen (O₂) and increasing carbon dioxide (CO₂) as compared to the ambient atmosphere which lowers the respiration/metabolic rate of the commodity, leading to slowing down of the natural senescence process, removal of ethylene and addition of carbon monoxide. The benefit of controlled atmosphere storage is related to the reduction of food deterioration from pests and diseases, since higher CO₂ levels generally have a negative impact on the development and growth of microorganisms (Thompson, 1985). Therefore, storing fruits and vegetables under a controlled atmosphere may significantly reduce the activities of postharvest losses and protection against insect and microorganisms (Table 4). Controlled atmosphere storage is widely applied to apples, pears and kiwi fruits for long-term storage. CAS are useful for crops that ripen after harvest, or deteriorate quickly; even at optimum storage temperatures CA stores have a higher relative humidity (90–95%) than normal cold stores and therefore retain the crispness of fresh foods and reduce weight losses. However, controlled atmosphere storage is lethal because there is low level of oxygen and high carbon-dioxide so they are harmful to human being.

Table 4. Losses of horticultural products at different stages.

Name	Loading, unloading and transportation (%)	Storage (%)	Wholesale and Retail market (%)	Total (%)
Fruits	15-Oct	-	20-Oct	20-35
Vegetables	10-May	-	20-Oct	15-30
Potatoes	5- May	10-May	10-May	15-20

Source: Gautam and Bhattarai, 2012).

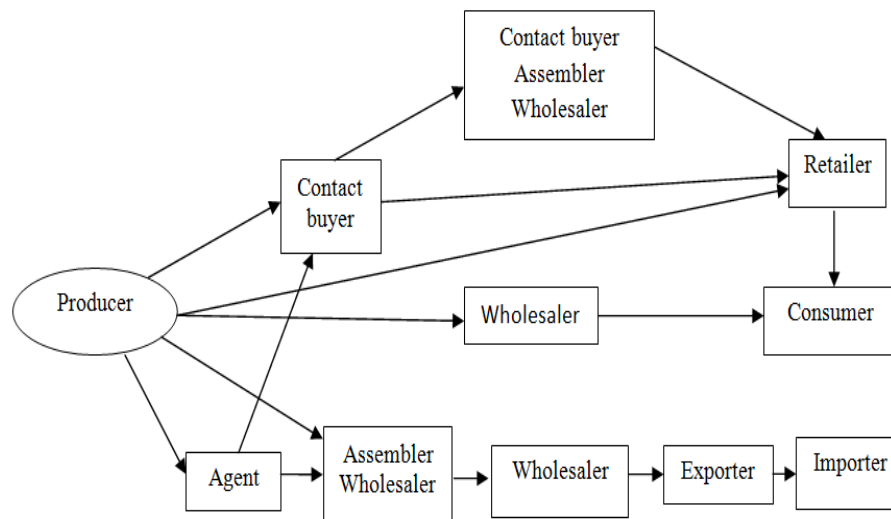


Figure 1. General Marketing channel for horticultural crops in Nepal (Acharya and Agrawal, 1999).

Table 5. Markets in Nepal (Gautam and Bhattra, 2006).

S.N.	Market	Type
1	Kalimati fruit and vegetable market	Wholesale market
2	Birtamod market	Wholesale market
3	Fruit and vegetable market dharan	Wholesale market
4	Biratnagar vegetable market	Retail market
5	Basantapur collection center, Teharathum	Assembly market
6	Duhabi market, Sunsari	Wholesale market
7	Kataharu fruit and vegetable market, Udaypur	Assembly market
8	Dhalkebar fruit and vegetable market	Assembly cum retail market
9	Bardibas fruit and vegetable market	Assembly cum retail market
10	Lalbandi fruit and vegetable market	Assembly cum retail market
11	Nawalpur fruit and vegetable market	Assembly cum retail market
12	Chandranigapur market	Retail market
13	Kalaiya vegetable market	Wholesale market

Modified atmosphere storage: The principle of modified atmosphere storage is similar to controlled atmosphere storage. But in this storage, there is no control in the environment. In MAS, the store is made airtight, and respiratory activity of fresh foods is allowed to change the atmosphere as oxygen is used up and CO₂ is produced. O₂ is reduced and CO₂ is increased as the storage organ continued to respire. To avoid excess CO₂ accumulation in MAS fresh hydrated lime can be included in the bag. Modified atmosphere storage has been used to extend the storage life of many perishable fresh horticultural crops stored under refrigeration. MAP treatment improves food shelf life by putting different gases inside the food package: suitable gas mixtures can retard microbiological growth. In commercial operation, controlled-atmosphere storage (CAS) and modified-atmosphere storage (MAS) are mostly used with apples and smaller quantities of pears and cabbage. Modified atmosphere packaging (MAP) is used for fresh foods and an increasing number of mildly processed foods, and they are gaining popularity as new applications are developed. Examples of MAP products include raw or cooked meats, poultry, fish, seafood, vegetables, fresh pasta, cheese, bakery products, sandwiches, potato crisps, coffee and tea.

Hypobaric storage: Hypobaric storage involves the cold storage of fruit under partial vacuum. Typical conditions include pressures as low as 80 and 40 millimeters of mercury and temperatures of 5°C (40°F). Hypobaric conditions reduce ethylene production and respiration rates; the result is an extraordinarily high-quality fruit even after months of storage (Bower, 2007). Hypobaric storage has also been referred to as low pressure storage, LPS and sub-atmospheric pressure storage. Hypobaric storage is also a form of controlled atmosphere storage in which the produce is stored in partial vacuum. The vacuum chamber is vented continuously with water saturated air to maintain oxygen level and to minimize the water loss. Ripening is retarded in hypobaric storage due to reduction in partial pressure of oxygen and also due to the reduction in ethylene level. A reduction in pressure of air to 10 kilopascal is equivalent to reducing the oxygen concentration to about 2.1% at normal atmospheric pressure. Hypobaric storage is expensive to construct so are not generally used in our country (Çelik and Arican, 2014).

Cellar storage: These underground or partly underground rooms are often beneath a house. Usually, cellar is dug on the north

facing terrace. It is constructed in such a way that all side is covered with earth except on one side towards entrance. There is provision of window and double door system which provide ventilation. The temperature prevalence inside the storage will be 15°C less than ambient temperature. In dry areas the relative humidity can be increased by supplying water through the perforated pipe lets or through small channel. Cellars have traditionally been used at domestic scale in Britain to store apples, cabbages, onions, and potatoes during winter. In Nepal cellar stores are used to store apple and citrus fruits in hilly area. Mandarin can be stored for about 3 months and apple for about 6 months in such stores about 1000 m asl (MoAD, 2015/16).

Rustic storage: Rustic storage is mainly used for the storage of seed potatoes (tubers). This type of storage is usually built-in higher altitude in hills and mountains to utilize surrounding lower temperature (Gautam and Bhattarai, 2012). A thatch house is constructed having provision of diffused sunlight inside it, instead of brick wall, chicken wire mesh, bamboo nor wooden sticks used all around the structure. Inside storage seed potatoes are stored in wooden rack one after another. Provision is made to provide diffused sunlight to the tubers. In diffused light, potatoes produce small sprouts having delayed growth rate.

Zero energy cold storage: Zero Energy Cold Storage (ZECS) sounds highly technical but the concept is pretty simple, and is based on the idea of a traditional cellar with direct evaporative cooling. It is a structure which is designed to keep fruits at a stable, cool temperature and humidity which will prevent them from damaging. It keeps fruits from freezing during the winter and keeps fruit cool during the summer months to prevent spoilage. Zero energy cold storage can be prepared anywhere with locally available materials like brick, sand bamboo, straw, gunny bag etc. with a source of water. The chamber can decrease the temperature 10-15°C than the outside temperature and maintain about 90% relative humidity. This type of cooling chamber is most effective during dry season and maintains high humidity of about 95% that can increase shelf life and retain quality of horticultural produce (Lal Basediya *et al.*, 2013).

Transportation

The majority of losses occur during transportation from the farm yard to the collection center and thereafter to the wholesale market and retail outlets. Transportation losses of different fruits and vegetables from the border of Nepal to different Indian markets ranged from 15-36% depending on commodity (Table 3).

Marketing of major horticulture crops

Horticulture marketing is one of the important branches of agricultural marketing and deals with the marketing of horticultural commodities (fruits, vegetables and flowers). Marketing system includes procedures farmers, traders, transporters, wholesalers, retailers and consumers as the main actors to carry out different activities (MDD, 2001). Marketing channel refers to the route through which products flow from the producers to the ultimate

consumers. In the context of Nepal, there are increasing number of vegetables marketing channels where farmers are selling their products directly to consumers or through traditional shops or majority of fresh horticulture produce sold to the consumer still goes through middlemen. The marketing channel for fruits and vegetables differ by the origin of the product (Table 5 and Figure 1). The products might come from local area or other areas within the country, or they might be imported (Thapa and Poudel, 2003). Thapa and Poudel (2003) reported that the following three marketing channels are in practice for fruits and vegetables supply in Nepal.

- Farmer → Retailer → Consumer
- Farmer → Consumer
- Farmer → Assembler → Retailer → Consumer

Conclusion

Horticultural crops are highly perishable and are subjected to higher post-harvest losses. Storage provides a suitable environment which minimizes the deterioration until crops are finally consumed. Proper temperature and humidity management are very effective tools in ensuring that the produce remains in good condition throughout the storage. Storage of fruits and vegetables are essential for extending the period of food availability and avoid the problem of malnutrition. However, the technique is purely based upon the scientific principles. Therefore, for successful storage of fruits and vegetables one should know the basic principles behind. Selection of storage structure depends upon many factors like nature of crops, economic status, storage duration etc. To increase the shelf life of all most all horticultural commodities the structure needs to be kept cool (refrigerated, or at least ventilated and shaded) and the produce put into storage must be of high initial quality. Nepalese farmers have small and scattered land holding as a result of which more than 90% of fruits, vegetable and flowers are produced in small scale. So, there are many problems for marketing of horticultural crops. Similarly, horticultural produces in Nepal are sold through different types of market. The most common flow is through rural haat bazaar where farmer often sell their produce by themselves. But in urban area the marketing system has become more complex with more agents involved in collection and distribution.

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Conflict of interest

The author declares there is no conflict of interest.

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