FRUIT & VEGETABLE PACKHOUSE EQUIPMENT

Introduction

The design and layout of packhouse machinery is very broad and varied, and is really dependent on the product being handled and its intended market. However, there are many operations that are common to numerous different products, and general brief principles will be discussed, starting with reception to the packhouse, and ending with the packaging. There are many machines that have been around for some time, and on the other hand, there are newer computer controlled camera sorting mechanisms, and robotic arm packaging devices similar to those seen on some machine assembly lines.

Box and bag tipping

The produce may arrive from the farm's harvester either in boxes or in bags; the boxes may be up to 5 tonnes in weight, but typically will weigh a little less than one tonne, and the bags (typically for potatoes) may be 1 tonne in size. The boxes are handled from the trailer up to the box tippers with a forklift truck; the box tipping units may be mobile or static, often with a weighing platform, and can handle 60 t/h + depending on the feed arrangements. Whatever the system, it is imperative that there is not a large fall height for the produce; typically a box will rotate about its front edge and there will be a restraining brush which slowly rotates to minimise the flow of produce onto the line. See Figs 1 and Fig 2.

Bulk trailers will normally tip into a bulk feed hopper; this will have tall sides and will be 0.50-10 t + capacity. To be most efficient, the feed hopper should have a belt 1.5-2.5m wide, and should slope up at a gentle angle. The main objective is to reduce damage due to abrasion, bruising and crushing. Trailers or lorries with moving floor discharge can unload straight into the beginning of the processing line. The crop is discharged through a hatch at the rear end. The belt is normally 450-600mm wide, and the remainder of the trailer floor slopes down towards this. Again, it is important that there is no significant drop height for the produce.

Conveyors

These are normally based on a PVC belt, with variations being a swan neck design for high lift applications, and those with a chevron design (or a 'T' cleat) on the surface for more grip. High wall belt elevators are available, and also U-trough screw conveyors which may be open or enclosed.

Feeders, as they are often called, are designed to provide an even feed of the produce to the processing line. Their capacity might vary between 1-50 t/h. For example, this might consist of a vegetable holding tank for carrots, with twin out-feed belts and a vertical filling head. It could have a stainless steel elevator with a 'food quality' belt; inspection conveyors with waste picking chutes; a vibratory soil remover for soiled vegetables. It needs to be very high capacity for crops like peas. The bulk feeder may have electric or hydraulic drive for on-site applications.

Cleaning

Cleaning, and in particular, de-stoning, may be necessary with potatoes, onions, carrots, swedes, red beet and parsnips. Soil may be removed with a dry rotary barrel. This may be 600-1200mm in diameter, which slowly rotates at 15-25rpm, and has a slight tilt (only a few degrees) to encourage the crop to tumble down to the exit. The walls are spaced bars or large aperture mesh; sometimes there are ‘spokes’ inside the barrel, but these can further damage the crop. See Fig 3.

In order to remove dry loose soil, this may be achieved by passing the produce over a horizontal web. The bars on this must suit the crop and be as wide as possible and agitated. There is a limit, however, to the amount of soil removal that can be achieved with a dry method.

An alternative to this, is to use rollers with spaced discs, moulded Diablo rollers or star spools – 4 or 5 armed starts in stiff rubber; adjacent banks of stars are staggered, and the action is gentle. Other methods include dry brushes or banks of coil springs, which will be adjustable.

Stone separation may be achieved with a flotation separator. Here, the crop is fed into a water trough, where the crop floats and is transferred out via a conveyor, but the trash (eg stones & heavy clods) sinks and is collected with another conveyor. Output of the machine may be 10-40 t/h, water consumption is negligible (provided a filter screen is used), and the electricity demand for the pump and elevator may be approximately 3kW. See Fig 4.

Washing

It is normal practice to wash many crops to make sure that there is good soil removal. Crops such as potatoes, carrots, parsnips, celery, leeks and fruit - even ornamental stock - often require washing. The barrel washer is a very common piece of equipment; it is similar to the dry rotary barrel cleaner. Washing may be achieved using by deluging or by immersion. The deluge washer uses a cascade of water, from a supply pipe above or inside the barrel. All the soil and water run from the base of the barrel. The immersion type is where the barrel sits partially submerged in a tank. Sometimes there are paddles inside the barrel in order to create agitation and propel the crop. See Fig 5 & Fig 6.

Washer water consumption is given in the table 1. The crop may take 15 minutes to get through the machine, capacity may be 1-50 t/h, and the barrel itself may a galvanised finish or stainless steel.

Table 1

Washer water consumption

Washer type	Water requirements (m^3/t)
Rotary barrel (deluge)	2.7-5.5
Conveyor	3.5-5.5
Conveyor & pre-soak	1.0-2.0
Rotary barrel (immersion)	0.2-0.4

(Balls, R 1986)

Other washers that may be used are the conveyor washer which may be used for delicate crops such as lettuce; here the crop is carried on a perforated conveyor through overhead and/or upwards and sideways water sprays. The pintle roller may be used primarily for potatoes, and is like a dry brush roller with added water sprays. This gives a combined action of water with gentle scrubbing by rollers which removes most soil.

Most of the water used for washing is recirculated, following a period of settling and screening to remove the worst of the dirt it contains. This water might not be fit for cleaning the second time round, but another final wash with clean and treated water suffices.

Drying

This may be necessary with some crops such as potatoes and apples for prepacking, to avoid leading to rot conditions in the pack. Usually, the crop goes across a sponge roller drier. The water is effectively squeezed out of the sponges by a metal roller pressing against the underside of each roller. Typical flow rates for the crop are 7m/min along the drier. Hot air can also be used for drying but the disadvantages of this are long drying conveyors needed and high inputs of air and heat required.

Grading

This involves both the rejection of unsuitable produce, and subdivision of acceptable material into a range of grades (Balls, R 1986). It is essential that the lighting *quality* and *quantity* are specified above any grading lines. The recommended illuminance level (quantity) above a table is 500-700 lux (Balls, R 1986), and this compares with a level of 100-150 lux (Ball, R 1986) for general packhouse illuminance. Artificial light normally consists of fluorescent tubes mounted above the table, and parallel to it. A 2.4m, 125W tube at a height of 0.5m should provide the recommended illuminance over a 0.6m wide table, so two tubes should be regarded as the minimum for a double-sided table (Ball, R 1986).

It is also important to get the spectral quality of the lamp correct, because various crops will appear differently under different lamps. Each crop will ideally have its own spectral requirements, but not many of these have published figures. Tubes commonly come in two or three colours, ‘warm light’, ‘daylight’ or a ‘north light’, so it is essential that a choice is made. Excessive levels of illumination can also be bad, causing eyestrain and wet or shiny produce can be missed.

Light Emitting Diodes (LEDs) are becoming more popular for many applications, including grading purposes. Their main advantages are that they are long lasting (up to 100,000hours), have low maintenance, energy efficient (reduced consumption by up to 80%), dynamic (digitally) colour control, small (design flexibility), directed light (= increased efficiency), robust and vibration proof, instant turn on, no IR/UV radiation, cool beam of light, low voltage and no mercury.

Produce may be graded by:

- Single dimension
- Two dimensions
- Three dimensions
- By weight

Grading by size

(i) Parallel rods/riddle – typically there are three moving mesh conveyors, using the sequential layout method. That is, the gaps between the bars are getting gradually bigger so that, for potatoes, *chats* will be removed first, followed by *smalls* and finally *larges*. In other words, 'oversize' go onto the next stage. Each size is taken off at right angles to the main conveyor. See Fig 7.

(ii) Stacked layout – typically three grids are in this grader, with the largest aperture on the top, then medium size and finally small size at the bottom. The undersize from one section falls onto the next, and the largest sizes are removed first. This action helps to minimise damage done to the smaller sizes. The grader is more compact than the first one, but crop flow is somewhat more contorted. See Fig 8.

(iii) Oscillating riddle/bar screen/mesh – this will only grade in one dimension, but is commonly used for potatoes, onions and various bulbs. It starts off with the smallest apertures, and ends with the largest apertures. The rods may run parallel or at right angles to the direction of travel. The endless screen sizer usually has square holes but round and oval holes may be used. Commonly potatoes, onions, beetroot and Brussels sprouts may be graded using this. This produces grades in two dimensions, with low damage eg less than 10% scuffing, with a throughput of 10-40t/h. Another variation on this is using a spool sorter. This is used to grade potatoes and onions typically. The spool shafts (often diablo type) rotate and convey the crop help the grading action with help also given to cleaning. This will grade in two dimensions. See Fig 9 & Fig 10.

(iv) Diverging roller – this will grade in one dimension only, and is used for roots including potatoes, carrots, parsnips and also tomatoes. The diagram shows two pairs of rollers, producing four sizes (at right angles). Larger varieties have 3-10 rollers sets; one unit with two rollers, would give approximately 1t/h, and has a roller angle of around 10°. Rollers may be either bare steel or coated with plastic. The whole grader slopes downwards towards the discharge end, at around 25-30°. They give lower damage than fixed aperture types; they tend to be more accurate but are more expensive. See Fig 11.

(v) Diverging belt – this grades in one dimension only, is quick and gentle, and is commonly used for Brussels sprouts, carrots, beetroot and onions. Belt is commonly a roller chain with plastic mouldings for the produce to rest on. Alternatively, it may be of nylon construction throughout. The belts diverge from parallel with increasing apertures. Very often, one belt will run faster than the other one in order to rotate the crop for grading more accurately. Otherwise, the crop can end up straddling two or more belts.

(vi) Expanding roller/variable aperture – this has increasing distance between spool shafts as they progress along the conveyor. It has a gentle action, with a multi-sizing ability by altering the cam track or support track angle. It is used for various vegetables and fruit, eg potatoes, swedes and red beet. It is quite a complex grader and more expensive than others. See Fig 12.

(vii) Length grader – this is used typically for carrot grading. It is a riddle with long slots; the crop is channelled along the riddle in its longitudinal direction. It will fall through the slot only when its centre of gravity goes over the edge before its end reached the other side. Consequently it is not very accurate, and the length graded is almost equal to a slot half its length. Multiple sizing may be done with banks of slots of increasing length from the in-feed end. See Fig 13.

Into-store separator

Fig 14 (Pringle, Bishop & Clayton, 2009) shows a layout of machinery that may be utilised for sorting potatoes as they move into storage. It demonstrates the individual processes that are often used in a farm situation.

Fillers

Bag, box and carton filling systems are available using a range of methods to convey produce gently with the minimum of drop. These include 'lowerator' belts, rising base fillers and other zig zag options. High-speed box filling machinery prevents the need for lifting the box and is therefore a safer system to operate. See Fig 15.

Electronic grading

There are several machines on the market that automatically sort vegetables to promote high quality standards and consumer acceptability. These systems have primarily been developed for potato handling, for example the '*Maf Roda'* system from *Tong Peal*. This has been developed to both weight grade and quality sort individual tubers at high capacities, in order to give added value to the crop as well as reducing labour requirements. It has an operating speed of 10 tubers per second per lane, with two, four, six and eight lanes available. Sizing is by weight on electronic weigh cells, and optical grading is by diameter, volume and shape. Camera sorting is achieved by colour and surface defects.

The system is designed to handle potatoes with a diameter from 45-90mm, and it will grade up to sixteen sizes, eight colour bands and four quality grades. All parameters are freely adjustable, corresponding to requirements. It self-adjusts the singulator roller rotation and vee belt pre-aligner speeds according to the average speed of the crop to ensure complete rotation and maximum capacity are achieved.

Palletising and robotics

There are some companies that now offer robotic arm handling functions. These are offered by the 'Haith *Tickhill Group'* and made by '*Kawasaki'*, who is the world leader in robotics. They offer both standard and custom built systems for handling bags, boxes, crates and pallet positioning. The main advantages are given as: tighter more uniform stacks; smoother, faster flow of materials from production to stage (and shipping); reduced handling-related product damage; decreased direct labour costs; fewer lifting-related employee injuries; improved cube utilisation; multi-function gripper; full system design and installation; handles multiple products on one line.

References

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