EQUIPMENT FOR POST-HARVEST PRESERVATION AND TREATMENT OF PRODUCE

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Summary

Equipment used in the post-harvest handling of produce varies widely according to the specific crop, its intended use, the nature of any particular enterprise and the point that produce has reached within the post-harvest handling system. This article overviews the wide variety of post-harvest equipment used in steps from harvest to consumption. These steps include handling, treatment, storage and transport operations.

Equipment used with perishable versus durable crops is discussed separately throughout much of this review because their physicochemical characteristics are inherently very different. The article concludes in considering a range of policy and future direction issues that are likely to influence, in the context of social, environmental and technological imperatives, the ongoing development and use of post-harvest equipment.

1. Introduction

This article presents an overview of equipment used in the post-harvest preservation of produce from the point of harvest to the point of utilization either in processing operations or by the consumer. Products within the mandate of the overview are either perishable or durable. In both cases the produce is alive. Perishable produce includes fruit (e.g. apple), vegetable (e.g. lettuce) and ornamental (e.g. tulip) crops. Durable produce includes relatively less perishable starch (e.g. wheat), protein (e.g. lentil) or lipid (e.g. peanut) crops. Grain crops are prominent among the durable commodities. The fundamental difference between perishable and durable crops is their rate of metabolism, which is reflected in their relative moisture contents and respiration rates. Perishable produce tend to have higher moisture contents and rates of respiration. As a result of these differences, perishable produce has a comparatively short storage life. Accordingly, post-harvest handling, treatment and storage of perishables is relatively more problematical.

The primary objective of post-harvest operations is to maintain product quality as high as possible and for as long as necessary. Cooling and low temperature storage and handling is probably the single most important post-harvest process affecting quality maintenance of perishable produce. With respect to durable produce, crop drying and dry storage can be considered the most important process. These operations are primarily directed at minimizing the rate of metabolism of harvested produce. Measures taken to control post-harvest pests and diseases are also of profound importance. Post-harvest operations generally cannot improve quality. However, some operations, such as waxing of apples to enhance surface gloss, might be considered exceptions to this rule.

Post-harvest operations applied to perishable or durable commodities tend to follow the general sequences depicted in Figure 1. Post-harvest operations are capital intensive. Expensive equipment (e.g. color vision graders, semi-trailer trucks) and facilities to house the equipment and/or produce (e.g. packing sheds, silos) are often required.

For more information on post-harvest equipment for perishable produce than is presented in this overview article, the reader is referred to the comprehensive works presented in the bibliography.

2. Historical Perspective

In early times, humans lived a hunter-gatherer existence. Bare hands and crude tools were used to harvest food plants and to kill food animals. The human brain and associated senses and opposing digits duly facilitated tool manufacture and use. The position and articulation of the thumb relative to the other fingers allowed firm grasping of objects.

Humans changed their hunter-gatherer life-style to the practices of cultivating crops and herding animals. This settled life-style resulted in the need to store produce for food and as planting material for the next cropping cycle. Increasingly more complex tools were devised. Plowing, planting, cultivating and harvesting machines were made. Engines were invented and farm tractors were subsequently developed. As a result, small traditional farming concerns have given, and still are giving, way to large modern operations. Such changes in production practices have been reflected in changes in post-harvest practices. More sophisticated equipment and facilities capable of handling and storing large quantities of produce have been developed. Massive post-harvest facilities, such as central fruit packing and controlled atmosphere storage sheds, often handle the produce of many small farmers. Larger facilities demand increasing investment and facilitate the continuing development of more sophisticated equipment. Manual post-harvest operations wholly controlled by humans have thus given way to electronic and/or mechanized operations largely controlled by computers.

3. Science, Engineering, and Technology

Post-harvest operations tend to link to one another to form handling systems. The following discussion progresses through the handling system from immediately after harvest to the point of consumption or other use of produce (Figure 1).

SEQUENCES OF OPERATIONS

A. PERISHABLES	B. DURABLES
Field handling	Field handling
Receipt	Threshing/shelling
Conveying	Receipt
Cleaning	Pre-cleaning
Sorting	Drying
Grading	Storage
Treatment	Transport
Packaging	Receipt
Unitization	Cleaning
Storage	Treatment
Dispatch	Storage
Transport	Processing
Wholesaling	Retailing
Retailing	Consumption
Consumption	

Figure 1. Generalized post-harvest handling schemes for perishable and for durable crops.

4. Field-based versus Shed-based Operations

Perishable produce. In the interest of expediency, operations that are usually carried out in packing sheds can take place in the field. For example, harvested heads of lettuce may be trimmed by hand in the field, packaged by workers on a mobile field packing station, cooled in a mobile vacuum cooler and loaded in the field straight into refrigerated transport for dispatch to storage or market destinations. Field packing stations may have conveyors to raise harvested produce up to a platform where manual or mechanized culling, washing, grading, treatment, packing and palletization operations take place. Field stations usually offer shade to minimize heating and prevent sunburn of harvested produce.

Where harvested perishable produce is simply moved from the field to a packing facility, care is generally taken to protect it from incident solar radiation and physical injury. In the latter case, equipment such as farm trailers may have padded (e.g. foam rubber) tray tops and partially deflated tires. Although not an equipment issue *per se*, farm roads should be well maintained and free of bumps and hollows.

Durable produce. Durable crops are produced either under largely manual regimes or totally mechanized. This applies to field operations, transport, storage and even subsequent processing. Rice in many parts of the world is manually processed at all stages, especially when grown in wet paddy fields. Similarly, maize and sorghum may be hand picked or harvested and then dried and threshed in the field. This approach accounts for a large proportion of cereals grown.

However, having duly acknowledged this fact, this overview will concentrate on the mechanized approach. The prairie farmer produces wheat using a fully mechanized growing, harvesting, handling, transport, and storage system. In such high production systems, grain is harvested by combine harvester and delivered into a trailer or truck for transport back to the farmstead. Grain is not fragile, so the condition of the roads is not critical. Pneumatic blower systems to handle grain from field to farm to cut down on energy use and road transport have been designed.

However, no commercial system is on the market as yet. Rail systems have been used for field transport of sugar cane for many years, representing one of the very few uses of fixed transport. Most durable crops, including oil seeds and nuts, are harvested once per year. Their field transport is generally reliant upon tractors, trailers, trucks and/or other multipurpose vehicles.

5. Receipt of Produce

Perishable produce. Produce can be received into shaded or refrigerated holding areas or fed directly onto grading and packing lines (Figure 2). The principal concern in transferring produce from field containers onto packing lines is minimization of physical injury. Hand transfer of produce is an option. For example, field-bunched cut flowers standing in containers of water are generally unloaded by hand. Field containers can vary in size from small buckets and baskets to large bins and trailers, such as the ‘gondolas’ used in California for processing tomatoes.

Dumps used in the transfer of produce can be either wet or dry types. The gondolas, for instance, are filled with water and the tomato fruit are hydro-handled. Produce in wood or metal (e.g. wire mesh) bins may be tipped into water or the bins may be wholly submerged and the produce floated out. Both wet and dry dump tippers may be fitted with deceleration chutes to slow produce as it leaves the container.

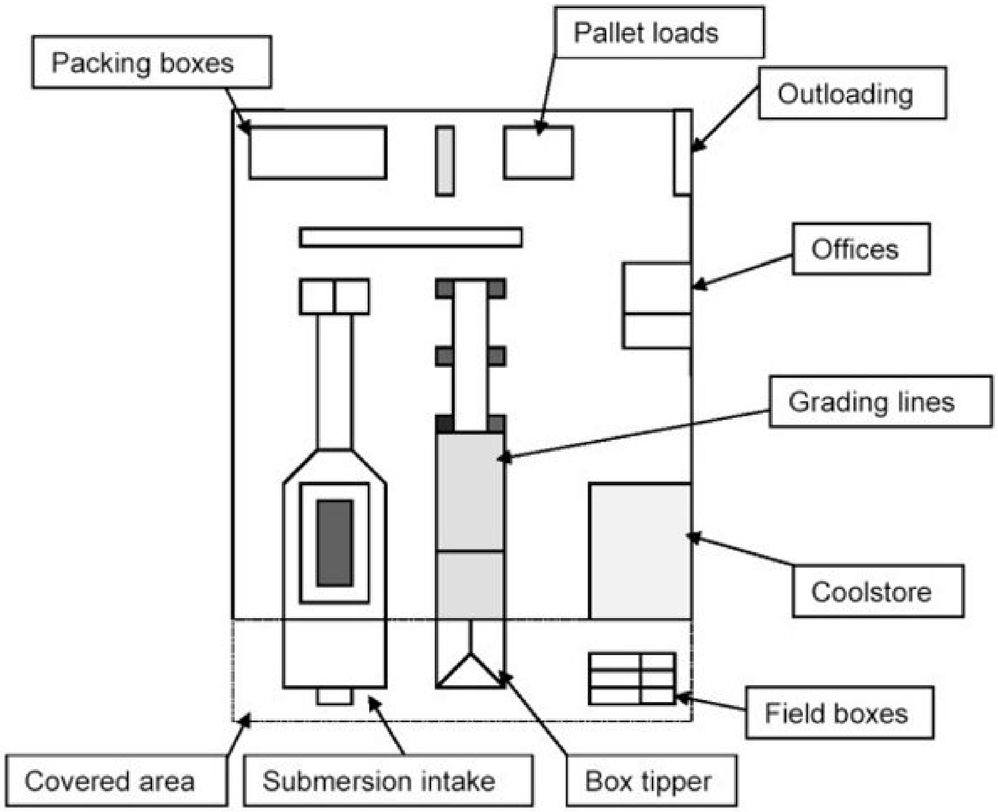

Figure 2. Typical layout of a small packing house for fruit.

Durable produce. Cereals usually need to be handled fairly quickly into the grain store to release the transport vehicle to return to the field for another load and to protect grain from the weather. In some countries, however, grain may be dumped outside, and perhaps sheeted-over without suffering unduly. Grain stores may have a reception pit into which grain is tipped and a hopper feeding a bucket elevator. Alternatively, the trailer could tip into the shallow hopper of a ridged belt conveyor which then transports the grain into the store. Trucks can, of course, drive straight into flat stores and tip the grain. A tractor with a blade or a bucket will then pile it higher in the store to optimize space utilization.

A subject of current research and development is achievement of greater accuracy in monitoring of grain weight at all handling stages, including the reception stage. A wide variety of weighbridges, weighing trailers, deflection devices, and other monitoring techniques are under development. The objectives of monitoring are to give the farmer more information about production levels. Such information can be integrated with other data being gathered with respect to farming practices or grain prices.

6. Conveying

Perishable produce. In some respects the most important, and possibly the most under-rated, post-harvest equipment is that used to convey produce. Fresh produce can be moved by solid or liquid systems. Metal chain-link, rubber, plastic or canvas belts, and wood, metal or rubber rollers are examples of the solid systems used to move either loose or packaged produce. Hydro-handling along flumes can be used for ‘water tolerant’ commodities such as apples, carrots and tomatoes. These conveying media are typically powered by electric motors that drive mechanical links, such as belts, chains and cogs, or pumps. Elevator belts or buckets are often used early in the packing line system. Thereafter, produce can be transferred between steps by gravity. Extreme care must be taken to minimize produce drop heights.

Water used in wet handling operations should be chlorinated to limit the spread of disease. Redox sensor-based chlorinators are ideal for hydro-handling. These systems comprise typically of a redox electrode and chlorine source, a pH sensor and acid/alkali dosing equipment, a re-circulation pump and traps and filters to screen out dirt and debris.

Durable produce. Grain conveyors do not have the same protective constraints as perishable crop conveying systems. Nevertheless, some precautions may need to be taken according to the intended use of the crop. Some grain conveyors may incorporate a thrower to help distribute the grain to the far reaches of the store to permit full use of the storage space. Galvanized steel silos are probably the most popular type of store (Figure 3).

Figure 3. Corrugated steel silos for grain storage.

In these, a bucket elevator raises the grain up to sufficient height so that delivery can be remotely switched to one of a range of round silos, and grain flows down the selected chute by gravity. A conical base to such silos aids unloading. These stores range from 10-ton to 10000-ton capacity. Concrete silos are often bigger than this but are not usual on farms. Rather they are located at dockside or merchant stores.

Pneumatic conveyors have been used for many years. Grain is sucked into a tube before metering into a pressurized section. This section delivers the grain to either a flexible pipe which may be moved around a store or else through a fixed pipe system to steel, wood or concrete silos. Recent work has focused on the use of the packed bed system of pneumatic conveying whereby grain is pumped with minimum air through the pipe. This system is quieter and less damaging to the grain, but is not yet on the commercial market. Main alternatives for the reception stage are the belt conveyor which is usually ridged and troughed and the scraper conveyor which pulls a chain on which scraper blades are mounted through a channel full of grain. Screw augers have long been a popular means of handling grain but they are limited in capacity and range. They can also damage the grain if it is intended for seed or malting. Similarly, they can very easily damage larger seeds, such as peas and beans.

Systems vary according to the final use of the grain, which may be for human food, animal feed, oil extraction, malting, seed, and a few minor industrial uses. The highest standards are probably demanded by the seed industry, where germination rate and purity must be maintained, followed by the malting, food, extraction and feed industry, respectively. Physical mistreatment, humidity or temperature problems can cause germination loss and downgrading to less stringent usage and lower price. Certain species of legume seeds, for example, are highly susceptible to impact damage and need very careful handling.

7. Cleaning

Perishable produce. The objective of cleaning operations is primarily to remove both abiotic (e.g. soil) and biotic (e.g. dead leaves) foreign matter from the harvested crop. Cleaning is particularly important for root crops and for mechanically harvested crops. In the first case, soil is the major contaminant. In the latter, sticks and leaves may be a problem. Foreign matter can be removed by wet methods including water sprays, water immersion, wet or dry brushing and/or wet tumbling. For example, potatoes are often washed under central axis-mounted nozzles delivering jets of water onto tubers tumbling down along an inclined perforated cylinder. Dry methods of cleaning produce include jets of air and mechanical screening and brushing. These methods are suitable, for example, against contaminating leaf materials, stones and scale insects, respectively.

Durable produce. Some durable crops need further processing at the reception stage such as threshing or shelling. Maize needs to be stripped of the husk and shelled from its core. The husk is stripped by hand in small-scale operations. A range of machines is, however, available to shell the grain. These usually operate on either an impact or a scratching principle. Large machines are mostly impact-based as these do not require any alignment of the cob. They can be designed to operate at high volumes, removing both husk and grain.

Rice is grown on steep hillsides in terraces in many parts of the world. It can only be processed by hand in the early handling stages. On flat land, however, rice can be grown, harvested and processed in a fully mechanized way. To facilitate storage at a reduced volume it is often milled at an early stage. This refers to hull removal and polishing to remove bran. Around 50% of the world rice crop is also parboiled to gelatinize the grain. This process aids milling, renders the grain inert, improves the nutritional properties and modifies the flavor. Parboiling involves soaking, steaming and drying.

Initial cleaning of grain and seeds is by either an aspirator or a pre-cleaning air-screen machine. If the grain is already clean enough this stage may be omitted. However, for a dirty crop it may remove up to 20% or more chaff, straw, weed seeds, insect and/or soil particles. This material must be removed before drying. The aspirator sucks light material from the crop as it is passed in a thin curtain across a vertical air current. The air-screen consists essentially of a set of at least two sieves over which the crop passes in order to remove both oversized and undersized trash. Trash can hinder flow in the dryer, as well as waste energy in drying.

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Biographical Sketches

Daryl Clifford Joyce, Ba. Appl. Sci. (Hort. Tech.), M. Agric. Sci., PhD. is a post-harvest horticulturist with 15 years of predominantly applied research, teaching and extension experience. He works on a wide range of ornamental, fruit and vegetable crops. Prof. Joyce is particularly interested in adapting and optimizing new technologies to enhance post-harvest operations and in postharvest plant physiology and plant pathology. He has authored or co-authored about 70 scientific articles and well over 100 popular articles, conference contributions and reports. Prof. Joyce has also co-authored a textbook for undergraduate students and industry personnel on post-harvest biology and technology. He has been employed by universities and government research organizations in California, Western Australia, Queensland and Great Britain. Prof. Joyce is currently Professor of Post-harvest Technology and leader of the Marketing, Food and Postharvest Group at Cranfield University at Silsoe.

Brian Clarke, PhD, BSc, MIMechE, Ceng, DIC has been Senior Lecturer in Agricultural Process Engineering at Cranfield University at Silsoe for the past 28 years, and recently became an independent consultant. He has specialized in machinery and equipment aspects related to post-harvest treatments and processing of both durable and perishable crops. His published work covers a wide range of topics, including oil extraction, grain cleaning, milling, extrusion, handling and seed technology. One recent textbook chapter gave a comprehensive review of pack-house technology for fruit and vegetables, and another of cassava processing. He has worked in over 20 countries and has experience in both temperate and tropical crops. Also, he has worked with over 40 British manufacturers, bringing together the needs of the crop and the best way to manage it. Dr Clarke designs prototype machines and processes for novel crops, optimizes factory approaches and advises on insurance and legal responsibility. He has extensive knowledge of scientific fundamentals, engineering practice, commercial expertise and local requirements.