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REVIEW ARTICLE

Postharvest technologies for fruits and vegetables in South Asian countries: a review

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Abstract

Agricultural systems in South Asian countries are dominated by smallholder farmers. Additionally, these farmers have limited access to pre- and post-harvest technologies due to their high initial cost. The lack of these technologies in postharvest handling is responsible for 20% to 44% of fruit and vegetable losses. These high losses are largely the result of a generally weak basic postharvest infrastructure for the preservation of products, which avoids damage from improper handling, transportation, packaging, and storage. High postharvest losses of products negatively affect food availability, food security, and nutrition, as the producer is able to sell less of the farm yield and the net availability of these food commodities for consumption is reduced. An underlying cause of these postharvest losses is the limited awareness and knowledge bases of stakeholders (researchers, farmers, governments, non-governmental organizations, and merchants) in the traditional supply chains in which these losses occur. The analysis presented in this paper explores the state of postharvest practice in South Asian countries and discusses options for low-cost postharvest technologies in the region that can support small-scale farmers and provide a viable pathway for supply to the market, joining with modern value chains and bringing about individual and regional reduction in postharvest losses of fruits and vegetables. The improvement of basic and simple low-cost technologies through precise research efforts has the potential to prevent such huge losses of products, and help meet the ever-increasing demand for food in South Asian countries.

Keywords: food quality, fruits, postharvest technology, South Asia, vegetables

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Introduction

Postharvest technology is a term applied to the treatment of agricultural produce after harvest to ensure its protection, conservation, processing, packaging, distribution, marketing, and utilization to meet the food and nutritional requirements of the consuming population. This technology must be developed with an eye to the needs of each society in order to most effectively increase agricultural production, prevent extensive postharvest losses, advanced nutrition, and improve the quality of the produce. Additionally, the intelligent development of postharvest technologies has the potential to generate employment, reduce poverty, and stimulate the growth of other related economic sectors. Fruits and vegetables are a significant component of the agricultural economies of the South Asian (SA) countries. The region grows a variety of native and introduced produce, but only 2% of fruits and vegetables produced in South Asia are exported. These countries primarily contain the small landholding farmers, and most agriculture is typically conducted at the subsistence level. This small-scale production has prevented these countries from adopting many postharvest technologies. Some commercial agriculture in the region is slowly adopting recent technologies for reducing postharvest losses and production costs using harvest machinery and improved packaging, but these changes are the exception, rather than the rule (Akter and Kalam, 2014). Postharvest losses are an especially significant threat to small-scale agricultural producers, who depend on their crops for their livelihood. Excessive losses threaten to undermine the productivity of these small farms. In South Asia, out of 125 million farm holdings with an average size of 1.6 hectares, more than 80% are considered small scale with an average size of 0.6 hectares. These smallholders support the needs of some 1.3 billion people (Rahman and Westley, 2001). According to studies (Chand, 2010), if farming cannot provide necessary income growth for farmers, these small farms will remain small. To create economic growth in a system limited by farm size, jobs can be created in non-agricultural sectors, transferring the small-scale farmers from subsistence farms to other work. For instance, in both Thailand and Vietnam, a considerable reduction in poverty was realized by transferring a large percentage of the population to non-farming activities. However, due to the strong attachment that South Asian people have to their land and homes, the success of this approach may be limited. Therefore, improving the profitability of small farms by reducing postharvest losses using post-harvesting technologies offers a potential way to combat the poverty of subsistence farmers.

In South Asia, high-value crops suffer tremendously from postharvest losses in the range of 25% to 40% as the result of ineffective handling methods for transporting fruits and vegetables from the fields to the markets. The technology required to reduce these losses can be quite complex and risky due to the perishable nature of horticultural produce (Akter and Kalam, 2014). Generally, a significant portion of postharvest losses are the result of deficient postharvest management (harvesting, packaging, transport, and storage and processing facilities), as well as the complex and fragmented market systems in the region (Srinivasaraghavan et al., 2014).

The purpose of postharvest processing is to maintain or enhance the quality of products and make it readily marketable. Careful attention should be paid to postharvest management, agro-processing, and value-adding technologies to reduce heavy postharvest losses and improve produce quality using proper storage, packaging, handling, and transportation (Kumar et al., 2008). The advancement of postharvest technology and its deliberate application requires an interdisciplinary and multi-dimensional approach. This approach includes scientific innovations, technological creativity, commercial entrepreneurship, and the contributions of institutions with the capability for research and development, all of which must coordinate their efforts to further the developmental needs of the region. South Asia is currently home to the largest concentration of poor people in the world. Nearly 400 million people in SA live on less than one US Dollar a day (World Bank, 2006). The successful implementation of appropriate postharvest technology has the potential to establish agriculturally centered rural industries, helping to alleviate this poverty.

The objective of this paper is to evaluate current postharvest technology practices, existing agricultural problems, and potential technological applications for their resolution. Through this evaluation, it is hoped that the adoption of postharvest technologies based on available technologies in South Asian countries can be better facilitated.

Background information on South Asia

South Asia consists of eight countries: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka, as shown geographically in Fig. 1. The region, centered roughly on the coordinates 25.0376°N and 76.4563°E, covers about 5.1 million km^2, which is 11.51% of the Asian continent and 3.4% of the global surface area (Arnall et al., 2010). Estimates indicate that SA is home to 1.567 billion people (as of the year 2011) or around 23.7% of the global population (Chand, 2012). However, despite the rapid growth of some of the economies in the region, there is still extensive poverty, hunger, and malnutrition, which have not seen a noticeable decline with the growth of these economies. About 43% of the world's poor and 36% of the world's undernourished population is located in South Asia. According to the State of Food and Agriculture 2012, South Asia is one of two regions in the world where hunger and extreme poverty are most widespread (FAO, 2012). Further,

Fig. 1. South Asian countries and geographical location of each country on a map.

large numbers of people in South Asia depend on small farm agriculture for subsistence (FAO, 2010). All countries in this region except for India are net importers of food as their domestic agricultural production is insufficient to meet the requirements of their populations. Despite the remarkable progress made in increasing food production at the global level, approximately half of the population in the developing world does not have access to adequate food supplies. There are many reasons for this, but among the more significant are the food losses occurring in the postharvest and marketing system.

The South Asian region has experienced many crises in recent years, from food shortages and high grain prices to natural disasters and the changing climate (Bhutani, 2013). Despite these struggles, the agricultural sector forms the backbone of all SA national economies, as shown the studies by (Stabinsky, 2014) in Table (1). About 18% to 34% of national output and 33% to 66% of employment accounted for by agriculture among the various countries in the region (Chand, 2012). The region is rich in topographic, climatic, and natural resources that support a wide variety of horticulture (Mhaske, 2010). The SA region has enormous potential for the growing of tropical, sub-tropical, and temperate crops of great commercial value for export (Akter and Kalam, 2014). The region features humid and moist sub-humid ecological zones (in India, Bangladesh, Sri Lanka), which benefit from seasonal monsoon rains and more than 180 growing days a year (Dixon et al., 2001). By improving the performance of the agricultural sector, positive change in the socio-economic life of the millions of people in SA countries can be realized, providing opportunities for income growth and an accompanying alleviation of hunger and poverty in the region (Akter and Kalam, 2014)

Global postharvest technology scenario

Postharvest technology has been a central development in making fresh fruits and vegetables available to consumers worldwide at a reasonable price (USDA, 2004). Because harvested produce remains alive and conducts associated metabolic activity for a time, the inevitable process of senescence must be controlled to prolong postharvest quality (Mahajan et al., 2014). The basic requirements for maintaining the quality and freshness of horticultural products between the harvesting stage and eventual consumption varies depending on the specific post-harvesting

Table 1. Basic statistics of agriculture in South Asia countries.

Country	Labor force in agriculture (%)	Population living in a rural area (%)	Agriculture GDP (as % of total GDP)
Afghanistan	59.0	Over 75	29.9
Bangladesh	44.0	80.0	18.6
Bhutan	92.8	85.0	18.7
India	54.0	69.0	17.7
Nepal	92.9	92.9	36.5
Maldives	17.8	57.4	3.1
Pakistan	38.6	63.0	21.2
Sri Lanka	43.0	80.0	12.8

GDP, Gross Domestic Products.

technology employed. These requirements also depend on the scale of each country's operations, the intended market for the produce, and the investment required by the technology. The appropriate use of post-harvesting technology can significantly enhance the profitability of agricultural efforts, and no single technology can do this alone: There are many coordinated steps involved in proper postharvest management for assuring the quality, longevity, and safety of horticultural crops (Kader, 2010). Improvements in transportation, in combination with other technological developments, can pave the way for reduced postharvest losses by reducing delivery time, maintaining product quality, and cutting shipping costs. In recent decades, it has become a simple matter for shipping companies to deliver horticultural products to purchasers thousands of miles away, with no considerable loss of freshness (USDA, 2004). For example, Australia currently delivers fruits and vegetables to Asian markets using both sea and air freight. By packing harvested produce in plastic bags stored inside cartons, high humidity and low temperatures can be maintained, preventing rot during transportation to Asian markets 40 - 60 hours from harvest or over longer time spans by using refrigerated containers for sea-based shipping (ATC, 2014).

Controlled atmosphere (CA) technology has been successfully applied across the world to maintain the shelf life and quality of a variety of fresh produce. This CA technology decreases the respiration rate of produce by monitoring and adjusting the levels of oxygen, carbon dioxide, and nitrogen within refrigerated containers. In this way, CA can slow ripening, delay discoloration, and otherwise maintain the freshness of produce (USDA, 2004). Additionally CA has been recommended for extending the shelf life of fruits in Southeast Asia, for having the ability to distribute products for the long distances (Kusumaningrum et al., 2015). Additionally, electronic and information technologies have enabled shippers and carriers to continuously monitor product quality, reduce the risk of liability claims, and adjust to changes in cargo delivery times. These information technologies have also resulted in the development of remote monitoring systems for refrigerated containers, which transmit and collect performance information electronically so that physical checks are not required while the container is stacked in the hold or on the dock. These remote systems are often capable of activating an alarm when problems arise, helping to minimize damage to the produce (USDA, 2004).

The sensing agriculture technology and precision agriculture are well known globally as field manager. Relatively applied in many developed countries with having the big fields and yield (Chung et al., 2016). As fast computational technology in the agriculture area, the smartphones used for several purposes. Additionally, with the ability to have simply usage, easily moveable, and having different functions. For instance, detecting the pathogens causing food born, measuring the quality of food, monitoring safety on products, gathering information related plant growth and damage, phenotyping of seeds in the research area and soil classifications actively used the smartphone with an alone camera and also combined with optical accessories (Kwon and Park, 2017; Lee et al., 2017; Lee et al., 2018; Sarkar et al., 2018). For example, the chlorophyll is a factor representing the growth characteristics of crops an Andriod App developed by (Vesali et al., 2015) for calculating the amount of content in corn leaves by contact imaging using a smartphone.

The potential gain from adopting these technologies must be measured against the costs of adopting them. The cost-effectiveness of a specific technology for the reduction of postharvest losses is directly related to the type of technology. For example, on-farm technologies for curing roots, tubers, and bulbs result in a profit 2.5 times larger than when these technologies are not used. Cooling practices used for vegetable can provide an increase in returns of up to 7.5 times the initial costs of implementation. Other technologies, such as crop shading, resulting in more limited gains, though the cost of implementation may be recouped more quickly (Rosegrant et al., 2015). The reduction in losses resulting from the use of postharvest technologies can be seen in developed countries by looking at their estimated range of losses. For instance, in the United States, losses between 2% and 23%, with an overall average loss from production to consumption of 12%, are estimated (Harvey, 1978). Note that at harvest, the growers essentially measure quality using the visual appearance of the produce, including shape, color, and dimensions, while the distribution chain measures quality by the physical-technological properties of the produce, such as firmness and storage compatibility (Cocetta, 2014). Studies conducted by Kader in 2009 indicate that both quantitative and qualitative losses can occur in horticultural products between harvest and consumption. The qualitative losses, such as loss of edibility, nutritional quality, caloric value, and consumer acceptability of the products are much more difficult to assess than quantitative losses.

The growth of global trade in fruits and vegetables is related to the forces of supply and demand, institutional and economic factors, and national, regional, and international characteristics (Cocetta, 2014). The largest importers of fruits and vegetables are the European Union, the United States, and Japan, who account for over 80% of the world's demand for imported fresh fruits and vegetables. International trade has expanded consumer access to a wide variety of fruits and vegetables, particularly during seasons when they are not domestically produced (USDA, 2004). High-income regions are also the top exporters of produce, led by the EU and United States. While the United States is the foremost exporter of fruits and vegetables in the world, it is not the largest producer. The largest producer of fruits and vegetables in the world is China, but because China does export a significant quantity of produce, it plays a smaller role in world produce trade than the United States because of this large domestic consumption of fruits and vegetables (USDA, 2004). This large international trade in produce means that minimizing the farm-to-consumption losses directly increases the availability of food and improves global food security. The economy of farming-based regions of the world is most heavily affected by high postharvest losses because in the global selling of fruits and vegetables have more potential income. For example, the livelihood of nearly 70% of people in Sub-Saharan Africa is dependent upon the production of fruits and vegetables (Singh et al., 2014).

For decades, agricultural science has concentrated on maximizing production through the development of new technologies. This approach has achieved massive gains in yield as well as lower costs for large-scale farming. But not only has this success come at a high environmental cost, it has not solved the social and economic problems of the poor in developing countries (IAASTD, 2008). Nearly 800 million people across the globe will go to bed hungry tonight, most of them smallholder farmers who depend on agriculture to make a living and feed their families (USAID, 2012). Particularly in South Asia and Southern Africa, many of the poorest people are farmers; nearly 75% of people subsisting on 1 USD a day or less live in rural areas, and it is estimated that the majority of will not change until 2040 (Ravallion et al., 2007). Still, agriculture is a major source of income and employment in these regions, meaning that poverty alleviation is directly linked to improvements in agricultural productivity. Thus, properly applied technology has the potential to greatly increase this productivity through higher yields, reduced losses, and improved quality of food (ATAI, 2011).

Akhter presented the biggest constraints on postharvest management in 2014. He observed that inadequate information, low skills in harvesting and postharvest handling, lack of infrastructure, high transportation cost, poor farmer access to market information, limited access to financial resources, and lack of awareness present the most significant challenges to the successful implementation of postharvest management techniques in developing countries.

Current postharvest technology for fruits and vegetables in South Asia

The main objective of postharvest technology is to limit the deterioration of products along the postharvest chain in order to fetch the maximum value on the market (Ilyas, 2010). The analysis spoke of abilities and limitations of agriculture technology for use in regional trade, and local technology of use for production (Mathew, 2015). Meanwhile ending poverty is the topmost target in SA, and the main reason that 23% routinely hungry live in the region is weak input technology for production. According to the World Food Programme, there are 805 million hungry people in the world and 98 percent of them are in developing countries. They are distributed as such 526 million in Asia and the Pacific, 227 million in Africa, 37 million in Latin America/Caribbean, and 15 million in the developed countries (WFP, 2014). For instance, India as the leader of the production has been accomplished in the face of insufficient infrastructure in the produce supply chain. Such as a lack of storage, poor warehouse conditions in village areas (Kumar et al., 2008), a lack of processing facilities for waxing and washing (Viswanadham, 2007) a lack of packaging facilities (Bhardwaj and Palaparthy, 2008) and inadequate marketing infrastructure for grading and standardization, as well as a lack of other processing machinery near farming regions (Dharn and Sharma, 2008).

The two major causes of fruit and vegetable losses are a lack of access to postharvest technologies and insufficient knowledge of proper handling and storage practices. Problems linking producers to markets can take the form of poor market systems, underdeveloped infrastructure, and incomplete value chain linking (Akter and Kalam, 2014). For example, Afghanistan has the suitable weather for apple production, yet while apple cultivation is widespread, it is mainly aimed at satisfying the small rural local markets due to unfavorable postharvest conditions such as a lack of storage facilities, packaging, and transportation, thus limiting the range of the domestic market. Most accessible areas and local markets face heavy competition from imported apples from Iran and Pakistan, which rely on more capable postharvest infrastructure (Yousufi, 2016).

Similarly, other South Asian countries face significant postharvest challenges. For example, mountain communities in Nepal lack adequate access to infrastructure and services. The marketing systems in Pakistan, Bhutan, and Bangladesh lack proper cold storage facilities and other beneficial postharvest handling technologies, which leads to heavy losses and means that farmers must often sell their produce below the average market price (Akter and Kalam, 2014).

South Asia is home to a considerably rich collection of exotic and in-demand varieties of fruits and vegetables. India, for example, is the second largest producer in the world of fruits and vegetables: It is the largest producer in the world of ginger and okra, and the second largest of bananas, papayas, and mangoes. However, the region has not seen the potential economic benefits from these fresh products. Fig. 2 shows that between 1991 and 2011, the gross production of fruits and vegetables in South Asia has increased, yet according to several studies, a substantial portion of this increasing harvest is wasted due to improper harvesting and postharvest practices, as well as a lack of facilities and technologies to extend the shelf life of produce. Nearly 40% of fruits and vegetables are wasted in India every year due to improper handling, storage, packaging, and transportation (Singh et al., 2014). This lack of proper postharvest technology has been observed in another analysis in India, that found the result in losses close to 50% of total fruit and vegetable production, which is quite detrimental to the availability of fruits and vegetables to consumers (Sudheer and Indira, 2007). These problems result in heavy losses of revenue for the growers, wholesalers, retailers, and exporters, and create inconvenience for consumers while lowering the export potential of these commodities.

The economies of most South Asian countries are primarily agricultural. Studies by the World Bank and other organizations attribute rural poverty in SA countries to low agricultural productivity.

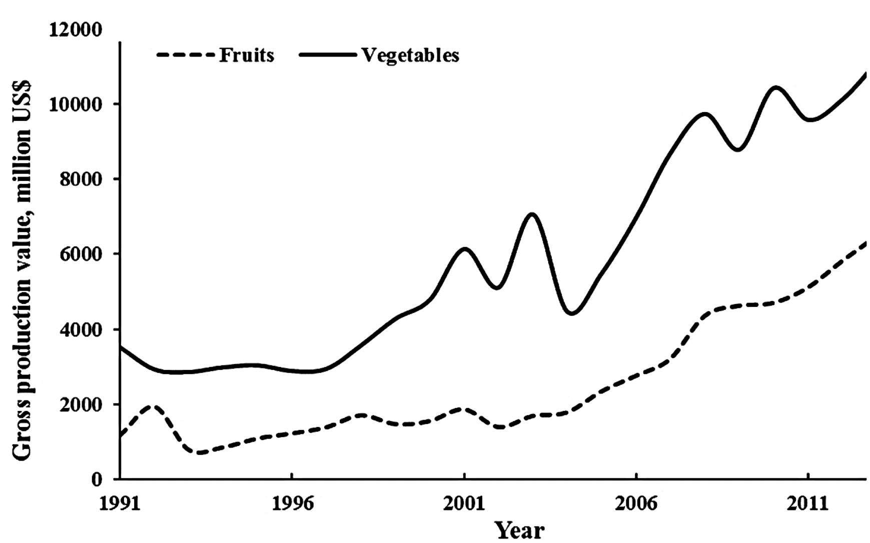

Fig. 2. The growth of fruit and vegetable production in South Asia between the years of 1991-2011 (FAOSTAT, 2017).

For instance, 90% of food products consumed in the Maldives is imported due to the limited potential for agricultural development as a result of a lack of available land for cultivation, poor soil conditions, and a shortage of fresh water for irrigation (FAO, 2011). The challenges faced by the limited agriculture in the Maldives since the 2004 tsunami illustrates the vital role that even small-scale agriculture plays in the livelihood of rural residents. The arable land of the Maldives is only about 103 m^2 per capita, and most economic activity is derived from the fisheries (MFAMR, 2006). Estimates show that two-thirds of the national population resides in rural areas, where they participate in fishing activities and kitchen garden agriculture (ADB, 2005), but after the destruction caused by the 2004 tsunami, agriculture never again played a vital role in the livelihood of the rural population, which now relies almost exclusively on the fisheries for survival. Bhutan faces similar challenges to domestic agriculture due to very steep slopes, rugged topography, and small land holdings (Tobgay, 2005).

Fig. 3A and B show the distribution of fruit and vegetable production, respectively, among nations in the SA region in 2014. The contribution for fruits in Afghanistan (0.4%), Bangladesh (3.8%), Bhutan (0.02%), India (69.7%), Maldives (0.02%), Nepal (6.8%), Pakistan (18.7%), and Sri Lanka (0.4%) is shown in Fig. 3A. The contribution for Afghanistan (1.4%), Bangladesh (3.2%), Bhutan (0.01%), India (85.3%), Maldives (0.01%), Nepal (7.9%), Pakistan (2.1%), Sri Lanka (0.2%) is shown in Fig. 3B.

Harvesting

Harvesting is an important part of crop production, and an inappropriate harvesting method can lead to huge losses of fresh produce. Unsystematic methods can result in damage to produce such as bruising from compression, force, and vibration (Sudheer and Indira, 2007). Postharvest handling begins at harvest, after which the quality of produce cannot be improved, only maintained. Therefore, it is essential to harvest fruits and vegetables at the proper stage and size, with the proper methods, to ensure peak quality (Ilyas, 2010).

The method of harvesting can have a significant impact on the composition and postharvest quality of fruits and vegetables (Sudheer and Indira, 2007; Choi et al., 2017). A study conducted in Afghanistan indicated that the main problem faced by apple farmers is bruising: small farmers cannot obtain the appropriate basic tools for harvesting (ladder, basket, and apple picker) according to the author from

Fig. 3. Fruit (A) and vegetable (B) production in the South Asian region in 2014 (FAOSTAT, 2018).

field observation. The farmers have the knowledge about different maturity indices (color, size, shape, and taste), but they should harvest before full maturity to prevent bruising and fetch the highest price later at the market (Masood, 2011). Harvesting methods and tools have a major role in creating a bruise. The studies show when the apple fruits harvested wet displayed more finger bruise, and the high finger bruise will happen when the pickers wearing gloves. To avoided bruise development on apples should be used padded buckets and it's more effective for reducing bruise than the soft-sided bag and unpadded buckets. The amount of bruise will increase by dropping harvested fruits from picking bags and overfilling of the bins. For instance, the studies show roughly filling the uncovered bins caused 89% bruised apple, and added foam cover decreased this amount to 64%, in contrast with gentle filling resulted in 28% bruise. The foam cover will do not reduce the bruising when the bin was filled considerately (Kupferman, 2006).

Almost all SA countries harvest their produce manually, and, problematically, most fruits don't reveal damage immediately after harvest. Mostly, the appearance of produce is judged only after harvest and ripening in retailer storage. For instance, in Sri Lanka, postharvest losses of bananas are relatively high due to physical damage occurring during harvesting, transportation, and handling. Because, bananas are harvested at the mature green stage, the damage is not evident until the banana ripens, meaning that though the bananas may often leave the producers looking suitable, the appearance of the ripened banana in a retail shop is extremely poor (Sarananda, 2000). Thus, for avoiding the bananas damage United Nation Food and Agriculture Organization (UNFAO, 1989) recommended issues. The fruits should be harvested when the temperature is low. The fruit can be harvested by cutting the stalk when the bananas are plump but green. Once harvested the stalk should be hung in a cool, shady place. Majority of the framers use men's shoulder to transport their fruits to the collection site and them not using packaging materials. This might create damages at the surface of fruits, harvested bunches are best carried on a foam-padded tray to reduce damage.

In addition to taking care to prevent bruising, harvesting should be conducted during the coolest time of the day, usually in the early morning, and harvested produce should be kept shaded (Ilyas, 2010). Naturally exposed fruits to the sun expanding internal temperature. The temperature with duration of the time could lead the produce to visible damage, wilting, development of fungal invasion, and high rate of losses. To avoid the huge losses can provide shade with extremely simple and cheap using local access materials. For example palm leaves, grain stalks, straw, woven mats and locally thatching materials (Rickard and Coursey, 1979).

The harvesting time varies from crop to crop. However, the several studies recommended the coolest part of the day. Additionally, other factors like availability of labor, transportation, and distance of packing house should be considered, to minimize the time to carry produce to packing house. Moreover, local weather could change the harvesting time. For example, it's not advisable to harvest the fruits in a wet condition by dew or rain the tissues are more sensitive to physical damage and the risk of postharvest spoilage is high due to not considering (UNFAO, 1989).

According to a review of the horticultural marketing and postharvest conditions in Afghanistan, most postharvest handling of horticultural produce is done in the open air on and sunny days that raises the respiration and water losses in the fruits (Kemal-ur-Rahim, 2003). Additionally, according to the author, field and market observations, early in the season apples are often harvested and transported in their immature state (green and small), because at this time the price of an apple is 50% higher than in the peak season (Masood, 2011).

Many countries in the SA region, such a Bangladesh, do not have access to mechanical harvesting systems and rely on the manual harvesting of fruits and vegetables. The harvesters often do not consider the maturity of fruits, which is essential for fetching a high price and providing sufficient nutritional quality. The deterioration of produce begins immediately after harvesting (Hossain, 2010), and physical damage inflicted during harvesting accelerates the loss of water and vitamin C, resulting in increased susceptibility to decay-causing pathogens. In most developing countries, including India, manual harvesting is performed with knife and spade, and the use of clippers for fruit picking is still widespread. Modern mechanical harvesting devices, on the other hand, employ direct contact methods such as combing, cutting, pulling, snapping, twisting, stripping, and compacting to prevent unnecessary damage to produce (Sarananda, 2000).

One of the biggest problems facing farmers in the SA region is a lack of information regarding best harvesting practices for avoiding damage. Farmers often lack knowledge of the best time and conditions for picking their crops for transportation to market, and they often lack appropriate technique and sanitation when picking. Additionally, many SA countries are susceptible to frequent unfavorable conditions for harvesting like high temperature and related humidity, which are often ignored. Ultimately, there is a lack of an accessible and established system for disseminating good harvest and postharvest handling practices to prevent the high losses of harvested fruits in the region.

Information gathered by Masood in 2011 casts light on the Afghanistan harvesting situation. The majority of losses during harvesting are caused by the lack of skill and knowledge among the harvesters. The main reason for limited harvesting knowledge is that most farm workers are illiterate, making it is difficult for them to readily understand the causes and significance of unfavorable conditions. For example, growers in the "Nerkh" district of Afghanistan harvest apples manually by hand, and this is often performed by either the farmers themselves, or hired laborers without considering good harvesting practice (Masood, 2011).

Harvesters in SA contribute significantly to fruit and vegetable deterioration by causing injuries and cuts through the misuse of harvesting tools, damage from pressing produce with fingers and nails, and bruising by dumping or throwing the produce into field containers. The overfilling of containers is another practice that contributes to damaged produce. Rough picking by pulling, detaching, and cutting the peduncle will contribute to the development of decay, increase the respiration rate and ethylene production, and result in excessive water loss from damaged parts.

Before the start of harvesting operations, workers must be trained in the best manner to pick the intended product, and on how to avoid damage when placing produce into field containers. However, such in-field training and demonstrations are not yet common. Good training and demonstration of the causes of damage can facilitate better understanding among workers as to why taking these precautions are important when picking and handling perishable crops.

Packaging

Packaging is the process of making produce ready for transportation to market. This can be done either in the field or at a packinghouse. The packaging process includes cleaning, sorting and grading according to quality and size, waxing, and treatment with an approved fungicide prior to packing into shipping containers. These packaging materials then protect the perishables from mechanical injury and contamination during transport and marketing (Ilyas, 2010; Jat, 2010).

South Asian countries remain behind the developed world in the standardization of fruit and vegetable packaging technology, as illustrated in Fig. 4. In most agricultural areas in the region, packaging techniques are largely ignored. In India, for example, fruits and vegetables are generally packed in the field without any pretreatment or packing station, and a large volume of production is transported directly to the market from the field (Rosa, 2006; Jat, 2010). Proper packaging protects produce from pilferage, dirt, and physiological and pathological deterioration during handling. Generally, in India, rather than wooden or cardboard boxes, bamboo baskets are used for packaging and transportation of fruits. In some cases, banana bunches are packed in old gunny bags covered with banana leaves. These fruits frequently deteriorate because of poor packaging and as a result fetch a low price at the market (Bhushan, 2013; Srinivas, 2015). However, good packaging can often be provided, particularly for products intended for export. For example, after washing, bananas for export are graded on the basis of their length, packed in plastic, and placed in cartons which are kept in cold storage. Bananas can be stored in a controlled, cool atmosphere for a period of 20 - 25 days (Srinivas, 2015). The use of CAP (controlled atmosphere packaging) has also produced good results, controlling the exchange and capture of gasses from the surrounding environment and the produce itself, enhancing the shelf life of fruits. In the region, it is rarely used for commercial purposes (Bhushan, 2013).

(a) (b) (c)

Fig. 4. Nature of agriculture operation system in South Asian: (a) packaging, sorting and grading in Afghanistan (b) packaging operation for mango in India, and (c) harvesting pineapple in Bangladesh.

Generally, in South Asian countries there are no packaging standards for produce from smallholder farmers, but because most fresh produce is fragile and highly perishable, the packaging is important. Unsuitable packaging is clearly correlated with high losses. In Afghanistan, the packaging is generally poor, with about 49% of produce packed in jute sacks, 36% of fruits packed in crates, and 15% of produce packed in baskets, particularly, in this case, pomegranates (FAO, 2004). Straw is often used as a packing material inside crates to prevent injuries to fruits from transport-related vibrations. Because cardboard packaging cannot be readily found in rural areas, the best option available for the producers is wooden crates, especially because of the rough roads, as the strength and durability of the wood can protect fruits as much as possible. Farmers selling their products along the roads often pack their fruits into plastic bags and transport them with a cart, while farmers who sell fruits like apples to retailers usually use wooden crates for packing, and street vendors rely upon all manner of packagings such as wooden crates, plastic bags, and polypropylene bags (Masood, 2011). Typically, the best opportunity for packaging improvement is in the cushioning of the fruit in the crates and the maintenance of cool crate temperatures during the journey to market (Kemal-ur-Rahim, 2003).

Packaging usage in Bangladesh is similar to that in Afghanistan: Mango fruits are packed into a bamboo basket with rice straw for internal markets. These packing materials are often of poor quality, and fruits are often packed either too tightly or too loosely, mixed in maturity, exposed to sun and rain, and roughly handled during loading and unloading. The shortage and high cost of produce boxes present a significant obstacle to the shipment and distribution of produce, and a standardization of packaging has not been established in Bangladesh (Hossain, 2010).

Skill and care in packing are important, as crops destined for storage should be as free as possible from skin breaks, bruises, spots, rots, decay, and other deterioration, which not only affect appearance but provide entrance to decay-accelerating organisms as well (Ilyas, 2010). It has been observed that a single bruise on an apple increases its moisture losses up to 400% (Bachmann and Earles, 2000)

Packinghouse operations can also cause damage and losses if the crops are not handled quickly and gently, or if the equipment is not kept clean and well maintained. To clean soil from the surface of produce, the use of hand polishing is suitable, but only for light soil contamination. Throughout the region, most fruits are not washed to remove dirt, instead, a scrap of cloth is commonly used. When properly conducted, the packing process will protect produce damage and will ensure a good appearance of the product. During packing, sanitation and food safety issues become more important. In SA, where most producers operate on small-scale, traditional practices for the packing of fruits and vegetables are usually relied upon, but for larger producers and commercial farms, quality standards and quality control procedures must be developed. To reduce contamination, all areas where fresh products are handled must be cleaned and sanitized, including all equipment that comes into contact with the fresh produce. Additionally, records of this cleaning and sanitizing must be maintained for traceability and verifiability as part of a larger quality assurance procedure.

Pre-cooling

Precooling of produce is considered essential in regions with high temperatures as it acts to remove the field heat from fruits and vegetables. The elimination of this heat prevents fruits from succumbing to the rapid deterioration that accompanies a decreasing respiration rate, ethylene production, and water loss. Additionally, without precooling, leaves will exhibit wilting in the market, or even before reaching the market, reducing the price and appeal of the product to consumers. Notably, refrigerated trucks are not designed to cool fresh commodities, but only to maintain the temperature of initially cooling products, so even a basic investment to decrease the heat of produce after harvesting can be effective (Ait-Oubahou, 2013). There are many types of precooling, such as room cooling, forced air-cooling, hydro-cooling, top or liquid icing, and vacuum cooling (Ilyas, 2010). Each method is appropriate for specific fruits and most are used commercially. In India, for example, forced air-cooling is used for small delicate produce, such as grapes and strawberries, to prepare it for the export market (Aswaney, 2007). Precooling is generally not performed with commercial harvesting in SA countries, and most commercial farmers can fetch a higher price by harvesting their fruits in the immature stage, commonly collecting their fruits before they completely mature. For example, a chamber named “zero energy cool chamber” established In India, with stacked bricks, a space filled with bricks and sand saturated with water between two walls. The fruits and vegetables placed inside, an entire surface of chamber flatted with a rush mat, for keeping moist. It used for commercial purpose for having a high price. And inside temperature in summer goes 15 and 18°C (59 and 65°F) and relative humidity 95% provided by the chamber (Kitinoja and Thompson, 2010)

Moreover, Aswaney in his study 2007 added, precooling can be made more efficient by several minimum cost methods and by better management. These methods include sealing air leakage area to forcing additional air through products, improving carton-stacking configuration or orientation, modifying pallet-tunnel length and width and proper temperature monitoring. Carton design must allow a minimum of 5% sidewall venting. For example, the evaporative cooler locally and extremely cheap used in the Philippines for cooling and storage of fruits (tomato, sweet peppers and mustard greens). The cooler is standing in a galvanized iron (GI) pan of water, and another pan installed at the top of cooler. And the sides and top are covered jute sacks and kept wet by wetting top and bottom edge into the pans of water. Similarly, the other one, the inside of cooler made of plain GI layer with fine holes (spaced at 5 × 5 cm) and the outer wall of cooler made of fine mesh (0.32 cm) wire. The space of 1.5 cm considered between inside and outside of the wall, which filled by rice brans, it kept wet by dipping with clothes cover which dipped in a pan of water fixed at the top of cooler (Acedo, 1997a).

The simply made coolers kept produce at good condition. Accordingly, the stored tomato and green pepper ripened slowly, with less weight loss. The cooler has the ability to under refrigeration for 3 weeks. To prevent decay problem recommended using chlorinated water for washing (Acedo, 1997b).

The washing of produce is uncommon in most SA countries, however, washing is a standard postharvest handling operation for many fruits and vegetables and is necessary to remove adherences, dirt, latex, and external pathogens structures. In Bangladesh, it has been observed that fruits and vegetables are not properly washed before entering the marketing channel, and this contributes to the poor quality and significant losses of produce (Hassan et al., 2010).

Ripening agents

Fruit ripening agents stimulate the fruits by applying ripening influences to control the rate of ripening. The health hazards and proper application of these agents are debated and treated differently according to the laws in each country. There is no specific policy in the SA region for the cultivation, preservation, and distribution of products, including the use of many ripening agents (Islam et al., 2016). While calcium carbide is mostly banned in the region for its threat to human health (Siddiqui et al., 2013), in India, 99% of mangoes are ripened using calcium carbide. This is mainly due to the economics of mango farming, but even with the reliance on this agent, the fruits do not often ripen uniformly and their quality remains poor. The best approach for assisting mango ripening is to expose the mangos to ethylene gas (at 100 ppm) in an airtight room for 24 - 48 hrs. Under controlled temperature and humidity (Bhushan, 2013).

A variety of ripening chemicals are available and used by growers and intermediaries in the SA region. A review of a study in Bangladesh revealed the use of ripening agents mainly on fruits and vegetables harvested at an immature stage, such as mangoes, bananas, tomatoes, and jackfruits. According to this study, a group of traders in Bangladesh (Bepari) use 28.57% chemicals for banana ripening, with the remainder conducted by conventional ripening methods such as the heating and peeling of the fruits before covering them with a polyethylene sheet (Hassan et al., 2010).

The key driver of the use of ripening agents by stakeholders and intermediaries is the high demand for seasonal fruits and the desire to avoid possible economic loss during storage and distribution.

Storage

Harvested fruits require energy to sustain their metabolic activities, and this energy is derived from respiration, which involves the oxidation of sugars to produce carbon dioxide, water, and heat. The lifespan of a harvested fruit is influenced by its respiration rate. When stored at low-temperatures, the respiration of produce is reduced and senescence is delayed, thus extending storage life (Aswaney, 2007).

Humans have stored crops for centuries using various structures, some of which still exist (Kader, 2010). The foremost purpose of storage is to provide a suitable environment to maintain the freshness of produce and extend the time span of its availability. The technology involved in the storage of fresh produce can be divided into common storage, refrigerated storage, and controlled atmosphere storage (Wang, 2010). The physiochemical quality of fruit is directly linked to the facilities in which it is stored, and the proper use of storage technology during the mature stage of fresh produce can minimize decay. The quality parameters of fruits and vegetables such as weight, shelf life, and bioactive molecule content are affected by this maturity (Siddiqui et al., 2013).

India is the second largest producer of fruits and vegetables in the world after China, yet only 10% of India's produce is stored using scientifically sound methods. The nonexistence of proper storage and handling results in 30% of produce is lost in the village stage, before even arriving at the market (Acharya, 2005). As a result, though India produces over 10% of the world's fruits and vegetables, the nation only has around a 1% share of global produce exports (Jat, 2010).

The present storage practices in SA countries are traditionally applied to only a few crops and are limited to older types of facilities. Bangladesh typically provides storage facilities only for tomatoes in many parts of the country (Hossain, 2010). Apple growers in Nepal and Afghanistan usually have no access to storage facilities with controlled temperature and humidity, instead using traditional techniques to store their products like cellars, which are usually small and have only a limited effect on the extension of the commercial lifespan of produce like apples (Awasthi, 2010, Masood, 2011). Similarly, Bhutan uses cellar storage for oranges, which are low in cost but of limited effectiveness since it only adds 3 months of storage and incurs losses of 20% to 25% (Rosa, 2006). These cellars have no temperature control and as a result experience a temperature range similar to that of a normal 15 - 20 m2 room. The spoilage rate is therefore very high in these cellars, in the range of 30% to 35%. On the other hand, modern cold storage plants are expensive to operate, and maintaining a constant supply of electricity remains a major challenge in many areas, while the use of generators to power commercial cold storage raises costs substantially (World Bank, 2014).

The available storage techniques and facilities in SA are poor. Traditional methods used are inadequate, as they do not sufficiently protect crops from deterioration due to their inability to control temperature and air circulation. Cold rooms are non-existent in many rural areas, and where these facilities do exist, they are not used efficiently for lack of a reliable energy supply. Consequently, small farmers in the SA region are unable to implement suitable postharvest storage practices and market their produce at a higher price.

Transportation

Transportation-related challenges for product distribution are significant in SA countries, which rely on a wide variety of transportation methods. Generally, in rural areas, farmers transport their fruits and vegetables using different methods of transportation according to the distance to market from field or storage. Especially for local transportation, produce is often carried by manpower (on the head or back), and as distance increases, the method changes to pack animals, bicycles, motorcycles, cars, vans, boats, and finally trucks for long distance transportation. Many of these methods mean that produce is subjected to rough handling and unprotected transportation, and there is almost never a “Cool chain” system for accommodating the perishable nature of produce. This often results in heavy damage, bruising, and loss during transportation. Additionally, transportation is usually conducted in two stages: from farm to local storage and then from local storage to the market, with produce only sometimes being directly sent to market after packing. In order to best understand the picture of South Asian produce transportation, the following information and studies performed in the region can be considered.

A study conducted in Bangladesh found a variety of transportation methods for fruits such as mango, jackfruit, and pineapple from farm to a nearby assembly market. These modes of transportation include head load, shoulder load, rickshaw, bicycle, and van, with the use of trucks generally limited to the long-distance transportation of fruits. Notably, as an example, 80% of market transportation by a group of traders (Bepari) relied on the use of vans, while trucks were found to be a vital transportation method for bringing 84% to 100% of mangos to distant markets, with no usage of refrigerated vehicles (Hassan et al., 2010).

The quality of fruits and vegetables is heavily reliant on transportation method. In the "Karokh" district of Afghanistan, tomato growers were found to experience tomato losses of up to 50% solely due to rough conditions during transportation. To assist farmers in reducing their losses, the development organization of Cultivating New Frontiers in Agriculture (CNFA) partnered with farmers to help purchase 1,500 plastic crates. The benefits were immediately obvious, reducing transportation spoilage to merely 5% (World Resources Institute, 2013).

As can be seen in Fig. 5, SA countries face significant challenges associated with produce transportation as most of the technologies for preventing transportation loss are too expensive for small-scale farmers to adopt. For example, in Bangladesh, the greatest portion of postharvest losses (between 23% and 43%) are due to inadequate transportation methods. Here, the major portion of fruits and vegetables, especially in the case of bananas and pineapples, are sent directly by a truck in bulk to the larger markets for sale. The remainder of the produce is packed loosely in bamboo baskets, gunny bags, and wooden boxes. Gunny bags are mainly used in the eggplant and cucumber trade, while plastic sacks and gunny bags are typically used for transporting okra. The use of plastic crates for transporting okra long distances accounts for only 4% to 8% of all packaging (Hassan et al., 2010). Of specific detriment, bulk truck-based shipments are exposed to sunlight and other weather elements, causing huge losses in the quality as well as the total weight of their cargo (Hossain, 2010).

(a) (b) (c)

Fig. 5. Transportation methods in SA countries: (a) long-distance truck transportation in India, (b) local market transportation in Bangladesh, (c) typical produce transportation in Sri Lanka.

There are some notable cost-effective techniques to reduce losses, such as placing packing leaves inside packages or between and on top of produce to reduce vibration damage. Additionally, these leaves help elevate CO_2 levels and concurrently reduce the concentration of O_2 inside the packaging, modifying the atmosphere to be more suitable for the storage of fruits.

Farmers face the same situation when distributing their produce in Sri Lanka. For banana distribution, trucks are often overfilled as bunches are stacked into a number of layers because the wholesaler generally attempts to transport the maximum amount of produce per truckload in order to minimize his transportation cost. To make matters worse, the cargo in some trucks is exposed to the direct sun and rain, which accelerates the deterioration of the fruit. This physical transportation damage not only leads to postharvest losses but also subjects fruits to various stresses. Such stresses can lead to physiological and morphological changes in the fruit (Shewfelt et al., 1987). Generally, where poly-sack bags are used for transportation purposes, losses have been estimated between 30% and 40% of total produce transported. Plastic crates have been introduced to mitigate such transport waste, but this measure has been largely rejected by farmers, vendors, and transporters because the crates decrease the volume of produce that can be transported by 48% and is more difficult to handle than poly-sack bags (Abeygunasekara, 2015). It has been shown that the use of these nestable plastic crates can reduce postharvest losses from between 20% and 30% to around 6% (IPHT, 2011). A study of tomato farming in Sri Lanka found that harvesting methods, tools, and time of harvesting all contributed less to lose than transportation from field to storage and from storage to market (Darshika et al., 2014).

Sorting and grading

Grading and sorting fruits and vegetables are typically based on physical characteristics like weight, size, color, shape, specific gravity, and blemishes, which depend upon the agro-climatic condition. Grading of produce in the fresh form of quality is essential, as the market increasingly demands quality. This is an important stage, as most consumers base their buying decision on these factors (Wakholi et al., 2015). Additionally, the grading of agricultural products is an essential activity for engaging in global trade. In the SA region, most farmers grade their produce manually. Grading is accomplished with consideration to the physical quality of the fruits and vegetables in question. As researchers discovered in Bangladesh, there are currently no specific scientific methods for grading for fruits and vegetables, which are typically subjectively classed based on size into large, medium, and small grades (Hassan et al., 2010).

India also lacks a scientific grading system for produce, despite their significant production of fruits and vegetables, though Indian agriculture still relies on sorting and grading to classify produce. Sorting in India is a separation based on a single countable property of raw product units, while grading is a measurement of the overall quality of a fruit using subjective attributes (Patel et al., 2015).

Similarly, in Afghanistan, the lack of an effective grading system means that farmers do not receive prices reflective of the quality of the products they sell (World Bank, 2014). Additionally, Nerkh district farmers have been observed sorting and grading their apples by size, color, and shape, and were unaware of any more stringent grading and sorting systems. In order to ensure an acceptable price for varying qualities of apples, farmers place apples in wooden crates and plastic bags such that the largest, fairest colored, and best-looking apples are near the exterior of the crates or bags and the low quality (small or immature) apples are in the middle of the package. The packs are then tied right with wire and aren't opened until time for sale at the market. The unavailability of skilled packers and subsequent bruising are the main issues facing the Nerkh district farmers during the packaging of their apples (Masood, 2011).

Grading and sorting are accomplished in a different manner in Sri Lanka, where most produce is graded manually by collectors, wholesalers, and retailers. Farmers typically send their products to market without grading (Gunathilake et al., 2016).

Manual grading is costly, and grading operations can be easily affected by a shortage of labor in peak seasons. Still, grading and sorting of any method are an effective means for removing damaged, diseased, and insect-infested produce, even on the basis of visual observation. Manual grading can also be performed on a limited basis using size, shape, color, texture, the degree of the visual external quality, and other readily apparent characteristics.

Processing/value addition

The value-added sector fulfills a need along the value chain for fruits and vegetables as they travel from farm to plate. Value-added products such as canned, frozen, or dehydrated foods offer an opportunity for the creation of sustainable livelihoods and the economic development of communities. The sale of value-added fruits and vegetables have become common in the last few decades (Swinnen, 2007)

Among all SA countries, the processing of fruits and vegetables is a profitable business opportunity, with the largest producer in the value-added sector being Pakistan. Currently, many growers are not familiar with the latest processing techniques that can add value to their products and bring in a larger amount of foreign exchange through export (Akter and Kalam, 2014). In India, the complexity and weakness of farm linkages and inefficiencies in the value chain mean that the level of value-addition is currently quite low, however, the value-added segment of the food market, including fruits and vegetables, is growing rapidly and attracting significant investment (Gulati et al., 2007). Investigation of the value-added sector in Bangladesh reveals activities by many large-scale companies (such as Program for Rural Advancement Nationality, Bangladesh Food Producing Company food, and Golden Harvest) engaged in the canning, freezing, and dehydration of fruits, though most of this production is for domestic consumption rather than export (Akter and Kalam, 2014).

Similarly, while the processing of fruits and vegetables is of tremendous economic importance in Sri Lanka, less than 3% of the total production of fruits and vegetables are exported as either fresh or processed products (Sri Lanka Customs, 2009).

Drying

The quality of agriculture commodities in the fresh form changes constantly after harvesting through the respiration and other physiological changes. Consequently, a different type of postharvest technologies is investigated to maintain product quality during storage and distribution and drying is one the ways to minimize the losses of fruits and vegetables (Lee et al., 2016; Kim and Han, 2017; Hong et al., 2017). Fruits and vegetables are irreplaceable in a wholesome diet. They constitute fabulous sources of nutrients such as vitamins, minerals, and fibers. Because the moisture content of fresh fruits and vegetables is more than 80%, they are classified as high perishable commodities (Orsat et al., 2015). The maintenance of fruits and vegetables in a cold chain system allows for the delay of decay and retains nutrient values longer. However, especially in developing countries where cold chain systems are poorly established or distribution systems and handling facilities are lacking, drying can be a suitable alternative for the prevention of produce loss by removing the water and preserving the nutrition. It has been noted that currently over 20% of the worlds perishable crops are dried to increase their shelf life and promote food security (Grabowski et al., 2003).

In Afghanistan, grapes are the main fruit crop, followed by apples, almonds, and pomegranates (FAO, 2004). Due to instabilities in the market, farmers tend to avoid selling their grapes in the short period of the harvesting season, electing instead to dry them into raisins which can be stored and sold many months later (Yousufi, 2016). Afghan farmers dry 20% to 25% of their grape harvest for raisin production (Safi and Bunnel, 2014). Raisins produced in Afghanistan can be divided into two types: those that are dried directly in the sun (black and red raisins, or Aftabi (sun-dried)), and those that are dried in the shade or in mudbrick drying houses (kishmish khana) away from direct sunlight. Afghanistan was the world's sixth largest exporter of raisins in 2011, accounting for 4% of the world raisin trade (Lister et al., 2004).

Solar dryers have been developed and implemented by several governments and organizations in SA countries, and a good body of research is underway in most of the countries in the region, propagating solar drying technology for the manufacture of value-added agricultural products. The main two categories of dryers, natural convection solar dryers, and forced convection solar dryers rely on different methods to dry produce. Natural convection dryers rely on the airflow induced by differential densities of hot and cool air, while forced convection solar dryers create airflow mechanically by using a fan operated by either an electric/solar module or a fossil fuel.

Solar drying systems for agricultural products are one possible way to encourage value-added production, especially in developing countries where labor costs are low and the cost of fossil fuel energy is very high. The availability of materials required to build solar dryers in rural areas is another advantage of these devices. Currently, conventional (fossil fuel based) dryers, as well as solar energy dryers, are under active development by non-governmental organizations and research institutes. For instance, there is a wide variety of dryer technology in India, including solar cabinet dryers, solar paddy dryers, solar tray dryers, tunnel dryers, and hybrid dryers. There are also various types of more advanced drying technologies in the region, mainly used in private sectors, such as osmotic dehydration, vacuum dehydration, high hydrostatic pressure dehydration, pulsed electric pressure dehydration, ultrasound dehydration, as well as several other technologies for drying fruits and vegetables.

The Sardar Patel Renewable Energy Research Institute (SPRERI) in India developed a forced circulation solar dryer that uses a modular air heater intended for a standard 2 m^2 surface area. This system can dry two 100 kg batches of fresh onion flakes in a day, and was found to be useful for drying other agriculture products as well (Chavda and Kumar, 2009).

In Afghanistan, where the climate is very dry, the preservation of fruits and vegetables by drying them outside is traditional. Usually, the produce is sliced and then laid out on a flat rooftop until bone-dry. Some drawbacks to this traditional approach are that the dust in the air and the clay from the roof sticks to the product and there is no protection from birds or insects. The non-governmental organization International Solar Energy Society (ISES) is developing a project in Afghanistan for producing high quality dried foods in a tunnel solar dryer (MSDA, 2007). Advantages of food drying aside, not all farmers have access to solar dryers and still rely on traditional methods of drying of fruits and vegetables under the open sun. Other small-scale farmers slice fruits and lay them on the floor, or dry herbs and hot peppers using room temperature, with the product strung in the air or

Table 2. Summary of postharvest technology in SA countries for fruit and vegetable production.

Operations	Afghanistan	Bangladesh	India	Sri-Lanka	Nepal	Maldives	Bhutan	Pakistan
Harvesting	Manual handling. (immature stage)	Manual (immature stage)	Manual & mechanical (private sector)	Manual handling	Manual handling. (immature stage)	-	Manual	Improper stage, roughly
Sorting, grading	Limited, based on observation, base color, and size	Limited, based on observation	Conventional and modern (Private sector)	Limited, based on observation (traders)	Manual	-	Limited	Limited (large scale traders)
Field Packaging	Plastic bags, wooden boxes, some plastic crates, cartons	Bamboo baskets, gunny bags, wooden boxes, paper cartons	Poly bags, plastic jute, gunny bags, bamboo boxes,	Poly sacks, plastic bags, steel boxes, fiberboard plastic crates.	Bamboo baskets, sacks, gunny bags, jute, plastic sacks.	Lack of packaging	Big plastic bags, wooden crates	Retailer stage, plastic bags, carton boxes
Storage Systems	Locally for some specific fruits, apples	Lacking, only some amount of potatoes	Only for 10% fruits and vegetables	Lack of cold chain	Traditionally only for apples	Limited facilities, 90% imported	Cellar storage for citrus	low cost
Transportation	Truck and small cars	Rickshaw, cycle, van bicycle, open truck	Open truck, lorries, tractor	Open truck, lorries, tractor	Van, truck, rooftop bus	Only Import	2-3% slopes, transport at a very low rate, truck	Open truck
Drying Methods	Sun, shade, and solar dryers	Sun and solar dryers	Sun and solar dryers	Sun and solar dryers	Solar drying and open sun	Traditional	Sun drying on Roof	Sun drying like dates and solar

tied in bundles and suspended from overhead racks until dry. Occasionally produce can be wrapped in paper bags with an opening for air circulation, allowing for gradual, protected drying.

Opportunities

Everyone suffers when resources are wasted, especially those in poor regions who already have so little. This is why it is so important to understand where waste and loss are occurring, so a pathway to reduce waste can be developed. The people and economies in the countries of South Asia are immensely dependent on agriculture. In the SA region, only 14% of the land is arable (Molden, 2007). Though it is tempting to solely focus on the improvement of crop yield and arable land, upon analysis the most effective method for increasing available agricultural resources is to adopt a range of postharvest technologies. From the technologies considered, it was found that the simpler postharvest technologies are more likely to be continuously used, and thus more likely to make a meaningful difference in the long-term mitigation of postharvest produce losses in the region.

Opportunities for the implementation of postharvest technology to reduce losses can be found at every step of postharvest handling. In rural areas, postharvest technology, tools, and supplies are rarely available. Local knowledge and technical capacity for using these tools are nonexistent. Information availability is another issue: Farmers lack access to existing postharvest information, supply markets, information sources, and credit. The lack of financial support for farmers limits growth and adaptation of improved handling practices. The limited market access for smallholder farmers means improvements to postharvest handling must rely upon small-scale practices, such as the use of improved containers to protect produce from damage during handling and transportation, the use of shade to protect harvest produce, the use of sorting and grading to enhance the market value of produce, the use of maturity indices to identify proper harvesting timing, and the use of on-farm storage and packaging, which can all be implemented very simply within the traditional agricultural framework of the region.

Sub-standard pre- and post-harvest management practices are often used by stakeholders (growers and intermediaries) in South Asia. Increasing the available knowledge and the development of need-based technologies are both crucial in the fight to reduce agricultural losses. Research indicates that improved practices are often adopted only if they have a proper place within the existing value chain and marketing system. The most important way to address the challenges related to agricultural production loss in the SA region is to improve the skill and knowledge of farmers and encourage them to learn more about the steps they can take to improve their yield, reduce their losses, and increase their returns at the market. All farmers should be aware of best practices in the postharvest agricultural sector and be able to implement these practices in a practical sense. The sustainability of technological innovations depends upon their obvious benefits in the local setting. The most important measures for addressing and eliminating the issue of postharvest loss are government policies and regulations that can be established to stimulate national and regional agricultural development.

Public and private partnerships are urgently needed to introduce simple postharvest technologies, beginning with basic fruit harvesting tools to prevent damage, to the use of appropriate transport vehicles, the use of ethylene-induced ripening technologies in storage and farm stages, the introduction of low cost, cost-effective storage. The introduction of plastic packaging systems can all work together to reduce postharvest losses, particularly where studies indicate they are the most severe, such as during transportation. Because the core problem of agribusiness development in the South Asian region is a lack of effective relationships between farmers, collectors, wholesaler, and consumers, a systematic linkage among government and non-governmental organizations, farmers' groups, and private entrepreneurs is needed for the better management of postharvest handling systems throughout the linkage, and these connections can be mutually beneficial to all involved.

Awareness of technology and practice and training in its implementation are the most effective ways to reduce postharvest losses as many existing postharvest problems are due to ignorance and lack of enforcement or monitoring by the appropriate authorities. By creating awareness and developing appropriate training manuals, experts in postharvest management techniques for harvesting, grading, sorting, packaging, transportation, storage (on the conventional and modern stage), processing (small and large scale) can make a significant difference in the quest to reduce losses. This work, performed in concert with governments and related stakeholders, has the potential to make a big change in the situation.

Conclusion and recommendations

Fruits and vegetables play a major role in the agricultural economies of SA countries. These countries grow a large variety of indigenous and exotic fruits and vegetables. Most countries in SA have, for the past several years, maintained positive growth in the production of fruits and vegetables, indicating the increasing role that intelligent agriculture plays in enhancing farmer's income, alleviating poverty, and improving the quality of local diets.

In order to feed a growing population, meet the requirements of the processing industry, and address the demand of the export trade, merely increasing the production and productivity of farms is insufficient. Greater emphasis must be given to postharvest management to maintain the quality and prevent losses of these highly perishable crops. The only way to address these growing demands is to undertake massive efforts to reduce postharvest losses, making more of the food already being grown available to consumers. To achieve this objective, we must adopt advanced technology and emphasize new, cost-effective and easily applied innovations for use at every level in the food system from smallholder farmers to the postproduction system.

Fresh fruits and vegetables are highly perishable, and estimates place the postharvest loss of production in the region to be between 30% and 50%. These heavy losses have led to a considerable gap between the production quantity and net availability of fruits and vegetables. The huge postharvest losses in SA countries are the result of poor practices in both the pre- and post-harvest stages, as well as a lack of proper technique for prolonging the shelf life of fruits and vegetables. These losses have negative impacts on farmer's income, consumer prices, and the nutritional quality of the produced fruits and vegetables. Implementation of efficient postharvest practices has been shown to minimize the losses of fruits and vegetables and enhance food availability, but most agriculture in SA is conducted by small-scale farmers with limited access to these technologies and the financial resources they often require.

To date, the effective addressing of postharvest losses has required strong communication and open exchange of ideas among farmers, postharvest engineers, food technologists, and transporters between farm and market. These cooperative efforts have advanced research into and application of new, adaptable scientific approaches in the region. Simple, practical, and appropriate postharvest technology and management can be an efficient way to enhance quality, improve produce shelf life, increase the safety of fresh produce, reduce postharvest losses, and add value to agricultural products. The uses of basic technologies either alone or in combination with other practices can be quite beneficial. Generally, small-scale farmers expect tools to work well for all crops, so it is recommended that basic postharvest materials be developed and farmers are trained in technologies and practices tailored to local conditions, costs, and benefits.

According to studies and research, for small-scale producers to reduce postharvest losses and compete on an even production stage, it is necessary that improvements take into consideration the appropriate scale, low cost, and easy operation of postharvest systems. The development of improved containers, low or zero energy cool storage, field packing systems, shade covers, and small cold rooms are all practical. Smallholder farmers are unable to handle the complex and expensive infrastructures used in developed nations because their limited resources cannot meet the requirements of such large and complex systems.

Simple food processing such as drying and the canning of sauces and jams are helpful methods for improving the availability of food in rural areas by transforming highly perishable produce into stable, transportable, and storable food. The adoption of low-cost postharvest technologies in the SA region will support small-scale farmers and provide a pathway for fresh produce to the market, joining small farmers with larger, modern value chains, and improving the lives of individuals, nations and the South Asian region as a whole.

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