Description and Costs for Post-Harvest Systems

General Considerations

The following discussion of handling systems for different groups of crops treats each crop as a granular unit and tries to isolate the post-harvest handling aspect of the market farm operation. However, post-harvest handling fits into the larger context of a harvest-wash-pack system on a farm, which fits into the still larger context of markets, labor availability, delivery schedules, and personal and professional goals.

Speed and Capacity

The speed of any function that requires a human operator is very person-dependent. This person-dependency can be mitigated by mechanization, but, in the end, the speed at which the operator feeds in the product and removes the product at the other end ultimately drives the efficiency of an operation. The fastest worker using a manual system will likely get more done than the slowest worker using a mechanized system.

Likewise, not all improvements to post-harvest handling systems make operations go faster on a per-person basis. Some improvements increase the number of people who can engage a job, thereby increasing efficiency by allowing for more product to flow through an existing system, while not increasing per-person capacity.

Product Form and Fit

When making choices about adding new products to a system with any degree of mechanization, a producer should consider how well the form of the product will fit with the machinery and tools already present, in addition to the market that exists. A grower utilizing a barrel washer to wash carrots may find increased efficiencies when she adds bulk beets, but bunched beets would require an entirely new system of handling.

Evaluating Costs

The costs presented throughout this document are based on delivered cost—but the prices quoted by a dealer or paid at auction only represent the cost of getting the equipment into your farmyard on a pallet. Assembling machinery and installing it in your packing facility almost always takes a significant amount of time and expense. Producers should take into account the time and money it might take to put a new tool into service in their operation.

Bunched Greens

The primary consideration in the post-harvest handling of bunched greens is rapid cooling and re-hydration of the product, normally accomplished either by

hydrocooling alone or in combination with package icing. Handling speed seems to be a function of personnel and size of the tanks, with larger tanks facilitating more rapid packing of crops.

The standard protocol on very large, commercial vegetable operations for rapid cooling and re-hydration of harvested product is a combination of hydrocooling and, where the crops are suited, liquid icing of the product. In large scale hydrocooling, a pump moves chilled water into contact with warm produce. The warmed water is then re-cooled and recycled. Since water removes heat from produce fifteen times faster than air, this method provides rapid cooling, although the wetting of some products can promote the growth of decay organisms.

For crops that can tolerate top icing, large, commercial vegetable operations will supplement or replace hydrocooling with the addition of crushed ice or a slurry of crushed ice and water that is pumped into open containers traveling along a conveyor under an injection nozzle.

On Upper Midwest market farms, hydrocooling takes place by moving the product through tanks of water. Larger market farms handle enough product to warrant investment in an ice machine for additional cooling and quality maintenance. The low level of mechanization means that the speed of the operation depends heavily on the personnel conducting it.

Water Tanks

Plastic livestock watering tanks, most often those manufactured by Rubbermaid, were used for hydrocooling bunched greens on the three farms included in this study. The plastic tanks, generally rectangular with rounded ends, have rounded edges and corners that facilitate easy rinsing of field dirt. Drains on these tanks are typically located on the long about one inch above the floor, and open and close by means of a threaded plug.

Most workers can easily move tanks sized up to 100 gallons. Because the drains on these tanks are typically located about one inch above the floor of the tank, workers still need to tip tanks over to completely change the water and clean any soil from the tank.

Fifty-gallon tanks do not provide much depth to keep product away from the settling dirt, but they do empty and fill relatively quickly. One-hundred-gallon tanks have the same footprint as the fifty-gallon tank, but provide more depth, as well as additional water to buffer the temperature changes. Tanks up to 100 gallons seem most suitable for a farm handling up to 500 bunches of greens per day, and the tanks facilitate handling up to 150 bunches per labor hour.

With two 180-gallon tanks, Gardens of Eagan reported handling up to 600 bunches of greens per labor hour. Two tanks enable alternate filling and draining, eliminating downtime for the workers. Gardens of Eagan modified their tanks by adding a two-inch PVC drain in the center of the bottom of the tank. The drains open and close by means of a ball valve.

For proper ergonomics, stock tanks of all sizes need to be elevated off of the floor. For tanks up to 100 gallons, plastic totes, wooden crates, sawhorses, and overturned tanks provide adequate support to prevent sagging. For their 180-gallon tanks, Gardens of Eagan welded racks with supporting crosspieces to position the tanks and prevent sagging. The racks also facilitated the location of the drain on the bottom of the tank.

Several Upper Midwest market farms use dairy bulk tanks for hydrocooling. Typically run without refrigeration, these tanks have the advantage of large-size, seamless, stainless steel construction, as well as a drain positioned at the bottom edge in such a way as to facilitate complete drainage of water and solids.

The size and number of tanks to buy will depend on the flexibility needed in an operation, the rate at which tanks can be filled, and the number of units processed through them. In addition to bunched greens, Upper Midwest market farmers use bulk water tanks for handling peppers, cucumbers, bunched roots, and bulk salad greens, as well as pre-soaking bunched roots.

Drainage racks provide an intermediate step between hydrocooling and packing the bunched greens, and are typically constructed of a wood frame with galvanized hardware cloth for a screen. Hog's Back Farm's use of PolyMax panels on their work tables provided an easily-cleaned option, although they did not use a drainage step in their process.

Ice Machine

The decision about whether to add ice to bunched greens will depend on the demands of the market place, since an ice machine serves to improve the quality and shelf life of produce, not to speed its handling. In addition to bunched greens, many other crops benefit from top icing, including asparagus, broccoli, cantaloupes, carrots, cauliflower, green onions, and sweet corn.

Upper Midwest market farmers use chipped and shaved ice to further cool and rehydrate produce. The cost of liquid or slurry ice would generally prove prohibitive to market growers. Ice provides cooling as well as a moisture shield for produce. It may find an additional use as an aid to displays at roadside stands and farmers markets.

Ice machines consist of a refrigeration system, an ice-making mechanism, and an insulated bin. They must be hooked up to a water supply system. The insulated bin for collection of the ice may be separate or integral, and additional bins may be purchased or manufactured. Gardens of Eagan scoops ice from their integral bin into two supplemental, wheeled bins for storage in their walk-in cooler, as well as optimal positioning for adding ice to boxes of produce.

Machine capacity is measured in pounds of ice made per day. Flaked ice stores well for several days in insulated bins in a 34°F cooler. Extension publications cite needs of approximately sixteen pounds of ice for each twenty-pound

carton of broccoli. In practice, Gardens of Eagan uses about five pounds of ice per case, probably due to the very-local nature of their sales and high turnover in the stores they sell to, since they deliver three times each week. Featherstone Fruits and Vegetables felt that "you can't have too much ice for broccoli." Precise data and calculations for ice requirements can be found at: http://www.bae.ncsu.edu/programs/extension/publicat/postharv/ag-414-5/.

Ice machines produce a substantial amount of heat, which may be taken into account when positioning them. Featherstone Fruits and Vegetables has decided to move their ice machines outside of the temperature-controlled packing area, and to use a stainless steel chute to move the ice into that room.

Ice machines require frequent cleaning and sanitizing, and have similar maintenance issues to commercial refrigeration units. These factors should be taken into account when considering an investment in an ice machine.

Scale and Costs

Up to 500 bunches per day:

2 100-gallon Rubbermaid-style livestock watering tanks - $150

Over 500 bunches per day:

2 180-gallon Rubbermaid-style livestock watering tanks - $280

2 welded stands - $100

2 homemade PVC drains - $30

Ice machine prices depend heavily on the amount of ice needed.

Tender Crops

As a category, tender crops cover a wide variety of produce. Specifically included here are peppers, winter squash, and cucumbers. Tomatoes, zucchini, and summer squash, as crops that require very gentle and very specialized handling, were specifically excluded.

On large, commercial operations, a water dump seems to be the most common method for removing dirt and dust, and, in the case of cucumbers, any remaining blossoms. In regions where contamination from wet soil does not present a problem for crop quality, field packing is a common practice. Hydrocooling is not normally a consideration for these crops, all of which prefer storage temperatures above 40°F.

Small-scale Upper Midwest market farms will handle these crops using a water dump, although a number of techniques and tools can increase the speed of this operation. Large operations in the Upper Midwest typically invest in a brush washer. The tools surrounding the infeed and outfeed operation of the brush washer typically expand the functionality and capacity of that tool on larger farms.

Removing excess moisture from the surface of these fruiting crops is extremely important to prevent decay. Where fruits touch each other in storage, water will not evaporate and will provide a point for fungal germination and bacterial growth.

Manual Handling

Manual handling typically relies on some sort of water dump to remove dirt and dust. The most basic tool is a water tank. Workers on various farms use a selection of clean cloths, burlap sacks, and cotton gloves to increase the speed of scrubbing, if necessary.

Mesh bags provide a mechanism on small farms to batch process crops such as peppers and cucumbers. The bags also provide a way to increase agitation for the removal of mud from crops. Workers hold one top corner of the bag in each hand, submerge the produce, and shake and swish the bag in the water to scrub the vegetables against each other. The entire bag is then removed and dumped onto a sorting table or drying screen.

Submerging peppers provides an opportunity to control for corn borer damage, considered by Upper Midwest market farmers to be the most common blemish that renders the fruit unusable. Damaged peppers take on water and sink to the bottom of the tank.

Winter squash must be handled more gently to avoid damage. At Spring Hill Community Farm workers clean the squash in the field using a burlap sack to removed dried-on dirt. Other manual cleaning methods include dunking individual fruits into a bucket or tank of water, scrubbing with a cloth or cotton glove to remove soil, and then drying with a towel to prevent decay.

The Brush Washer

Linda Halley, Gardens of Eagan, said “If you have two crops to put through a brush washer, then as soon as you can afford it, buy one, regardless of the scale of your operation.”

A brush washer, as part of a vegetable wash line, is perhaps the most versatile and most widely-used piece of post-harvest handling equipment on small vegetable farms in the Upper Midwest. A series of ten rotating brushes move produce through a water spray, scrubbing and rinsing dirt away from the product.

A vegetable wash line can include multiple components, in addition to the basic washing unit. An in-feed belt provides a space to dump totes or large bins of produce and pre-sort any obvious culls before they are conveyed into the brush washer; neither Gardens of Eagan nor Hog’s Back Farm uses this addition, instead feeding produce into the brush washer by hand. Hog’s Back Farm has a dedicated table for staging totes of produce, while Gardens of Eagan uses overturned plastic totes. Gardens of Eagan had purchased an in-feed belt when they acquired the brush washer, but no longer uses it.

After product has been cleaned by the washer, it proceeds to the out-feed system. Most commonly, the first step is a series of foam "donut" rollers, referred to as an "absorber," that squeegee water off of the produce, removing surface moisture that can promote fungal and bacterial growth. A kicker brush moves the produce on to the next piece of equipment in the line. Hog's Back Farm did not have an absorber, but planned to make that investment in the near future.

From the donuts, produce may move onto optional sizers. Belt sizers are three feet long and grades one size onto a side packing table or side conveyor for packaging. A punched conveyor belt moves the produce from one sizer to the next, allowing produce that fits through the sizer to fall through to the side packing area. One or more sizers may be in use. Produce not captured by the sizers moves to the main packing table.

The packing table may be a homemade tray slanting away from the brush washer. Models sold with the wash line are round and have a rotating table to move produce out of the way of further produce coming off the line, as well as to move product in front of multiple packers. A low rail keeps produce from falling off of the packing table.

A single motor normally powers the in-feed belt, the washer, the absorber, and the sizing belts. The round sorting table is powered by its own motor. Mid-sized machines use about one and a half gallons of water per minute.

In addition to tender crops, Upper Midwest market growers use brush washers to clean round root crops, tomatoes, and potatoes. Brush washers can also be used on fruit crops such as apples.

Speed of handling is generally increased by using more people on the line. At Gardens of Eagan, one person feeding the machine can keep up with two workers packing; at Hog's Back Farm, one worker feeds while a single worker packs. While even the smallest machines are rated at 100 bushels per hour, growers in this project reported speeds of around twenty bushels per labor hour with two or three workers operating the machine.

Used machines are available, but not recommended as brush washers tend to show wear quickly.

Scale and Costs

1 bushel of peppers = 25 pounds; 1 bushel of squash = 35 pounds; 1 bushel of cucumbers = 48 pounds.

Up to 10 bushels per day:

2 100-gallon Rubbermaid-style livestock watering tanks - $150

5 mesh bags for gentle agitation - $25

Over 10 bushels per day:

16 inch brush washer - $1200

Absorber - $741

5 feet rotary packing table - $870

(optional) 4 feet in-feed belt - $548

Dry-Cured Alliums

Dry-cured alliums include sweet, red, and yellow onions, as well as garlic and shallots. These crops all require a "curing" step after harvest to seal the leaf tissue that makes up the bulb against moisture loss and entrance by pathological organisms. In addition, dirt, loose skin, tops, and roots must be removed prior to sale.

Large, commercial operations use a variety of machines for removing scales from the bulbs, but these are not widely available for farms not operating in major onion-producing areas.

Diversified Upper Midwest market farms use a variety of innovative techniques for accomplishing these tasks using manual labor. Larger, diversified operations frequently invest in a roller topper to achieve the desired result with large table onions. Shallots and garlic are almost all cleaned by hand.

Curing

Onion and garlic bulbs are made up of leaf tissue, a part of the plant designed to transpire water obtained from the roots. As onions and garlic reach maturity, the outer leaves senesce, forming a dry layer that prevents this transpiration process. At harvest, growers take steps to fully dry the outer layer and seal the neck of the bulb and the leave pores against water loss and the invasion of disease-causing bacteria and fungi.

Most diversified Upper Midwest market farmers do not have specialized curing systems, instead putting crates or bins in an unused transplant-production greenhouse, or spreading the onions in a single layer on greenhouse benches. Portable barn fans are used to circulate air and promote drying.

Some farmers have developed specialized systems for curing onions by forcing air through the onions in a manner similar to that used in grain bins. Heating the air can reduce drying time and help to cope with wet periods that are not uncommon during the Upper Midwest onion harvest. At Common Harvest Farm in Osceola, Wisconsin, farmer Dan Guenthner uses a squirrel-cage fan to force air into a plenum under mesh benches in a pre-existing outbuilding. At Rock Spring Farm in Decorah, Iowa, the author, Chris Blanchard, uses a Sunderman Manufacturing greenhouse heater with a squirrel cage fan to force heated air into a plenum under stacked trays of onions and shallots.

Thorough curing greatly eases and speeds the removal of dirt, loose skin, tops, and roots. When removing dried alliums from refrigerated storage, condensation can cause the skins to soften and become difficult to clean.

Manual Cleaning

The most common method for removing the loose skin and roots of onions, shallots, and garlic is for workers to rub the bulbs between their hands. A number of inexpensive aids can facilitate the process and increase speed and effectiveness.

Because direct fresh-market sales, whether to stores, CSAs, or farmers markets, place a high value on earliness, growers frequently begin to process cured alliums before the curing process is fully complete. At this stage, the loose skins can be quite difficult to remove. A well-wrung kitchen towel can help add friction to slip the skins off at this stage, according to Hog's Back Farm's David Van Eeckhout.

When skins are fully cured, nitrile surgical gloves and cotton gloves with vinyl dots can help to "pop" the skins off by applying pressure while moving the hands across the bulb.

Sharp bypass pruners can cut the tops off of hardneck garlic bulbs without crushing the stem.

Roller Topper

A roller topper consists of multiple pairs of longitudinal rollers that rip the necks and skins from fully-cured onions. The rollers have metal ridges that corkscrew down the length of the cylinder. The ridges on alternate rollers corkscrew in opposite directions, and alternate rollers rotate in opposite directions, resulting in a gripping and ripping action that moves the onions down the length of the sloped topping bed.

The rotation of the rollers bounces the onions around quite severely, so only very hard varieties should be cleaned in this way, and only just before sale. This piece of equipment is only suitable for use on round onions. Driftless Organics uses their roller topper to pre-clean yellow and red storage onions, then uses manual cleaning to achieve a finished product.

Market garden machines can be obtained on the used market and typically consist of two sets of four-foot long rollers. These are undoubtedly the most dangerous piece of packing shed equipment considered here, and their use should be carefully considered on farms with young or unskilled workers.

Scale and Costs

Time data was not collected for the different onion-cleaning options, so no specific recommendations are made here. A return on investment analysis should provide reliable information.

For Manual Cleaning:

Vinyl-dot gloves - $12 for a pack of 10

Mechanical Cleaning:

Used Roller Topper, 2 lines - $1150

Bulk Roots and Tubers

The removal of soil from bulk roots and tubers provides one of the primary means of quality differentiation for this group of crops. Crops are topped prior to storage and washed using a combination of scrubbing action and pressurized water.

The cleaning methods used by Upper Midwest market farmers resemble those used on very large, commercial operations in their methods, if not their scale. Barrel washers and brush washers, similar to those used by market farmers, predominate on large operations.

On market farms that have not made the investment in mechanization, root washing takes place in a variety of innovative ways, either through pressurized water or agitation in a tank of water.

Manual Root Washing

At a very small scale, most market farmers choose to use a tray and a hose to wash roots. By attaching an inexpensive shut-off valve to the hose, a pressurized spray can be achieved by closing it part way, similar to putting one's thumb over the end of the hose.

A logical next step might be to substitute an electric pressure washer for the hose and shutoff. Variable pressure is important to adjust for different roots; carrots and beets can withstand higher pressure for faster cleaning than can crops such as daikon radishes. By shortening the wand and twist-tying the trigger into the open position, the wand can be placed over the shoulder, rather than supported in the style of a gun. This technique also increases the distance between the nozzle of the gun and the crop being washed. Using this technique, 100 to 300 pounds of roots may be washed per labor hour. Beets and turnips wash up easily twice as fast as carrots and celeriac. Rock Spring Farm uses a 2000 PSI, 1.5 GPM model with adjustable pressure.

A less expensive and less skill-dependent method involves the use of a mesh bag to vigorously agitate roots in a 100-gallon Rubbermaid-style tub filled with water. Workers hold one top corner of the bag in each hand, submerge the produce, and shake and swish the bag in the water to scrub the vegetables against each other. The entire bag is then removed and dumped onto a sorting table or drying screen. Hog's Back Farm reports rates of about 140 pounds per labor hour using this method.

Brush Washer

A brush washer makes a versatile addition to a packing operation for root crops, since it will gently wash beets, turnips, and winter radishes. Carrots and daikon radishes tend to "skate" through without getting rolled around by the brushes. Celeriac does not get adequate soaking and agitation to clean the convoluted roots.

Extra soiling on root crops, as compared to the tender fruit crops discussed previously, may make pre-soaking desirable in certain circumstances. Hosing down bins or totes of produce can improve the performance of the brush washer. In especially muddy conditions, an in-feed belt makes an additional rinsing step easier.

For root crops, a brush washer will clean about 300 pounds of roots per labor hour.

Barrel Washer

When it comes to washing roots, the barrel washer is the king of packing equipment. Made of wood or metal, a motor-driven barrel rotates to agitate roots in a bath or shower of water. Roots work their way through the barrel by the addition of dirty roots at one end and the tendency of the roots to spread out in the barrel.

Two basic barrel designs are found on Upper Midwest market farms. In the one most common at the smaller end of the scale, a copper pipe with small holes in it runs lengthwise through a thirty-inch wide, eight-foot long wooden barrel. Water running through this pipe is pressurized through the holes, while the rotation of the barrel causes up to 250 pounds of roots to slide up the walls of the barrel and back down again, creating a scrubbing action between individual roots. The barrel is supported by a frame with casters on the hoops of the barrel. A small electric motor drives the rotation of the barrel by means of a sprocket and chain.

At a slightly larger scale, a second type of barrel is more common. Rather than using pressurized water from a pipe, the barrel sits in a tank of water. Paddles running the length of the barrel lift the roots up and drop them back down into the water. While both types of barrel washer can bruise tender roots such as turnips and winter radishes, the paddle-style washer does much more damage.

Speed of operation is determined by the capacity of the washer. The smaller, smooth-walled barrel washer holds up to about 250 pound of roots, while the paddle-style barrels can hold much more. The rate at which roots go through, and how clean they get, is determined by how fast roots are added at the in-feed end. With both styles of washer, a gate on the out-feed end keeps a batch of roots tumbling in the washer until they are clean. At Rock Spring Farm, the author uses a smooth-walled barrel washer to clean 500 pounds of roots per labor hour.

Some growers use an additional manually-controlled application of pressurized water at the out-feed to further polish the product.

With both a brush washer and a barrel washer, Linda Halley notes that in her previous experience, carrots, rutabagas, beets, and celeriac were handled with the barrel washer, while turnips and winter radishes were best handled with a brush washer.

Scale and Costs

Up to 500 pounds of roots per day:

2 100-gallon Rubbermaid-style livestock watering tanks - $120

5 mesh bags for agitation - $25

-or-

Variable pressure pressure washer - $630

Over 500 pounds of roots per day:

Smooth-walled barrel washer - $2300

(optional) Variable pressure pressure washer - $630

Baby Salad Greens

For the purpose of this study, salad greens includes the common mixed greens sold as "spring mix" or "mesclun," as well as loose-leaf spinach and arugula. In general, the harvested leaves "fit on a fork," (known at Rock Spring Farm by its acronym, FOAF) and are presented to customers as a ready-to-eat product, whether farms advertise it as such or not.

The primary considerations in the post-harvest handling of salad greens are the rapid cooling of the product and removing water from the surface of the leaves. Handling efficiency seems to be a function of personnel, with the size of washing tanks a minor consideration. The spinners used for drying can present a bottleneck in the operation.

Large, commercial operations utilize a wash line and conveyor belt system, moving the leaves through a series of wash tanks to cool the crop and remove grit. Visual inspection removes contaminants such as weeds or rotten leaves as the produce moves through the line.

On Upper Midwest market farms, the most common method for cooling and cleaning is to submerge the greens in a tank of water using a tray or bag, then to mix the different ingredients or do a final rinse in a larger tank. Most operations use a clothes washing machine set to the spin cycle to remove standing water from the leaves. The low level of mechanization means that the speed of the operation and the gentleness of the handling depend heavily on the speed and care of the personnel conducting it.

Many farms have moved away from the production of salad greens because prices have declined or failed to increase with the cost of production. Smaller CSA operations limited their offerings of salad greens, while mid-sized operations universally felt they could do better, but did not have much motivation to improve this area of production.

Bags and Trays for Initial Rinsing

On the surveyed farms, greens are harvested into a variety of containers, which determine the way in which the initial rinsing is managed.

At Rock Spring Farm, salad greens are harvested into wooden bushel crates lined with a mesh liner. Farmer Chris Blanchard notes that lining the crates isn't very efficient, but he has the red mesh bags on hand and the wooden crates are the only harvest containers currently in use at Rock Spring Farm. After harvesting, the bags of greens are weighed and folder over at the top, then transported to the packing house. At the packing house, bags are dunked in a 100-gallon plastic tank, then palletized and put into the cooler until the packing crew is ready for the final rinse and mixing, which happens in a 300-gallon dairy bulk tank.

At Hog's Back Farm, greens are harvested into ventilated plastic totes. Greens are poured into 100-gallon tubs of water, then transferred into a second tank using a bulb tray, then removed into a hand-cranked salad spinner. Hog's Back Farm has moved to delivering salad greens only twice over the course of their summer shares.

Featherstone Farm forgoes the initial rinsing step, moving salad greens directly from harvest totes into large tanks of water.

At Driftless Organics, salad greens are washed using black bulb trays. Greens are placed in one tray, another tray placed on top of that, and the whole thing swished around in the tank to remove any field dirt. In cases of weedy crops or questionable quality, washed greens are sorted at a table by pouring from one tray into another and picking out the cull leaves and plants.

For mixing greens or washing bulk in large tanks, it is essential to handle the greens gently. At Rock Spring Farm, workers slide their hands into the tank of greens and use a circular motion underneath the greens to agitate and blend the leaves. The goal is to use the water instead of the hands to mix and move the product.

Spin Dry

To increase the storage life of baby salad greens, it is essential to remove almost all of the water from the surface of the leaves. All of the surveyed farms accomplish this by means of some sort of spinner.

The most common spinner on Midwest vegetable farms is used clothes washing machines. Only the spin cycle is used, typically for about forty-five seconds. The best practice is to monitor the outflow and turn off the spinner when

water ceases flowing. With enamel paint on the exterior and an enameled or stainless steel basket, these have food-safe food contact surfaces.

Every grower visited uses mesh bags to hold the greens. These bags provide for ease and gentleness of transfer. About six pounds of greens are dried in each batch, usually in two bags to balance the machine.

Hog's Back Farm, which grows only two crops of salad greens each year, uses a five-gallon, hand-cranked Dynamic Salad Spinner. With a removable basket, this spinner can handle about three pounds of greens and takes about one minute to completely dry the greens. Rock Spring Farm used the same machine before upgrading to a washing machine.

Greens removed in mesh bags can be stockpiled to await spinning. According to growers, baby greens should not remain in the water for more than about twenty minutes.

For winter greens production, it is important to note that water frozen in the washing machine takes an extraordinarily long time to dry out. At Rock Spring Farm, the author was always grateful to have the Dynamic Salad Spinner as a backup device.

Overall washing speeds ranged from twenty to fifty pounds per labor hour.

Scale and Costs

The growers surveyed for this project all produced eighty to 100 pounds of salad mix each day that they packed it. The largest farms were packing salad mix up to four times each week, while the smallest packed it just one time each week.

None of the growers visited was entirely happy with their handling setup for salad mix.

The author used a hybrid system of Driftless-style bulb tray rinsing and bulk tank mixing on a farm where he worked in the mid-1990s. With this system he washed up to 200 pounds of salad mix in a day using a 400-gallon stainless steel bulk tank. At Rock Spring Farm, in the mid-2000s, 150 pounds of salad mix was washed daily. At larger volumes, speed and equipment remain the same, but greens are processed in multiple batches. Larger final wash tanks allow for more settling of sediment.

Scale and Costs

Up to 100 pounds per day:

2 100-gallon Rubbermaid-style livestock watering tanks - $150

1 used washing machine - $20 *or* 5-gallon Dynamic Salad Spinner (manual) - $240

20 mesh bags - $100

100 – 250 pounds per day

1 100-gallon Rubbermaid-style livestock watering tank - $75

1 used washing machine - $20

1 300-gallon Rubbermaid-style stock tank or used stainless steel tank - $300

Beans and Peas

The overriding consideration for the post-harvest handling of beans and peas is rapid cooling. Excessive moisture can promote rapid breakdown, especially with beans.

On large, commercial operations, hydrocooling is common. However, wetting the pods can promote spoilage unless the water is treated to prevent the growth of fungus. A variety of sorting and grading tables are the most common method for grading, since crops tend to be mechanically harvested. Beans and peas are packed into well-ventilated containers, such as wooden crates or mesh bags.

In the Upper Midwest, none of the visited farms used machinery to grade beans or peas. Because all of the visited farms harvested by hand, there was a feeling that quality was close to adequate when product came into the packing shed. Use of hydrocooling versus forced air cooling was independent of the scale of the operation.

Air Cooling

For air cooling, well-ventilated containers are critical. Regardless of the actual harvest containers used—visited farms used five-gallon buckets or plastic-lined bushel baskets—most farms used well-ventilated plastic totes for initial storage in the cooler. Pallet bags or individual bags were added after the initial removal of field heat to preserve humidity.

Hydrocooling

About half of the farms visited hydrocooled beans and peas using a water bath in a bulk tank. Beans and peas were removed from the water bath using mesh bags or ventilated containers. At Rock Spring Farm, a fishing net is used to scoop the last beans out of the tank.

Peracetic acid, as found in the commonly-used organically approved water additive Tsunami 100, has been noted to cause peas to turn rusty. This creates a conundrum for organic growers wanting to use hydrocooling, since moisture on the peas promotes breakdown.

Sorting

Since all of the farms visited relied on manual harvest for their beans and peas, sorting needs were limited. The farms that used hydrocooling also use that step for quality control.

At Featherstone Fruits and Vegetables, poor harvest conditions occasionally resulted in a need to conduct more rigorous quality control sorting. To do this, butcher paper of the sort available at an office supply store is rolled out on eight-foot plastic banquet tables. Washed peas and beans are poured out on the butcher paper and moved down the paper by hand. The waxy coating provides a food-safe surface and allows the product to slide easily down the table, where it is re-containerized for cooling.

Scale and Costs

Because the hydrocooling and air cooling operations do not use any machinery, the labor efficiency of the process is entirely dependent on the speed and motivation of the labor crew.

Up to 20 bushels (600 pounds of beans)

Visited farms picked and packed up to 600 pounds of beans in a day using the methods described above.

Folding Banquet Table – $170 to $300, depending on quality.

Broccoli, Cauliflower, and Cabbage

For the brassica family of crops, rapid cooling and the maintenance of cold and humidity are the primary post-harvest concerns, normally addressed by package icing or hydrocooling. Because it is largely a manual process, handling speed is a function of personnel and equipment capacity.

Rapid cooling is not as much of a concern for cabbage.

For large, commercial operations, most broccoli and cauliflower is field packed directly into cartons. Mechanical cutters and banders are used to bundle the broccoli, which is packed immediately. Ice and liquid ice, combined with forced air cooling, are the primary methods for removing field heat and rapidly cooling to the desired temperature.

Most Midwest market farms do not bunch broccoli, although some do. It is more common on truck farms to produce larger heads of broccoli grown on a wider spacing than that used in large-scale commercial production. Broccoli is either

hydrocooled or top-iced. Cauliflower is most often air-cooled, unless it has insect frass on it.

Hydrocooling

At Hog's Back, Spring Hill, and Rock Spring Farm, broccoli is brought in from the field in totes or crates and hydrocooled in plastic or stainless steel bulk tanks. David Van Eeckhout notes that at Hog's Back Farm, "We don't dump the broccoli, we *transfer* it into the tanks." David leaves the broccoli in the tank for a full fifteen minutes to remove the field heat.

Soaking broccoli has the additional advantage of dislodging cabbage worms if they are present.

Cauliflower is handled more gently. Most of the surveyed growers are not hydrocooling it, because cauliflower bruises more easily than broccoli. A plastic brush can be used with a water bath to remove frass, if necessary.

Cabbage does not get hydrocooled.

Top Icing

At Gardens of Eagan, broccoli is harvested into field totes and placed into a shaded field truck. The truck is backed up to the packing shed and the broccoli is moved directly into labeled boxes. The boxes are set open on a pallet, one layer at a time. Five pounds of ice is scooped into each box, and then the layer of boxes is closed and another placed on top. One worker can process about thirty-five-to-twenty-pound cases per hour in this process.

Bunching

At Featherstone Fruits and Vegetables, broccoli is harvested into totes and then poured into a bin in the field. The bins get hosed down to rinse and hydrocool when they come in from the field, then six inches of ice nuggets are spread over the top in an ice cap. The broccoli is left in the cooler overnight to chill through, then a crew of four people works to bunch the heads.

A crew of two people work to pull the broccoli out of the bins and put it in appropriately-sized bunches. Another worker manages the pneumatic broccoli buncher. A rubber band is placed on metal fingers that stretch the rubber band, then two to four stalks of broccoli are placed in the mechanism, and a switch is triggered causing the broccoli stems to be cut to a uniform length and the rubber band to be applied. A fourth worker packs the cases and applies the ice.

For bunching broccoli, Featherstone packs about twenty twenty-pound cases each hour with a crew of four people. Bunching broccoli provides some flexibility in harvest timing, since multiple small heads can be combined to meet demand prior to full maturity of the crop.

Cabbage

Cabbage was handled manually at all of the visited farms, by trimming the stems with a sharp knife and peeling leaves. The speed of this operation is entirely dependent on the efficiency of the workers and the quality of the crop.

Scale and Costs

Up to 300 pounds per week

1 – 2 180-gallon Rubbermaid-style livestock watering tanks - $140

Over 300 pounds per week

Ice machine prices depend heavily on the amount of ice needed.

Automatic Buncher/Cutter - $300 used (only necessary if the market demands bunched broccoli)

Tomatoes

The primary considerations in the post-harvest handling of tomatoes are to avoid damage from handling and to control the ripening process of the fruit. Rough handling results in both visible and latent damage. Some dust may need to be removed from the fruit as well.

Large commercial operations harvest fresh market tomatoes at a mature green stage and use controlled atmosphere and ethylene gas to control ripening. Pack lines sort by size and provide a belt for grading and sorting the tomatoes according to ripeness. A slow roller conveyor that slowly turns each tomato provides an opportunity to inspect thoroughly for defects. A brush washer using very soft brushes and a small amount of water may be used to remove dust and foreign material.

Upper Midwest tomato market farms rely on hand sorting and modest temperature control to grade and prepare tomatoes for market. None of the surveyed farms uses a mechanical washer or grader of any kind. All of the farms were using some sort of manual wiping to remove dust and contaminants.

Harvest and Packing Practices

To a large degree, harvest practices determine the necessary post-harvest handling steps. Operations selling primarily through a CSA were more likely to sort tomatoes for ripeness in the field, while operations selling through wholesale markets had developed more sophisticated systems for grading tomatoes by ripeness.

Spring Hill Community Farm harvests all of their tomatoes at the “red” stage (90% or more red) and packs them into CSA shares the same day. Stems are

popped in the field, and no sorting happens except as the tomatoes are packed into CSA shares.

At Hog's Back Farm, tomatoes are harvested once each week, on Tuesdays for Thursdays delivery, and sorted and graded in the field into oranges, reds, and over-ripes. The tomatoes are allowed to sit for a day to expose any latent problems before packing. Two workers harvest the tomatoes, and David, the farmer, does the sorting. Two thousand tomatoes (600 to 800 pounds) takes three people a little under four hours to harvest and pack.

At Gardens of Eagan, tomatoes are harvested twice a week, still showing a hint of green. This stage is known as "pink" in the tomato industry. Workers harvest using white cotton gloves and remove the calyx in the field. Packing may happen in the field or in the packing shed, depending on quality. A large, laminated table in the packing shed provides space for grading. Tomatoes are graded according to the needs of different buyers.

Featherstone Fruits and Vegetables harvests tomatoes at the breaker stage and brings them into their temperature-controlled packing area to cool them down to fifty-eight degrees. Tomatoes are harvested in the afternoon and cooled overnight. In the morning, using a packing list, two workers use an ad hoc arrangement of plastic tables in the temperature-controlled room to pack out of harvest totes into boxes. A rag is used to remove dirt. It takes about ninety minutes to grade and pack 800 pounds of tomatoes. Packing in the cool room prevents condensation on the tomatoes and makes it possible to harvest tomatoes before orders are received.

Scale and Costs

The major difference in cost at different scales of production seems to be in handling systems rather than equipment, and the equipment needed does not vary according to scale. At a minimum, food-safe tables should be available for sorting.

Folding Banquet Table – $170 to $300, depending on quality.