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Considerations for Harvesting and Storage of Vegetables and Fruits in The Guatemala Highlands

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Prepared for the
U.S. Agency for International Development,
Guatemala

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CONSIDERATIONS FOR HARVESTING AND STORAGE OF VEGETABLES AND FRUITS IN THE GUATEMALA UPLANDS

INTRODUCTION

USAID/Guatemala sponsors projects to assist small farmers in the Guatemala highlands and improve their production techniques. As a part of these efforts, the project leader requested the specialized assistance of consultants to provide input and expertise regarding certain aspects of the project. The harvesting and storage of vegetables and fruits in the western highlands is an area of expertise for which assistance was requested and provided through the Postharvest Institute of Perishables, an institute of the University of Idaho's College of Agriculture. Through the auspices of the institute, two consultants, Mr. Alton F. Robertson, P.E. and Dr. David Creech were retained to accomplish several aspects relating to the above project.

This report summarizes the activities of the consultants during a field visit to the Guatemala highlands from October 28 to November 10, 1984. It includes recommendations for improvement to harvesting and storage techniques based upon observations made during that field trip. The information describing present methods as well as optimum circumstances and specific recommendations are included and will be made a part of a seminar on that subject which is to be conducted in the spring of 1985.

Background

The Small Farms Diversification Project of USAID is headquartered at Quetzaltenango in the western highlands of Guatemala. The project is aimed at enhancing the diversification of the crop production practices in the Region 1 area. The switch from essentially subsistence forms of agriculture to a "cash crop" basis has already impacted on the region. The five member USAID team includes a fruit specialist, Len Wooten, a vegetable production specialist, John Fitzgerald, an animal scientist, John Diel, an ag economist, Gary Smith, and the project director, Bill Ross.

The climate and soils of many of the valleys that dissect the region contain a wide variety of microclimes that make fruit and vegetable adaptation studies difficult. Tropical and semitropical highlands are often characterized by abrupt changes in temperature and precipitation within short distances. The western Guatemalan highlands are no different. A rainy summer and early fall tendency is prevalent throughout Region 1, but there are marked differences in degree-day accumulations and chilling-hour accumulation throughout the region. An extended dry and cool period is predominant during October to March. With valley slope and valley floor farms and this region's climate, it would be difficult to "predict" what fruit and vegetable varieties and what practices would do well except within a limited area. Move a mile and the horticultural picture would be different.

In spite of this lack of climatic precision, some general observations can be made. The history of vegetable and fruit production in this region has been long enough to "weed out" many unsuccessful varieties and practices. The general good health of the majority of vegetable farms is testimony enough to the potential in the area. While the general climate might be somewhat inhospitable to many temperate fruits, a wide area can successfully grow stone and pome fruits. Production constraints are not prohibitive to high quality cool-season vegetable production. Variety trials being undertaken by John Fitzgerald and his Guatemalan DIGESA counterpart in 12 sites should go a long way to defining vegetable growing parameters.

The temperate fruit production picture is made extremely difficult because of rainy summers and a lack of sunlight needed to color the fruit properly. This is particularly burdensome to the apple grower who must endure a long-scheduled spray program to produce scab free apples. Other temperate fruits are grown and have potential particularly if the correct variety is chosen and a conscientious care and culture program is initiated.

Purpose and Scope

The purpose of this project is to suggest methods by which farm level storage and harvesting of fruits and vegetables in the western uplands of Guatemala can be improved. The suggestions advanced by the authors are based

upon a broad base of knowledge about the general techniques involved and upon their personal observations of the techniques currently being used in the country. Care has been taken to insure that the suggestions are adaptable with the social and economic structure existing on the highlands farm. Because the time available for this consultancy was limited, the scope is directed to a general commentary about harvesting and storage techniques for vegetables and a similar treatment for several fruits.

The fruits that were of greatest interest are apples and peaches. The vegetables included a range of currently produced truck crops. Recommendations about harvesting and storage of these fruits and vegetables are generally limited to current applicable practices on conventional farms in appropriate sections of the United States. Those harvesting and storage techniques were taken as optimum although it is recognized that more advanced techniques may be available.

The recommendations presented in this report do not represent a comprehensive review of all aspects but rather are intended to provide guidelines to the extension service personnel of the country as to how these aspects of the fruit and vegetable industry in the country should be approached in their dealings with farmers of the highlands. For this reason, numerous references are made to optimum techniques although it may not be feasible to implement them for many years. Specific implementable recommendations are addressed directly.

PRODUCTION HARVEST AND POSTHARVEST

Vegetable

The time frame of the consultants (October 28 through November 10, 1984) visit coincided with a wide range of cool season vegetable growing and harvesting. The crops encountered included carrots, celery, potato, broccoli, cauliflower, kale, brussel sprouts, beets, lettuce, radishes, various greens, and some other typical cool-season vegetables. The many locations visited provided a wide adaptive look at the microclimes and their impact on cropping patterns. Some areas (Almalonda, for instance) appeared to be suited to a long planting season and, therefore, an extended harvest season. Other areas

plan the planting and harvesting period based on anticipated rainfall patterns. The presence and conscientious use of irrigation was in most cases responsible for, and allowed change in cropping patterns.

In general, many of the areas visited appeared to have strong potential in the production of certain high quality cool-season vegetables. An analysis of the economics surrounding each vegetable's production and then making a comparison to the U.S. production and pricing picture indicates several points:

1. Those vegetables that appear very competitive to U.S. production are those that have an inordinate amount of manual labor involved in the care, culture, or harvest stage. The vegetable types that are mechanically harvested from large fields in the U.S. have a price configuration similar to prices in Guatemala. Appendix A is a compilation of a few vegetable types with U.S. and Guatemalan production and pricing compared. It is important to note that these figures are averages and would vary considerably in both countries from year to year with supply and demand changes.
2. Guatemalan production advantages center around care and culture considerations that U.S. producers would find hard to duplicate. Extreme high density plantings favor high production but also increase costs and may make cultivation difficult. There is a great deal of attention given to the crop because of small field size, and this encourages superior production.
3. Highly perishable crops in the U.S. are harvested quickly and precooled within hours. Guatemalan farms are too small and too remote from processing/distribution points to allow rapid entry into the market place. A rigid grading standard is attached to the marketing strategy of most U.S. vegetable production and a general standardization of shipping containers for each crop is accepted (see Appendix B). Horticultural production in Region 1 is either not graded or is graded roughly by hand prior to shipment to market or at the market place itself.

It is difficult to evaluate the percentage of vegetable production that is lost because of improper handling, harvesting, or postharvest procedures. Vegetable harvesting systems currently in use in the western highlands are varied but generally involve woven baskets or bags. The pickers work only

small patches of land so the harvesting work load is not too heavy for the owner. Needless to say, much of the produce is mishandled. The harvest containers are then manually moved from the field to the farmstead, to a central community, or to transport. In many cases, the baskets are large (30 to 40 kilos) and this precipitates additional compression bruising. Quality, of course, suffers. The produce is often poured into other baskets or net rope bags to make a longer journey to market, often aboard the bus services. The bouncy journey on the roof of a bus further abuses the produce.

The degree of loss would, of course, depend greatly on the perishability of the vegetable and the time to market. Many vegetables (carrots, cabbage, beets, etc.) probably suffer few losses. Cauliflower, broccoli, greens, and other poor storage vegetables suffer greatly. The many markets visited by the consultants could be characterized as having a wide variety of produce with a considerable portion of it being of poor quality. It is beyond the scope of this report to illuminate crop by crop the recommended procedures involved in vegetable postharvest technology. Appendix C is included to be used as a reference point when considering the vegetable harvesting and storage factors that lend themselves to maximum product shelf life.

A major problem facing the highland vegetable grower is the marketplace. Local markets become quickly oversaturated and prices tumble to unprofitable levels. Crops like cauliflower, brussel sprouts, and broccoli are not popular enough to keep prices high and processing plants are located a long distance from Region 1 growers. Four or five freezing/fresh produce plants are operating in and around San Lucas, near the capitol. Alcosa, Ciusa, Inexa, and Ramon Pedraz operate intermittently and have exported production to the U.S. Procurement problems face the management of these plants. At times, the plants are unable to handle the supply available, but at other times the plants are unable to secure produce. The possibility of moving the Region 1 production is beyond the scope of the local market, and export opportunities must be considered if the highland valley farmer is to have a chance at a reasonable improvement in his return on investment.

Some interest has been expressed by local officials and growers in the possibility of opening a freezing processing plant in the Region 1 area, perhaps at Quetzaltenango. The area does promise a region of high production potential and wide ranges of harvest time associated with many of the

vegetables. This reduces "lay down" time of the plant. DIGESA would provide the Agricultural infrastructure to plan and encourage the seasons of harvest and provide technical assistance all the way through.

There is little doubt that the current pricing structure surrounding Guatemalan highland cool season vegetable production does offer strong profit potential if that produce were to be marketed at U.S. prices. An alternative in regard to this production would be to market through the existing plants at San Lucas, in spite of the distance involved from grower to factory. The distances, in fact, are not that great but the logistics involved in transport need additional study.

Harvesting, packaging, and movement of produce to the transport would entail involved planning and would require a change in containers for harvest and shipping. The switch in the U.S. back to "field packing" of many cool season vegetables (lettuce, broccoli, cauliflower, etc.) has been created because of economics. U.S. growers that once bulk harvested, transported the produce to a shed, then graded and packed it have found that the entire procedure can be done in the field at less cost. Guatemalan growers could certainly do the same. A standardized and rigid harvest/shipping container is available on the Guatemalan market and could be incorporated into this concept.

Vegetable Recommendations

1. A determination must be made if Region 1 vegetable production can be assimilated into the existing freezing/processing plants located near the capitol. The impact of the addition of this area's supply to the plants in operation must be considered and the harvesting time frames evaluated.
2. Upgrading of existing harvesting procedures to include grower education on the bruising and perishability of product. The acceptance in the industry of standardized rigid containers and the availability of transport must be attempted if export as well as local markets are to be upgraded.
3. The construction of a freezing/processing plant in the Region 1 area must be explored. Interested financial backers, local government, and industrial interests must be scrutinized to insure that

management can deal with the project attempted. The varying degrees of success of numerous cooperatives and processing plants in the highlands suggests that this project be carefully scrutinized prior to implementation.

4. The Region 1 extension and research personnel should be given in a two-day seminar a broad overview of the preharvest, harvest and postharvest technology entailed in developing export potential.

Fruit

Apple production in the western highlands can be characterized as diverse. Many orchards appear to be suffering from the ill effects of inadequate chilling; a long bloom season has resulted in a long harvest season. This type of harvest is difficult for pickers being asked to pick apples at certain stages of maturity. A long rainy season favors the life cycle of apple scab and necessitates a tedious and repetitious spray program. The common rootstock utilized in Guatemala results in standard-sized trees; average yields are substantially lower than in nations utilizing high density orchards based on adapted dwarfing rootstocks and superior varieties. Varietal trials now being undertaken and soon to be initiated are a long way from making major changes in the varietal picture; Red Delicious, Jonathan, Winter Banana, and Wealthy are entrenched as the common varieties.

Apple orchards in the highland region often suffer from poor care and culture; pruning and training is either not performed or is improperly attempted. Acreages are increasing because of the promise of profit and a unique marketing picture that has stimulated apple storage. Harvesting begins in August and September and the product is generally sold on the local market at low prices. Apples that are stored and marketed close to the Christmas holiday season receive a remarkably higher price. This has encouraged many growers to invest in storage rooms. A grower can expect to receive 3 to 4 quetzals per crate at harvest and 25 or more quetzals per crate during the holiday period. The 7-or 8-fold increase in realized gross income has encouraged cooperative cold storage investments as well as investments by individual growers.

Sixteen cold storage plants were reported to be operating in the area with varying degrees of success. Only a small percent of the apple crop is stored. The high cost of storage (charge per box) has prevented many growers from placing their fruit into storage. Most of the stored fruit encountered during the consultancy varied considerably in quality. Temperatures were above optimal storage standards in most cases. Storages often contained over-ripe fruit or bruised fruit; enhanced ethylene production increases the respiratory rate of adjacent fruit and makes storage difficult.

Apple harvesting techniques vary between growers but many pick fruit from the tree into a mesh or fabric bag held by a single shoulder strap. The picker then transports the bag to a nearby sorting and packing area. Many farmers find it necessary to carry apples long distances manually after harvest. This is accomplished with the Indian woven rope bag secured with a strap that runs across the forehead. The picking bag holds about 45 pounds of apples and the fruit is dumped onto a sorting table prior to being packed into a woven round basket. The basket is lined with paper and when fully packed holds approximately 100 pounds.

Grading generally separates the fruit into two or three classes. This is essentially an individualized system based on the grower's evaluation of color, size, and blemishes and is not as predictable as the grading standards used in the U.S. (Appendix D). The packed basket is often loaded onto local transport where it makes its way to local or distant markets. Apples that are graded and packed for the commercial market are usually placed into wire bound crates often lined with paper. The crates hold about 40 pounds and are generally not rigid enough to prevent apple bruising and compression damage in storage or during transport.

Apple production is increasing and the present pricing picture will change as supplies increase. The present embargo on apple imports has given the Guatemalan apple industry marketing and price advantages that growers will enjoy in the years ahead. The climatic and economic reality of the western highlands precludes export into the fresh market of the western world. Color and quality aspects of the Guatemalan apple do not compare to U.S. standards.

The apple industry and the Guatemalan agricultural community should explore the juice concentrate market. That market is international and reliable and while prices paid per ton are not high, it does offer growers an alternative market place.

Many temperate fruit types can be grown in various areas of the western highlands. Peaches, particularly early ripening types, appear particularly well suited to offering profit potentials. Peach trees are common inhabitants of many areas and are often dooryard in nature. Orchards suffer from many of the same problems as apple plantings. A seasonal sequence of varieties has not been established. There has been, instead, a heavy reliance on a few varieties. This places a strain on the market place during "peak" periods.

A multi-site variety trial of a reasonable collection of low-chilling, early-ripening peach and nectarine varieties is recommended. The highly perishable nature of peach and nectarine and the June-August "glut" that saturates more northern producers (U.S. and Europe) has created a good profit picture for those growers that market in April and May. The western highlands offer many areas that harbor suitable winter temperatures and spring heat to allow adaptation of early maturing types.

The success of fruit and vegetable sales from Chile is based on a supply of perishable products to the U.S. market at a time when U.S. growers are unable to produce. The close proximity of Guatemala to northern markets and the opportunities afforded by a semitropical highland climate suggest strong export potential.

Fruit Recommendations

1. Apple harvesting improvements necessitate a change in picking bags. A rigid metal or plastic bucket with a drop bottom canvas hanger that can be released. Two wide shoulder straps carry the load. Fruit is removed from the basket by means of the folded canvas bottom, allowing the fruit a gentle transfer to the sorting table or to another container. A rigid transport container will further reduce bruising, compression and vibration damage.
2. Explore alternative markets for apple products. The concentrate juice market deserves consideration. The strength of the domestic fresh apple market is difficult to determine. The economics of apple storage will serve to increase its use. Acreages that are still young are soon to come into production and will test that market strength. Mechanisms that would allow growers to unite and promote

their product should be sought.

3. The apple storage attempt by passive as well as cold storage means will increase. Guatemalan agricultural officials should be made aware of the processes involved in extending apple shelf life. While U.S. growers have mastered apple storage to the point of making the product a year-round commonly consumed fruit, the Guatemalan apple industry is just now pushing this crop to the Christmas season. The strength of the market past Christmas has not been tested and is an issue that must be addressed. The effects of temperature, humidity, sugar, firmness, and starch conversion must be appreciated by growers and cold store operators.

4. While it is difficult to consider long-term returns when immediate problems need attention, the initiation of expanded fruit variety trials would enhance the production picture in the years ahead. Expanding the harvest season several months eases marketing problems. The dwarfing rootstock trials with apple must be included in multi-site trials. New fruit releases exhibit a wide range of desirable characteristics not present in many of the varieties utilized in Guatemala. Their adaptation deserves study.

STORAGE AND COOLING

Vegetables

Vegetable production in the Guatemala highlands is still in a relatively infant stage of development. Crops are somewhat restricted in regard to their variety as well as to the area devoted to production. There are notable exceptions in the highlands to this general observation, and those exceptions occur generally near Guatemala City, in the area of Almolonda near Quetzaltenango, and in the Province of San Marcos near the City of San Pedro in Region 1.

Marketing of the vegetable products is somewhat limited and consists chiefly of sales on the local market and in some instances to regional sales to other Central American countries. Because of the parochial nature of the markets, no extensive efforts have been made to develop cooler facilities for vegetables in Region 1.

There are many advantages to be gained from cooling vegetables soon after harvest. The market life can be significantly extended by cooling, and it allows storage to be extended for days and even months. Because deterioration is a function of time and temperature, faster cooling can substantially extend the shelf-life of vegetable products.

Consumer satisfaction with fresh commodities is related to quality aspects such as appearances, flavor and ripeness. Fast cooling and good temperature management are vital to protecting these quality aspects.

There are numerous forces that work in opposition to good cooler storage. Products that are handled and transported in baskets and nets, as is common, or even on pallets are often very tightly packed and cause cooling problems to be more severe. Container vents, even if adequately sized, are often blocked when containers are cross-stacked and much of the product does not have access to the cold air. Cooling in such circumstances is irregular and slow and often inadequate without some modification in container design and venting, stacking patterns, and cooling systems.

The conflict between the need to achieve more rapid cooling and the difficulty of cooling appears almost impossible to resolve through the use of conventional room cooling procedures. However, rapid cooling systems are available which can achieve good results if properly used.

Cooling as a Part of the Handling System

The entire product handling system should be considered when cooling facilities are planned because any change in the system may affect cooling rate, uniformity and other requirements. The packing method will dictate how, and sometimes when, the product is presented for cooling. Packaging materials and design will affect access of the coolant to the product, and stacking patterns will influence coolant flow through and around containers. Loading patterns, transport equipment, and marketing procedures all greatly affect cooling requirements. The maximum market life of many commodities may be approached when they are transported from the highlands to the coast for ocean transport for export marketing.

Cooling and Storage are Two Separate Operations

The refrigeration capacity for fast cooling and for cold storage are quite different. For example, it takes about 100 times more refrigeration to cool peaches in 24 hours than to store them for 24 hours in cold storage. Even when the fruit is cooled over a six-day period, the daily refrigeration capacity during cooling is almost 25 times that for cold storage. This ignores the refrigeration required to remove the heat entering the facility through walls, doors, fans, etc.

There are other differences between cooling and cold storage that must be considered. During fast cooling, high air velocity will not increase total water loss from the product if it occurs only while the product is being cooled. However, during subsequent cold storage, high air velocity will desiccate most fruit and vegetable commodities because of the long period of exposure to the rapidly moving air. High relative humidity is essential to prevent excessive water loss during cold storage, but is not as important during the short cooling period.

Cooling and storage are two separate operations that have vastly different requirements. The specific requirements for achieving fast, uniform cooling must be considered independently of the cold storage requirements.

Cooling Methods

Several cooling methods are available for use with horticultural commodities. Room cooling, forced-air cooling, hydrocooling, package icing, and vacuum cooling are used before storage or loading for transport. Top-icing, channel-icing, and mechanical refrigeration in transport vehicles are used for transit cooling. A few cooling methods, e.g., room cooling and hydrocooling, are used with a wide range of commodities, but most commodities respond best to 1 or 2 of the cooling methods.

The following paragraphs describe several cooling methods and the types of commodities for which they may be suited. Economic considerations may dictate which cooling method is used. Some, such as hydrocooling, forced-air cooling, and vacuum cooling, require considerable initial capital investment. Some of these methods require technical skill that is only now becoming available in

the country. Other cooling methods require less capital investment, but may require expensive water-tolerant shipping containers, and may have higher product loss and higher operating costs.

Room Cooling - This cooling method involves placing produce in field or shipping containers into a cold room. Typically, cold air is discharged into the room near the ceiling, moves horizontally across the ceiling, and then sweeps past the produce containers to return to the heat exchanges. For best results, containers should be stacked so the moving cold air can contact all container surfaces. An air flow of at least 200 to 400 feet per minute is needed to provide the turbulance to achieve heat removal. Well-vented containers can greatly speed room cooling by achieving some air exchange.

Room cooling allows produce to be cooled in the same location where it will be stored, thus requiring less rehandling. Best room cooling, however, requires more spacing than is needed for good storage management, thus rehandling may be needed to achieve good storage space utilization.

Products for room cooling must be tolerant of slow heat removal, because much of the cooling is by heat conduction to the container surface. For such commodities there is a potential economy from room cooling, because the refrigeration load is distributed over a longer period, and because air flow requirements are often less than for fast cooling. Because the air velocity needed for cooling is greater than that needed for storage, products stored in the cooling room will lose water faster than when under more ideal storage conditions.

Room cooling becomes increasingly difficult for commodities being handled in large field containers or tightly unitized on pallets. The increasing difficulty results from the longer path for conduction cooling and the greater difficulty of getting effective air movement with the large product units.

Ceiling Jets - This modification of room cooling directs air flow past container surface in an attempt to improve heat removal. A ceiling is constructed in the room, with small inverted open cones installed to direct air vertically toward the floor. Air leaving the heat exchanger is directed into the space above the ceiling. This creates a slightly positive pressure which results in the air flow from the cones. The floor of the cooling room

is carefully marked for spaced stacking of pallets or bins so that air from the cones will sweep down the corners of the stacked units and spread into the channels that were created during stacking. The air return duct then draws the air in one direction.

Cooling Bays - For both cooling and storage, a single large room is divided into bays by installing partitions part way into the room from each side. Air supply channels are constructed to direct the air into each bay. When a single bay is filled with warm product, supply ducts can be opened to direct a large volume of cold air behind the product. Air return generally occurs down the center fork-lift aisle of the room. When cooling is completed, the air supply can be reduced in that one bay to create desired storage conditions. With this system, a cold product located in one bay is not warmed by warm product in other bays.

Forced-Air Cooling (Pressure Cooling) - Forced-air cooling can solve many difficult cooling problems because it provides for cold air movement through, rather than around, containers. The system, which creates a slight pressure gradient to cause air to flow through container vents, achieves rapid cooling as a result of the intimate contact between cold air and warm product. With proper design, fast, uniform cooling can be achieved through stacks of pallet bins or unitized pallet loads of containers. Various cooler designs can be used, depending on specific needs. Converting existing cooling facilities to forced-air cooling is often simple and inexpensive, provided sufficient refrigeration capacity and cooling surfaces, e.g., evaporator coil surfaces, are available. Some of the variations in forced-air cooler design are described below:

Forced-Air Tunnel - This is the more traditional forced-air cooling system. Essentially, two rows of containers are placed on either side of an exhaust fan leaving an aisle between rows. The aisle and the open end are then covered to create an air tunnel. With the exhaust fan operating, a slight negative air pressure is created within the air tunnel. Cold air from the room then moves through any openings in or between containers toward the low pressure zone, sweeping warm air from around the product as it moves. The

exhaust fan can be a portable unit that is placed to direct the warm exhaust air toward the air return of the cold room or it can be a permanent unit which also circulates the air over the cooling surface and returns it to the cold room.

Cold Wall - This is a permanently constructed air duct equipped with an exhaust fan. It is often located at one end or side of a cold room, with the exhaust fan designed to move air over the cooling surface. Openings are located along the room side of the duct against which containers can be placed. Various damper designs have been developed so that air flow is blocked except when a container is in place. Each will start cooling as soon as it is in place; thus there is no need to await deliveries to complete a tunnel. Shelves are often built so that several layers of containers can be accommodated by proper design of the damper system. This is a benefit in some operations where a range of commodities or varieties is handled. Each container must be promptly moved from the cooler as soon as it is cold in order to avoid unnecessary desiccation from continued rapid air flow over the product.

Serpentine Cooling - This system is used for forced-air cooling of produce in pallet bins which are constructed with bottom ventilation slots, with or without side ventilation. It requires modification of the cold-wall design to allow access openings between bins to be used as air supply and return ducts. The cold air moves vertically through the product within each bin in response to the slight pressure difference between ducts. Bins may be stacked several rows deep against the cold wall, depending on the cooling speed desired and the available air flow. The air flow capacity of the small opening ducts is the primary limitation. To achieve the desired air flow pattern, openings are provided in the cold wall to match alternate access openings, starting one bin up from the floor. On the room side of the bins, these same openings are then blocked. Thus, air flowing into an open slot between bins must pass up or down through one bin of product to reach the cold wall. This system requires no space between rows of bins, and is not limited in height. Rapid cooling is achieved because air flows vertically through a relatively shallow layer of product.

Container Venting - Effective container venting is essential for forced-air cooling to work efficiently. Cold air must pass through all parts of a container. For this to happen, container vents must remain open after stacking. Thus, venting patterns are important. If containers are palletized, container side or end vents will suffice, provided they are properly located in relation to trays, pads, etc. If cross-stacking is used, then matching side and end vents are very desirable. For a 400x300 mm container cross-stacked on the 1200x1000 mm pallet, vertical vent slots on 100 mm centers around the container perimeter should be considered, because they will remain matched when cross-stacked.

Too little venting will restrict air flow and too much venting will weaken the container. A reasonable compromise appears to be about five percent side and/or end area venting. A few large vents are more effective than many small vents for speeding the cooling rate. Locating vents midway from top to bottom is adequate unless trays or other packing materials will isolate some of the product. Any type of bag, liner or vertical divider inside the package will eliminate much of the effect of the vents. Vertical slots, at least 12 mm (1/2-inch) in width are better than round vents.

Hydrocooling - The use of cold water to cool produce quickly is an old and effective cooling method used for a wide range of fruits and vegetables in bins or in bulk before packing. Its use is limited for packed commodities because of the difficulty of achieving sufficient water flow through the containers, and because the containers must be water tolerant. The product must be tolerant of wetting, not susceptible to water heating damage, and tolerant of chemicals that are used to prevent the spread of disease organisms via the hydrocooling water. Sanitation, including frequent cleaning and the maintenance of a low chlorine concentration, is important. Product tolerance to chlorine must be known. Shower-pan holes must be cleaned daily to avoid plugging, which causes uneven water flow over the product.

Potential limitations of hydrocooling must also be considered. When the hydrocooler is operating at capacity, arriving warm produce must remain at ambient temperatures to await cooling. Further, when cooling is completed, the product must be moved to a cold room, or rapid rewarming will occur.

Hydrocooling operations can require rehandling of the containers prior to packing or storage. Cooling efficiency may be low, unless the hydrocooler is operated continuously at maximum capacity, or is inside a cold room or an insulated enclosure.

Package-Icing - Some commodities are cooled by filling packed containers with predetermined quantities of ice, depending upon the initial product temperature. Initially the direct contact between product and ice causes fast cooling. However, as soon as the ice in contact with the product has melted, the cooling rate slows considerable. Package ice may be finely crushed ice, flake-ice, or a slurry of ice and water called liquid-ice. Liquid icing distributes the ice throughout the container, achieving better ice/product contact. Package-icing requires use of more expensive, water tolerant shipping containers. In small operations package ice is hand raked or shoveled into containers; in large volume operations it is done automatically with mechanical icers. Liquid icers for automatically icing pallet loads of packed cartons can be used for cooling some field packed vegetables.

Vacuum Cooling - Vegetables that have a favorable surface-to-mass ratio, such as leafy vegetables, can be rapidly cooled by this method. It is also used to cool cauliflower, celery, some sweet corn, carrots, and bell peppers. Its use with carrots and peppers is primarily to dry the surface and stems, respectively, to inhibit postharvest decay. Cooling is achieved by reducing the atmospheric pressure inside a large, strongly constructed steel chamber containing the product. Reducing the atmospheric pressure also reduces the pressure of water vapor in the chamber. When the water vapor pressure in the chamber is reduced below that in the product's intercellular spaces, water will evaporate from the product resulting in cooling. Vacuum cooling causes about one percent product weight loss (mostly water) for each 6°C of product cooling. This amount of weight loss can be objectionable for celery and some leaf lettuce. Weight loss can be greatly reduced by the addition of water in form of a fine spray during the vacuum cooling cycle.

Some vacuum coolers are permanently located. However, most vacuum cooling equipment is now portable, and used in two or more areas each year. This allows amortization of the high costs of vacuum coolers over a longer period

each year. While early vacuum coolers were primarily of the stem-jet type, most presently used coolers are mechanical, rotary vacuum pumps.

Cooling Before Packing - Cooling problems with products in unitized pallets, or poly-packed products, can be avoided by cooling them before packing. This increases the basic cooling cost because products that are subsequently removed (culls or diverted products) are also cooled. If 20 percent cullage occurs after cooling, the cooling cost increases 25 percent. If 50 percent is removed (diverting peaches to a processor, for example), then the cooling cost per ton of packed product doubles. The cost may become prohibitive unless the cooling adds considerable value to the diverted product.

Some rewarming will occur if produce is packed after cooling. With a mild breeze, products can rewarm to near ambient temperatures within 30 minutes. This rewarming can be reduced by only partially cooling the product before packing, followed by complete cooling after packing. One system has solved this problem another way. The fruit is forced-air cooled in bins on arrival from the field and the bin dump is located in the forced-air bin cooling room. The cold, dumped fruit moves from the cold room to the packing area, where it is sorted, sized, and tight-fill packed into containers within 3 or 4 minutes. The packed containers are then conveyed into a cold room for palletizing within 6 to 7 minutes after leaving the bin cooler. Fruit temperature rise in that system is minimal.

Vegetable Recommendations

Currently, the extent and size of the market for fresh vegetables from the Guatemala highlands is too limited and uncertain to justify pre-cooler and cold storage. More certain markets should be identified. The several products that have sufficiently large markets to justify cold storage are near or to Guatemala City. Produce in the highlands could be shipped to existing storage nearer the capitol.

Pre-cooling vegetables before storage or transportation will increase their shelf-life and most likely add value to the product. Room cooling facilities are the most cost effective systems for the quantities of vegetables currently produced. Although the efficiency of room coolers is

less than for more advanced systems, they have the advantage that the management and technical aspects are much less complex and thus more adaptable to the existing circumstances in the highlands.

Fruits

Most of the pre-cooling and storage aspects discussed in regards to vegetables are appropriate to fruits. Particular care must be given to certain fruits because of their individual characteristics. In addition, there are environmental factors that influence deterioration of fruit products. These factors are briefly discussed below:

Temperature - Temperature is the most important environmental factor which influences the deterioration rate of harvested commodities. For each increase of 10°C (18°F) above optimum, the rate of deterioration increases by 2- to 3-fold. Exposure to undesirable temperatures results in many physiological disorders. Temperature also influences how ethylene, reduced oxygen, and elevated carbon dioxide affect the commodity. Spore germination and growth rate of pathogens are greatly influenced by temperature. Some pathogens, such as Rhizopus rot, are sensitive to low temperatures. Thus, cooling of commodities below 5°C (41°F) immediately after harvest can greatly reduce Rhizopus rot incidence.

Relative Humidity - The rate of water loss from fruits and vegetables depends upon the vapor pressure deficit between the commodity and the surrounding ambient air, which is influenced by temperature and relative humidity. At a given temperature and air rate movement, the rate of water loss from the commodity depends on the relative humidity. At a given relative humidity, water loss increases with the increase in temperature.

Atmospheric Composition - Reduction of oxygen and elevation of carbon dioxide, whether intentional (modified atmosphere storage) or unintentional, can have the effect of accelerating or retarding deterioration. The magnitude of these effects depends upon the commodity, physiological age, O_2 and CO_2 level, temperature, and duration of holding.

Ethylene - The effects of ethylene on harvested horticultural commodities can be desirable or undesirable. Thus, it is of major concern to all handlers of fruits and vegetables.

Light - Exposure of potatoes to light should be avoided because it results in greening due to formation of chlorophyll and/or solanine (toxic to humans).

Other Factors - Various kinds of chemicals (fungicides, growth regulators, etc.) may be applied to the commodity to affect one or more of the biological deterioration factors.

Temperature Management

Temperature management is the single most important consideration to extend the shelf-life of fresh fruit commodities. Proper temperature management begins with the rapid removal of field heat by using cooling methods such as hydrocooling, in-package icing, top-icing, evaporative cooling, room cooling, forced-air cooling, serpentine forced-air cooling, vacuum cooling or hydro-vacuum cooling.

Cold storage facilities are the second temperature management tool. They should have: (a) good construction and insulation including a complete vapor barrier on the warm side (usually outside) of the insulation, (b) strong floors, (c) adequate and well-positioned doors for loading and unloading, (d) effective distribution of refrigerated air, (e) sensitive and properly located controls, (f) enough refrigerated coil surface to minimize the difference between the coil and air temperatures, and (g) adequate capacity for expected needs. Commodities should be stacked in the cold room leaving air spaces between containers and room walls as well as among pallets to insure good air circulation. Storage rooms should not be loaded beyond their limit for proper cooling. In monitoring temperatures, commodity temperature rather than air temperature should be used.

Delays between cooling after harvest and loading into transit vehicles should be avoided. Proper temperature maintenance should be ensured throughout the handling system.

Control of Relative Humidity - Relative humidity can influence water loss, decay development, incidence of some physiological disorders, and uniformity of fruit ripening. Condensation of moisture on the commodity (sweating) over long periods of time is probably more important than the relative humidity of ambient air in enhancing decay. Proper relative humidity is 85-95 percent for fruits and 90-98 percent for most fruits and vegetables. Some root vegetables can best be held at 95-100 percent relative humidity.

Relative humidity control can be achieved by one or more of the following procedures:

a. Addition of moisture (water mist or spray, steam) to the air by humidifiers.
b. Regulation of air movement and ventilation in relation to produce load in the cold storage room.
c. Maintaining temperature of refrigeration coils to within about 1°C (2°F) of the air temperature.
d. Use of moisture barriers (insulation of storage room and transit vehicle walls, polyethylene liners in containers, plastic films for packaging).
e. Wetting the floor in storage rooms.
f. Use of crushed ice in shipping containers or in retail displays for commodities which are not injured by such practice.

Rustic Bodegos

Of special interest for fruit cooling and in particular for apples is the use of small storage buildings referred to in the highlands as "rustic bodegos". These buildings make use of a method of cooling known in the U.S. as air cooling. They make use of the cool evening air temperatures to keep the fruit products cool during the warmer parts of the day. For small producers, those buildings can be very effective to prolong the shelf-life of stored apples. Although the buildings may vary in size, they generally have several characteristics in common.

1. Walls and roofs are adobe and very thick (40 cm).
2. False floors are made of wood slats to allow air circulation.

3. The basement is filled with water and rocks to maintain high humidity and to moderate temperature fluctuation.
4. The basement doors are opened at night and closed during the day.
5. Roof vents are opened during the night to promote air circulation.

Fruit Recommendations

Several cold storage facilities were visited in the Guatemala highlands that were well-operated, effective systems. In most cases, there were several common faults in the operations that, if altered, could improve the effectiveness of the facilities.

1. Temperature should be maintained at $32^{o}F$ ($0^{o}C$).
2. Relative humidity should be kept above 90 percent by any of the means suggested in the text of this respect.
3. Vapor doors of plastic should be used on all doors that are opened.
4. Packing of fruit boxes should not be so dense as to inhibit air flow to the fruit.
5. Rotted apples should be culled periodically.

Several recommendations specific to the design and operation of the Rustic Bodegos could improve their effectiveness.

1. Where possible, those buildings should be placed so that they are shaded most of the time.
2. Roofs and sides of buildings should be white-washed or painted white.
3. During hot days when the temperature is above $80^{o}F$, water should be sprayed on the roof to promote evaporative cooling.
4. Plastic curtains or doors should always be installed and used.
5. Care should be taken not to overload the buildings. Packing volume should be at most 60 percent of the internal volume of the building.

APPENDIX A

VEGETABLE PRODUCTION REGION 1*

Vegetable	Guatemala Kilos/ha	Quetzals/Kilo	U.S. Production** Kilos/ha	$/Kilo*** $/Kilo***
Swiss chard	3,551	.60	-	-
Celery	16,454	.28	55,104	.73
Potato	20,909	.14	33,600	.13
Beet	20,000	.19	22,400	-
Carrot	31,360	.19	30,016	.22
Broccoli	8,636	.32	8,960	1.10
Onion	27,270	.37	34,832	.20
Cauliflower	13,050	.23	10,528	.77
Brussel Sprouts	14,090	.37	14,000	2.20

* The Guatemalan statistics were provided by Mr. Mario Morales, DIGESA

** Avg. U.S. production obtained from Knott's Handbook for Vegetable Growers, 1980, Wiley-Interscience.

*** U.S. price configuration from market news reports in early November, 1984.

APPENDIX B

U.S. GRADE AND CONTAINER STANDARDS

The vegetables listed below are used as a review of the grade classification used in the U.S. and typical shipping container status:

ASPARAGUS

Iwo federal grades apply to asparagus - U.S. No. 1 and U.S. No. 2. Generally speaking, U.S. No. 1 requires the stalks to be fresh, well-trimmed and fairly straight. They should be free from decay or damage. Unless otherwise specified, the stalk should not be more than one-half inch thick and stalk coloring should be not less than two-thirds green.

Ihere are four common shipping containers used for asparagus. These include loose-pack pyramid-crates, holding approximately 32 pounds net weight; one-half pyramid crates, holding 15 to 17 pounds; cartons holding 16 one and one-half packages, 24 to 25 pounds; and pyramid wire-bound crates, holding 12 bunches, 30 pounds.

New Jersey also maintains a state grade called New Jersey 1, which specifies a 9-inch stalk length and two-thirds green coloring. If a stalk is less than 9 inches, it must have 6 inches of green. Stalk diameter must be not less than six-sixteenths inch.

BROCCOLI

Broccoli falls under the specifications of three U.S. grades; U.S. Fancy, U.S. No. 1 and U.S. No. 2. Fancy consists of bunched broccoli free from decay and damage from overmaturity. Bud clusters in each bunch must be neatly and fairly evenly cut at the base and well trimmed.

U.S. No. 1 requires bunched stalks be free from decay and damage with bud clusters in each bunch fairly compact. Bunches should be neatly and evenly cut at the base and well trimmed.

BRUSSELS SPROUTS

Brussels srpouts are classified under two grades: U.S. No. 1 and U.S. No. 2. Generally speaking, U.S. No. 1 requires sprouts to be well-colored, firm, and free from damage. Diameter is specified at not less than 1 inch, and length should not be more than 2-3/4 inches.

Common shipping containers for brussels sprouts include loose-pack cartons holding 25 pounds, and flats and cartons holding 12 10-ounce cups (7-1/2 to 8 pounds).

CABBAGE

Cabbage is graded U.S. No. 1 and U.S. Commercial. Requirements include that the heads be of reasonable solidity and not be withered, puffy or burst.

Common shipping containers include flat crates containing 53 to 60 pounds, mesh sacks holding 50 pounds and cartons that hold 53 pounds.

CARROTS

Grade standards for carrots are many, with different standards for bunched, topped and carrots with short-trimmed tops. There also are standards for fresh carrots.

Topped carrots are subject to grades U.S. Extra No. 1, U.S No. 1, U.S. No. 1 Jumbo and U.S. No. 2. Bunched carrots and carrots with short-trimmed tops are subject to U.S. No. 1 and U.S. Commercial.

Bunched carrots are shipped in cartons containing two-dozen bunches and weighing between 23 and 27 pounds. Those without tops are shipped in film bags in master containers, wirebound crates and mesh sacks averaging about 50 pounds. They also can be shipped in burlap sacks.

CAULIFLOWER

There is one grade for cauliflower, U.S. No. 1. Requirements state that heads must be compact and not discolored or overmature. They must be free from damage and at least 4 inches in diameter.

Most cauliflower is shipped film-wrapped in cartons holding 21 to 25 pounds or in crates holding 40 to 60 pounds.

CELERY

Celery falls under the stipulations contained in grades U.S. Extra No. 1, U.S No. 1 and U.S. No. 2.

Common shipping containers include the 15-1/2 inch crate and wirebound crates holding between 60 and 65 pounds and the 14-1/2 inch wirebound crate holding between 55 and 60 pounds.

LETTUCE

Lettuce is subject to three U.S. Grades: U.S. Fancy, U.S. No. 1, and U.S. No. 2.

Lettuce is shipped in a variety of containers. Big Boston most commonly is shipped in a 1-1/9 bushel eastern wirebound crate; Iceberg in western Iceberg cartons; Romaine in 1-1/9 bushel wirebound crates, looseleaf in cartons and wirebound crates and leaf, greenhouse varieties in wooden baskets.

ONIONS

Onions are subject to a number of grades, some of which vary according to type. Dry onions other than Bermuda-Granex-Grano and Creole types are classified U.S. No. 1, U.S. Export No. 1, U.S. Commercial, U.S. No. 1 Boilers, U.S. No. 1 Picklers and U.S. No. 2. Grade standards for Bermuda-Granex-Grano types are U.S. No. 1, U.S. Combination and U.S. No. 2.

Mesh bags, of the 50 pound size, are the most common container for dry onions. Cartons that hold 48 to 50 pounds also are used, as are a variety of consumer-sized bags, varying from 1-1/2 to 10 pound bags shipped in master containers.

PEAS

There are two USDA grades for classifying peas: U.S. No. 1 and U.S. Fancy. Color, size, firmness and freedom from decay are grading considerations.

POTATOES

There are four U.S. standards for potatoes, U.S. Extra No. 1, U.S. No. 1, U.S. Commercial and U.S. No. 2. Among the qualifications for U.S. No. 1 are that the potatoes be firm, clean, fairly well matured and shaped and free from disease or internal defects.

Potatoes are shipped in a variety of containers including 100 pound sacks, 50 pound cartons and sacks, 20 pound film bags and 10 pound film bags.

APPENDIX C

VEGETABLE HARVEST AND STORAGE CONDITIONS

POTATOES - *Solanum tuberosum*

Harvest: As tubers mature, the vines turn yellow. For early harvest the vines are beaten down or cut a few days before digging to "set" the skin on immature tubers. Tubers should be dug and carefully handled as bruising and subsequent blackspot formation can occur.

Curing: A period of 4-5 days at 16-21° C in high humidity will suberize or heal cuts and surface injuries of the tuber. Curing is usually not practiced by growers.

Storage: Storage at 4-10°C at RH 90% is recommended. Low temperature storage induces conversion of starch to sugar. Reconditioning (conversion of sugar to starch) is accomplished by transferring to 18-21°C for 7 or more days. Tubers should be stored in the dark to prevent greening (chlorophyll formation) and solanine formation (a toxin).

Sprout Inhibitors: Maleic hydrazide spray at 1000-6000 ppm solution to the plant 2-3 weeks before harvest has been effective in inhibiting sprouts. Also a 0.5% solution of Chloro IPC (isopropyl N-tetrachlorocarbamate) and nonyl or amyl alchohol at 0.05-0.12 mg/liter concentration in the atmosphere of storage rooms has been effective in controlling sprouts.

SWEET POTATO - *Ipomea batatas*

Harvest: Usually harvesting is 130-150 days from transplanting. Roots are considered ready for harvest when the leaves turn yellow and abscise or the exudate from a cut root dries rapidly and does not change color. However, harvest of sweet potatoes can be made at any time. To avoid chilling injury of the roots, harvests should be made before the soil temperature gets below 10°C.

Curing: Curing heals the wounds on the roots from harvesting. This prevents microbial invasion and water loss. Conditions for curing are 27-29°C at 85-90% RH for 4-7 days. Healing rate is slower at rates below 27°C or above 35°C and also at RH values below 85%.

SWEET POTATOES (continued)

Field Curing: In warm climates roots are stacked 60-90 cm high with sweet potato vines 12-15 cm thick. The vines act as insulation and raise the humidity in the pile. Often paper is placed over the pile to insure high humidity and reduce circulation of air through the stacked tubers. Respiration of the roots raises the temperature. Roots are left in the pile 7-10 days for the curing process.

Storage: After curing, temperatures should be lowered to 13-16 C at RH 85-90%. Lowering temperature increases the storage life of roots due to decreased respiration rate. There are considerable differences in storage life among varieties. (Two to six months is common). If storage is 0°C, damage can occur in a few days. Freezing occurs at -11°C. Storage at 10°C or below results in chilling injury.

ONION - *Allium cepa*

Harvest: When the tops begin to fall down (about half of tops fallen), the bulbs are ready to harvest. In the tropics, this often does not occur as new leaves continue to form; bulbs are harvested with the tops still green and standing.

Curing: If the neck of the onion is not dry, curing is necessary. Curing is accomplished by allowing the harvested onions to air dry either in windrows or pen slotted crates in the field for 10-12 days. The dried or partially dried tops are usually cut off. In the field, the stacked bulbs must be protected from the sun. This is accomplished by placing the green tops or other materials over the pile but still allowing air circulation through the bulbs. Curing can be accomplished by forcing heated air at 46°-47°C through the pile for 12-24 hours.

Storage: Bulbs store best at 0-7°C, or at a high temperature of 25°-35°C. At these temperatures bulbs can be stored for 3-6 months without sprouting. Poorest storage is at room temperature (15° - 21°C). If the humidity during storage is kept at 40% or lower RH and temperatures at 3°C, some cultivars can be stored for almost a year.

GARLIC - *Allium sativum*

Harvest: Garlic is ready for harvest when the tops are partially dry and bent to the ground. The bulbs are

pulled either by hand or mechanically and windrowed. They are left to cure about 1 week, covered with materials to prevent sunburn but air is allowed to circulate through the piles. Where rain or dew is a problem, the bulbs should be protected from moisture.

Storage: Garlic bulbs for consumption can be kept for several months at ordinary temperatures but for prolonged storage, they should be held at near 0°C at humidities below 60%. The cloves sprout quickly at 5°C so temperatures near this point should be avoided. As with onions, bulbs can be kept at temperatures above 25°C but shrinkage occurs at this temperature.

LETTUCE - Lactuca sativa

Harvest and Storage: Lettuce requires 60-80 days to harvest in the summer and fall and 90-145 days during the winter and spring depending on temperature conditions. Over half of the fresh weight of the head is attained in the two weeks before harvest.

Lettuce is very perishable as it has a high water content. Ideally, lettuce should be precooled to about 1°C and held at this temperature at high humidity (95-97%) for storage or transport. It will remain in good quality for 10-14 days under the above conditions.

COLE CROPS - Brassica oleracea

Harvest and Storage: Cole crops reach harvestable maturity according to climatic conditions, nutrients, and moisture available during growth. Maturity dates depend also on the variety selected.

Cole crops should be stored at 0°C at high humidity, 95-98°C RH. Under these conditions, cabbage can be stored 4-6 months; brussel sprouts, kohlrabi, and cauliflower for about a month; broccoli and kale for about two weeks.

CELERY - Apium graveolens

Harvest and Storage: Harvesting occurs when plants have attained marketable size. The outer petioles become pithy with increase in maturity so the crop should be harvested before

this occurs. The plants are usually topped so that the stalk is mostly petiole tissue. The outer leaves are removed and plant with the upright petioles is marketed. Celery is stored at 0°C at very high humidity and can be held about a month at these conditions.

CARROT - Daucus carota

Harvest: Carrots for the fresh market are harvested when the majority of roots are 2 1/2 - 3 1/2 cm in diameter at the crown. They can be harvested 65-85 days and longer after planting, depending on the temperature. Processing carrots are left in the ground longer, as both dry matter and color increase with maturity.

Storage: Carrots store best at 0°C at high humidity. The roots store best with the tops removed as moisture and nutrients are transferred to the tops from the roots during storage.

PEAS and BEANS- Pisum spp. and Phaseolus spp.

Harvest: Peas and lima bean are harvested for the fresh market, freezing, or canning when the seeds are still immature, succulent, and before the seeds are too starchy. The optimum harvest period for peas and lima beans is a few days when the weather is cool and only a day or two in hot weather.

With edible pod peas, string or snap beans, and other legumes, the pods are harvested at the immature stage before the seeds are starchy and the pods are succulent and "strings" are absent.

Storage: Peas should be stored at 0°C as quickly as possible after harvest to prevent loss of sugars. High temperatures result in poor quality. Shelled peas and lima beans suffer loss of quality from bruising and loss of moisture much faster than the immature seeds in the pod.

Beans and other warm season leguminous crops need to be stored at high humidity (not less that 85% RH). The best storage temperature is about 5°C. Lower or higher temperatures decrease the storage life. Shelled beans may require storage colder than 5°C.

PEAS

Harvest: For vegetable use the pods should be well filled and contain no starchy or hard seeds. Under cool

temperatures, the peas do not mature rapidly and remain at the proper condition for several days. However, under warm temperatures, the seeds accumulate starch rapidly, and the optimum quality lasts for only a day or two.

Storage: Harvested pods or shelled peas should be cooled as quickly as possible to 0°C to prevent conversion of sugars to starch and to reduce respiration rate. Shelled peas should be washed in ice water to remove field heat and to prevent decay organisms from growing. Peas in the pod may be stored at 0°C for 3 weeks and two weeks at 5°C. Storage in controlled atmosphere (CA) of 5-7% CO_2 at 0°C give better quality after three weeks than storage in air at the same temperature.

TOMATO - Lycopersicon esculentum

Harvest: From planting of seed to harvest takes 60-90 days depending on varieties or climate. Fresh market tomatoes are often harvested at the mature green stage and ripened either in transit or storage. Ripening of mature green fruits must take place at temperatures greater than 10°C. Above 10°C the rate of ripening increases with increasing temperatures. Some exposure to light is necessary for the red color, lycopen, formation to occur.

Tomato fruits are classified according to maturity stages given below:

MATURITY STAGES OF TOMATO RIPENING

Stages	Days from mature green at 20°C	Description
Immature green	—	Fruit still enlarging, angular in shape, color dull green, no skin luster. Seed cut with sharp knife when sliced. Gel not well formed. Seed immature and will not germinate. Fruit will not ripen properly.
Mature green	0	Color bright green to whiteish-green and well rounded. Skin has waxy gloss and cannot be easily scraped off. Seeds embedded in gel and are not cut when fruit is diced; seeds mature and will germinate. Fruit will ripen under proper conditions.
Breaker	2	Turning pink at blossom end; internally the placenta is pinkish.
Turning	4	Pink in color from blossom end covering 10–30% of fruit.
Pink	6	Pink to red in color covering 30–60%.
Light red	8	Pink to red in color covering 60–90%.
Red	10	Red color at least 90% of fruit.

Storage: Mature green tomatoes should be stored at 13-18°C and 85-90% humidity. At this temperature chilling injury does not occur and the fruits will ripen more rapidly at temperatures greater than 18°C but at constant temperatures of greater than 30°C the red color does not readily form. Ripe red fruits should be stored at 3°-4°C; at higher temperatures, the fruit will continue to ripen and quality deteriorates rapidly.

EGGPLANT - Solanum melongena

Harvest: From 75 to 90 days are required from transplanting to harvest of first fruits. Plants continue to produce under favorable conditions for some time. Plants can be rejuvenated by pruning back unproductive disease free plants and stimulating new growth. Applications of fertilizer may be necessary.

Maturity can be tested by pressing the thumb against the side of the fruit. If the indentation springs back to its original shape, the fruit is too immature. With increasing maturity the flesh softens. When the thumb pressure leaves an indentation, the fruit is ready for harvest.

Storage: Eggplant can be stored at 10°-15°C at 85-90% RH for about 10 days without much loss of quality. Storage below 10°C causes chilling injury; and after removal from such storage, pitting and decay occurs after several days at room temperature.

PEPPERS - Capsicum annuum

Harvest: From 60 to 90 days from transplanting, the fruits are ready for harvest. Bell peppers are harvested when they have attained full size and still green. This stage is comparable to the mature green tomato. The ripening process is similar to the tomato. Fresh chilies are harvested green, but for processing they are harvested ripe (red), as are pimientos and paprikas.

Storage: Peppers of the mature green bell type can be stored for 10-15 days at 7-10°C. Below these temperatures, chilling injury results in rapid decay.

CUCUMBER - Cucumis sativus

Harvest: For the fresh market, fruits are harvested before they have fully elongated and the seeds are still succulent. For pickling several stages of immature fruit are harvested. Depending on the temperature and variety used, 55-70 days are required from planting to first harvest.

Storage: Cucumber fruits held lower than 10°C suffer chilling injury. Cucumbers should be stored at 12°-13°C and 95% RH. Yellowing occurs at 15°C. Waxing or packaging in plastic film retards water loss.

MUSKMELONS, CANTALOUPES, HONEYDEW - Cucumis melo

Harvest: Cantaloupe maturity can be judged by the abscission zone (slip) which develops between the fruit and the peduncle; also there is a change in ground color from green to yellow and a slight development of aroma from the blossom end.

Honeydew also develops a change in color to yellowish white from greenish white and a waxy feel to the touch develops on the rind. A slight aroma around the blossom end is present when honeydews are ripe. Honeydews do not form the abscission zone.

For shipment both cantaloupe and honeydew are harvested before they are eating ripe. If stored a few days at room temperature, the cantaloupe fruit ripens naturally. The honeydew generally requires gassing with ethylene to ripen. After ethylene treatment the melon ripens; softening from the blossom end and forming aromatic compounds. The sugar content of cantaloupes ranges from 8 to 14%, whereas in honeydews it ranges from 10-16%.

Storage: Following harvest, cantaloupes should be cooled rapidly to 10°C. This is best accomplished by hydrocooling. Hard ripe cantaloupes should be stored at 4°-5°C to ripen further; 95% RH preferred. Cantaloupe does not require ethylene treatment to ripen properly.

Honeydews of different ripeness require different treatment as follows:

1. Unripe but mature melons (fruit with white background color which may have some light green,

MUSKMELONS, CANTALOUPES, HONEYDEW - Cucumis melo

Storage: (continued)

surface may be covered with fine fuzzy hairs; blossom end hard, no aroma, not springy). Gassing with ethylene (200 ppm) is essential at temperatures above 20°C for fruits to ripen.

2. Fruits that have initiated ripening (fruit with white background color and slight waxy surface: blossom end slightly springy; slight development of aroma). Gassing with ethylene (200 ppm) is not essential but is considered beneficial.

3. Ripe fruit (fruit creamy white in color and has a waxy surface; entire blossom end springy; at room temperature good aroma from blossom end, eating ripe). Needs no ethylene treatment.

4. Slightly overripe (early senescence). The surface color creamy white to pale yellow and quite waxy to touch. Flesh is soft and has strong aroma. Quality not good as (3) but still edible.

5. Overripe (senescent). Entire surface yellow and soft. Strong somewhat fermented odor. Flesh soft, stringy, and mealy. Usually not edible.

Honeydew melons need no precooling. After treatment of maturity (1) with ethylene, the fruit should be cooled slowly in 2 to 2 1/2 days to 16°C and further cooled to 7°-10°C and held 2-3 weeks at 85-95% RH. Chilling injury occurs when the fruits are held below 5°C. If melons are not eating ripe from storage, they can be further ripened at 20-27°C to the proper ripeness.

WATERMELON - Citrullus lanatus

Harvest: The fruit is harvested when the flesh is sweet but not overripe. When overripe the flesh becomes mealy and stringy. The following criteria are often used for ripeness: 1) the ground spot, light colored, or white spot where melon rests on ground, changes from white to a light yellow color; 2) by thumping, immature fruits give a high pitched sound; ripe fruits give a low pitched sound; 3) the tendril directly opposite the fruit penduncle changes from green to brown and may appear dry; however, ripe melons with criteria 1) and 2) sometimes have green tendrils. The best way is to plug or cut a few melons in several parts of the

field and taste and examine the flesh for ripeness, it can be assumed that most fruits of comparable size in the field are in the same stage of ripeness. The use of refractive index of the juice is a measure of percentage soluble solids. Good quality melons should have a soluble solids reading of a least 10.5% at the center or core of the fruit. This location is important as the soluble solids content varies with the location within the fruit; the highest is at the center and the bottom rind (ground spot) and the stem end the lowest.

Ripe fruits harvested during the early morning hours are turgid and may easily crack while those harvested later in the day are not quite as turgid and less apt to crack when handled.

Storage: Watermelon fruits being a warm season crop, can be subject to chilling injury. The recommended temperature is 13°-16°C for storage up to 2 weeks. For storage of longer than 2 weeks 7°-10°C is recommended. The flesh color fades at temperatures below 10°C. RH of 80-85% is recommended since water loss from the waxy rind is very low at the recommended temperatures.

SQUASHES AND PUMPKINS - Cucurbita spp.

Harvest: Summer squash are harvested while the fruits are very immature, usually 2-7 days after anthesis, the size depends on the market preference. Fruits should be continually picked off since fruits left to mature on the vines suppress pistillate formation. Care should be taken to avoid bruising or cutting harvested fruits.

Fruits of pumpkins and winter squash are allowed to mature on the vine. In temperate climates, if the fruits are mature, the rind is hard and the vines begin to senesce; they should be harvested before frost. A sharp knife should be used to cut the peduncle leaving about 2-5 cm on the fruit.

Curing: Cuts and bruises of mature fruits can be healed by suberization. This is accomplished at 27°-30°C and 80% RH for 10 days. The healing of cuts and bruises prevents decay organisms from entering the wounds. Following this period the temperatures should be lowered to 10°-15°C and lower humidity.

Storage: Summer squash can be held 1 week at 10°C and for only 2-4 days at 4°C; chilling injury occurs if held for several days at temperatures below 10°C.

Winter squash and pumpkins can be held 30-180 days, depending on the cultivar at 10°-15°C and 60% RH. If stored at temperatures greated than 15°C, respiration rate is high, resulting in loss due to shrinkage. The fruits should not be piled on top of each other as humidity increases, which results in decay.

SPINACH - Spinacia oleracea

Harvest and Storage

Harvest occurs when plants have reached good size, usually 35-70 days after planting depending on the season and climate. A plant ready for harvest has five to six fully developed large leaves. From 22-26 leaves develop from seedling to mature plant ready for harvest. The older leaves senesce as the plant grows. For quality spinach there should be no seed stalks or yellow leaves. Whole plants are cut at crown level for the fresh market; for canning, the leaves are cut (mechanically mowed) above the crown.

Harvested spinach stores best near 0°C and under very high RH; under these conditions they remain in excellent condition for 10-14 days.

The concentration of NO_3 in the petioles of spinach can reach toxic levels for humans. This is true when high amounts of nitrates and ammoniacal nitrogen is used to fertilize the crop.

ASPARAGUS - Asparagus officinalis

Harvest: It generally takes 2-3 years from seeding to harvest. The first cutting (2 years old) is very short, from 3-4 weeks; the three year old field is cut longer, for 8-10 weeks, after which the ferns (tops) are allowed to grow for the remainder of the season.

In the warm frost-free regions of the world (subtropics), asparagus plants have very short dormant periods, or sometimes none at all. Two harvest periods are possible, one in the spring and another in the fall. The ferns (tops) are allowed to grow between harvest periods to supply carbohydrates to underground storage roots.

A technique has been devised for the growing of asparagus in the tropics. The so-called "mother stalk" method, wherein four or five stalks of ferns are allowed to grow in order to provide the food needs of the plant, is being practiced in Taiwan. Every 3 or 4 months, new stalks are allowed to grow out into ferns as the older ones get diseased or start to become senescent. A year-round production of spears can be attained by this method with yields twice that by conventional methods practiced in the temperate region in a 4-5 month harvest period.

Storage: The recommended temperature for the harvested spears is 2°C at 90% RH. Under these conditions asparagus will keep for about 3 weeks.

SOURCES:

Yamaguchi, Mas. 1983. World Vegetables. Avi Publishing Co., Westport, Ct.

Ryall, A.L. and W.J. Lipton. 1979. Handling, Transportation and Storage of fruits and Vegetables. Avi Publishing Co., Westport, Ct.

APPENDIX D

U.S. APPLE GRADING STANDARDS

Apples are subject to five grades: U.S. Extra Fancy, U.S. Fancy, U.S. No. 1, U.S. Utility and Combination grades.

Some of the more common shipping containers for apples are cartons and boxes, loose pack, weighing approximately 38 to 42 pounds; cartons and boxes, tray-packed weighing 40 to 45 pounds and cartons, cell-packed, 37 to 43 pounds.

As a rule, nothing smaller than a 175 is marketed fresh. Extra-large apples will have a count of 48, 56, 64 or 72; large have a count of 80, 88 or 100; the count for medium is 113, 125 or 138; and small, 150, 163 or 175.

Carton counts with minimum diameters include: 2-1/4 inches, 180; 2-1/2 inches, 160; 2-5/8 inches, 140; 2-3/4 inches, 120; 3 inches, 96; and 3-1/2 inches, 80.

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