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Transformed traditional storage of crops in India – Challenges and potential impacts

SHRIKALAA KANNAN*, DARWIN LYEW, VIJAYA RAGHAVAN

Department of Bioresource Engineering, Macdonald Campus, McGill University, 21111 Lakeshore Road, Sainte-Anne-De-Bellevue, QC Canada H9X 3V9

ABSTRACT

One out of every eight individuals in the developing world goes to bed hungry. It is predicted that as the global population increases, the amount of food produced has to double by 2050 in order to feed the world population. One of the strategies, often the first choice, is to increase yield by increasing the amount of cultivable land and using intensive agricultural practices. Such agricultural practices however result in environmental degradation. This warrants for the development of eco-friendly and sustainable agricultural practices to ensure food security. Post-harvest losses as it stands accounts for almost 27–40% of the total food produced globally, with almost 50% of the produced food going to waste in developing countries. Food, if properly stored for longer periods, could eventually help feed millions of people in the developing world and help combat malnutrition and ensure food security for future generations. This is really important in era of global food insecurity. Storage of grains and horticultural crops under proper conditions of temperature, humidity and types of structure used are critical in determining the storage life. In India most of the storage structures used are traditional, that have been in practice for hundreds of years. These structures are not updated to accommodate the latest findings from storage research so as to minimize losses. This paper highlights the challenges faced in implementation of 'transformed traditional structures' for storage. These challenges vary from farmer's economy, lack of governmental policies, lack of awareness and proper infrastructure. Some of the traditional structures used in the storage of horticultural crops, its pros and cons were discussed and several case studies where scientific intervention and transformation of traditional structures were reviewed confirm a reduction in storage losses.

Key words: Controlled atmosphere storage, Cooling, Drying, Post-harvest, Refrigeration, Storage

Food security and food safety are two most pressing issues that agricultural engineers are tackling in the current global scenario (FAO, 2013). Our current agricultural practises with the use of synthetic chemical fertilizers to increase yield, pesticides, fungicides and weedicides to prevent infestation of the crop to preserve quality is detrimental to the soil quality (Kader, 2002). It degrades the fertility of the soil by contaminating the soil with excessive levels of chemicals. Further, it pollutes the watertable as the chemicals seeps deep into the groundwater. Also, current irrigation systems and post-harvest processing of the produce demand high energy inputs which further leads to usage of coal and fossil fuels as main energy sources, leading to increased levels of green-house gas emissions (Kays, 1991). This warrants for the development of more eco-friendly sustainable agricultural practises that meets the market demand with high yield of produce. Also, newer eco-friendly source of energy is needed to meet the future demands of agricultural energy to preserve our earth 'green'. This calls for several areas of agriculture and food management practices to perfect laws related to policies and standard operating procedures to meet the increasing demand.

Agriculture is the mainstay of the Indian economy, as it constitutes the backbone of the rural livelihood security system. It is the core of planned economic

*Corresponding author e-mail: *shrikalaa.kannan@mail.mcgill.ca*

development in India, as the trickle-down effect of agriculture is significant in reducing poverty and regional inequality in the country. Growth in agriculture has a maximum cascading impact on other sectors, leading to the spread of benefits over the entire economy and the largest segment of population. It is essential not only for self-reliance but also for meeting the food and nutritional security of the people, to bring about equitable distribution of income and wealth in rural areas, and to reduce poverty and improve the quality of life. India is bestowed with a varied agro-climate, which is highly favourable for growing a large number of horticultural crops such as fruits, vegetables, root tuber, aromatic and medicinal plants, spices and plantation crops. India is the second largest producer of fruits and vegetables in the world (Narrod et al., 2009). In 2006, horticultural crops occupy around 13% of India's gross cropped area, producing 177.41 million tonnes (Malaisamy et al., 2007). The Government of India has identified horticulture as one of the major areas for priority attention and immediate action. The major problem facing the horticultural sector is the deficiency in postharvest management. Lack of suitable infrastructure, technological options and market information is the cause of huge postharvest losses in India. It is estimated that only 2% of the horticultural produce is processed and postharvest losses as it stands accounts for almost 27–30% of the total food produced globally, with almost 50% of the produced food going to waste in developing countries (Fig. 1) (Parfitt et al., 2010). Reclaiming these losses would provide the country with enormous resources to help feed millions of people in the developing world and help combat malnutrition and ensure food security for future generations.

Food, being readily perishable, is easy target for moulds, fungi, bacteria and viruses that could cause harmful diseases in humans (Eskin, 1989). Postharvest technology from ancient times had focussed on slowing down or eliminating microbial growth to extend the shelf life of food. Our ancestors took advantage of the weather conditions that they experienced, in tropical climates they adapted sun drying to preserve vegetables and fruits, in cold regions they used ice to preserve meat and meat products, in regions bordering oceans they adapted salting technique to preserve food. Refrigeration technology began with the use of ice to cool the food, thereby extending the shelf life. The refrigeration technology was adapted in large scale by the meat processing industries in late 1800's. Since then refrigeration has evolved from using toxic mercury chloride as refrigerant to environmentally hazardous chlorofluorocarbons to hydrocarbons which are eco-friendly and is current standard for the refrigeration units. Refrigeration has been widely employed to extend the shelf life of horticultural produce from farm to fork in the developed world. However, there are huge gaps in the refrigeration cold chains in the developing countries, which could explain huge post-harvest losses seen in developing countries. In addition to this, most small scale farmers in the developing countries still rely on the traditional practices to store harvested produce from the field. These traditional structures often do not incorporate the advances in engineering, science and technology to minimize losses.

Agricultural engineers are addressing these challenges by developing research strategies that evaluate newer and better green technologies to be implemented in agricultural practises. With their commitment, the field of postharvest technology

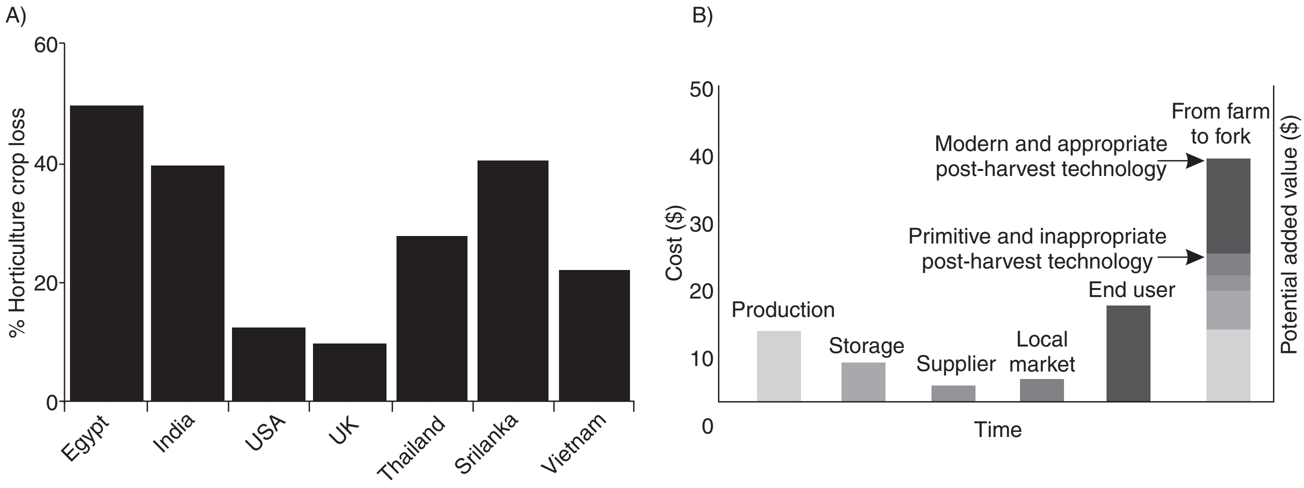

Fig. 1. (A) Post-harvest loss in horticulture crops in different countries (data from (Parfitt et al., 2010)). (B) Post-harvest loss in horticulture crops at different stages (G.S.V 2005). The losses incurred post-harvest intensifies during storage and distribution. With the advent of post-harvest technology, there is value addition at each stage

has seen some of the greatest ideas and techniques being implemented in industries to preserve food. With respect to horticultural industry, post-harvest technology aims to store the produce to preserve/ maintain the freshness of the produce for extended periods of time. For instance, postharvest technology with respect to meat products includes canning, salting, pickling, drying and frozen food. Our environment conscious society may even perceive the fresh horticultural produce to be more 'green' as there is less energy input demand compared to the more energy demanding industry processed preserved foods. In addition, there is no pollution from the packaging material in the packing-free horticulture produce. For this reason, horticulture industry has heavily invested in finding new eco-friendly preservation techniques. This paper focuses on issues and challenges faced to develop amenable technology towards better food security and safety practices and advancements over the past few decades in Indian scenario that is inching us close to better sustainable food safety and security.

CHALLENGES TO TRANSFORM TRADITIONAL STORAGE STRUCTURES

Horticulture produce after harvesting undergoes biological processes that might deteriorate the quality of the produce. The normal physiological processes do not cease to function after harvesting, as the produce is fresh. The golden rule in the field of post-harvest biology is that the horticulture produce could be stored to maintain quality but never to be processed to enhance the quality of the produce (Dongowski, 1973). The quality of the produce at harvesting and post-harvesting is determined by the physiological factors such as respiration, transpiration and water loss, level of ethylene and ripening state of the produce.

ENVIRONMENTAL FACTORS

Apart from the above mentioned physiological status of the produce, the ambient environment where the produce is stored post-harvest can determine the quality of the produce.

MECHANICAL STRESS

Horticulture produce is rich in moisture. As a result of which their tensile strength is poor (Sudheer and Indira, 2007). They are susceptible to damage even with mild mechanical stresses. Improper harvesting practices, poor handling during storage, packaging and transport could lead to enormous amount of losses to the produce (Sudheer and Indira, 2007). Such practices could lead to scoring, splitting, breaking, and other forms of injury. This is a serious concern as such damages make the produce very susceptible to microbial invasion.

DEVELOPMENT AND GROWTH

Some of the produce is harvested when they are young in their life cycle (Verma and Joshi, 2000). As they grow they germinate, sprout and develop shoots and roots, which is detrimental for the quality and nutrition content, as they are used for the growth of produce. This makes the produce less attractive for the commercial market (Chadha, 2001).

MICROBIAL AND PEST SPOILAGE

As horticultural produce is rich in nutrition, they are a very attractive source of nutrition for microbes (Sela et al., 2009). Despite the innate defence mechanism that prevents microbial invasion, horticultural produce is susceptible for microbial contamination and spoilage. This is further enhanced by the fact such produce are rich in moisture (Sela et al., 2009). Refrigeration could help avoid or slow down such growths, spoilage from pests and insects are other major contributors to huge post-harvest losses in India.

POLICY FACTORS—DEFICIENCIES IN INFRASTRUCTURE

All of the above factors could be partly corrected by establishing proper infrastructure by the policy making and governing agencies. Lack of proper infrastructure is at multiple levels. It could be split into farm level and governance level. As the quality of the product at time of harvesting greatly determines the quality of the produce during post-harvest storage and in market, it is essential to address the issues related to harvesting (Kitinoja et al., 2011). In India, agricultural practices are mostly traditional, as the knowledge about agricultural practices is acquired from ancestors. Such practices are age old and the agricultural engineers have made tremendous progress in farm mechanization over the past few decades. However in Indian agricultural scenario, which is rich in small-scale farmers, the idea of mechanization is seen as financial burden (Kitinoja et al., 2011). This is mainly due to the ignorance of the farmers about the advantages of farm mechanization. This leads to the common belief that mechanization is a risk-full adventure. This scenario has to be changed by establishing proper outreach and educative counselling programmes for the farmers (Kitinoja et al., 2011), which are being done with the current infrastructure, however, it needs to be modernized and expanded.

TRANSFORMATION OF TRADITIONAL STORAGE STRUCTURES

Mobile pre-cooling technology

The horticultural growth rate in south India has been about 6% in the last decade. However, this has not resulted in an income growth for farmers on any substantial scale. The losses after harvesting are huge and are occurring at a level of 30 to 40%. One of the key problems in handling fruits and vegetables, is the damage arising from the field heat. It takes 6 to 9 h to transport the produce to the markets or retailers, and much of the damage occurs during this time period. The tropical climate of Tamil Nadu leads to an average produce temperature of 30º to 35ºC during transport and handling. This has resulted in faster degradation and consequent loss of produce. With the rapid pace of economic growth in the state and the building of 4-lane highways connecting major commercial centres of Tamil Nadu, the time taken for transport of commodities from rural to urban areas has fallen by about 50%; however cold storage is the biggest missing link in the food supply chain. It would be ideal to have mobile pre-cooling equipment that would cool the produce from 30–35ºC to 10–12ºC in about 5 h.

Initiatives were taken to design and develop pre-cooling devices suited to a variety of situations. A hydro cooling technology was designed for cooling fruits such as tomatoes (*Solanum lycopersium* L.) and root vegetables such as carrots [*Daucus carota* subsp. *sativus* (Hoffm.) Sehubl. & G. Martens]. For leafy vegetables, vacuum cooling is the preferred method of removing heat (Rennie et al., 2001). However, this method is more expensive than other pre-cooling methods. So, we usually recommend a pre-cooling method that is compatible with the product to be pre-cooled. Pre-cooling has successfully reduced the high level of wastage of lettuce C in transit in a hot humid climate from 40% to 5%, thereby helping the farmer to increase their revenue substantially (Sosle et al., 2008).

VENTILATION AND EVAPORATIVE COOLING

Potatoes (*Solanum tuberosum* L.) in Nilgris district is often subjected to traditional pit storage. Potatoes of cultivar 'Kufri Jothi', harvested in November 2011 in Ooty were put into ventilated storage trials for 4 months. The temperature in the Nilgiris district varies between 14º and 28°C during the day and from –3º to 14°C during the night in the storage season. Since the air temperature at night time is low, it was used as a source of cold air for ventilation. When ventilation is used in potato storage, it will remove the heat and CO_2 resulting from metabolic activities. Potatoes storages were subjected to the following treatments: (*i*) night time ventilation; (*ii*) ventilation and evaporative cooling; (*iii*) traditional pit storage; (*iv*) pit storage with ventilation; and (v) cold storage. The effectiveness of the treatments was evaluated in terms of mass loss (which includes physiological, sprouting and rotting losses), and biochemical properties such as dry matter content, reducing sugar and starch contents. The total weight loss at the end of a 120 day-storage period was the highest in the traditional pit storage at 53% and the least in cold storage at 0.5%. The weight loss was 9.8% in ventilated storage and 3.2% when evaporative cooling was combined with ventilation (Sosle et al., 2008). The quality of potatoes under ventilation was comparable to those under cold storage. This study demonstrated the potential of night-time ventilation in Ooty as a low-cost alternative to cold storage for the growers.

One of the other traditional storage structures of potatoes is called 'thumboo' or 'daddi' and it is erected in the fields. Upon implementation of the use of perforated plastic pipes that are laid through the potato piles in criss-cross fashion to provide ventilation into the bottom and centre of the piles prevented the occurrence of hot spots due to the respiration of the potatoes which would lead to rot. The ventilation provided by the pipes decreased loss of potatoes in storage due to rot from 56 to 80% down to 3 to 5%. The use of the new structures and the ventilation pipes greatly extended the length of storage from 40 days to 120 days and tripled the income for the farmers (Sosle et al., 2008).

OTHER POTENTIAL MODERN TECHNOLOGIES

Solar drying of tomatoes, chillies, and coconuts was demonstrated with great success in southern India (Orsat et al., 2008). Large-scale and small-scale tunnel dryers were built and implemented in the field to minimize loss. Controlled atmosphere (CA) storage is emerging as an important technology option for extending shelf life of high value commodities in south India such as mango, flowers, onions and vegetables. The CA storage of tomatoes, citrus and lime has shown to extend the shelf life up to 50 days.

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