NICARAGUA

ARAP

Agriculture Reconstruction Assistance Program

COOLING TECHNOLOGIES FOR THE DEVELOPMENT OF THE NICARAGUAN PRODUCE INDUSTRY

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Introduction

The success of the produce industry development in Nicaragua depends on adequate postharvest cooling technology and sufficient cold storage infrastructure. Inadequate postharvest conditions result in rapid deterioration and quality losses in fresh fruit and vegetables. In order to preserve the market life of perishables, appropriate cooling and storage techniques must be followed. Maximum shelf life is attained by rapid removal of field heat (cooling) followed by holding the product at its desired optimum storage temperature. The benefits of cooling are realized only if the cold chain remains intact during the entire transportation and distribution process the product follows to consumption.

Consumers in both the Nicaraguan domestic market and in the U.S. are becoming increasingly demanding for consistent supplies of high quality produce. Appropriate cooling technology and infrastructure is critical to preserving the quality of harvested produce. The objective of this study was to assess the postharvest handling and storage systems used for produce items, and to determine what additional cooling infrastructure is needed.

A series of in-country visits and interviews were made in order to obtain the current status and condition of postharvest cooling equipment used for perishables in Nicaragua. Recommendations were made pertaining to the type of cooling systems needed to strengthen the Nicaraguan produce industry and their physical location. In addition, cost estimates were obtained for the recommended forced air-cooling systems and cold storage rooms.

Present Condition and Availability of Precooling Equipment in Nicaragua

There is a limited amount of cooling equipment currently available for perishables in Nicaragua and very little is state-of-the-art. In addition, the vast majority of the existing equipment is not designed to rapidly remove field heat, but rather only to hold product at a specific temperature. Some of the largest cold storage facilities in the country are run by APENN. They are located at the airport, in the Sébaco Valley, and in Jinotega. The facilities at each site are described below:
Managua International Airport

Las Mercedes Air Cargo Terminal
Km 10.5 Carretera Norte
Managua
Phone: 505-263-3151
Fax: 505-263-3152

This facility was opened in 1996. Three adjacent cold rooms are located inside an enclosed warehouse building adjacent to the airport. Each room can be set at different temperatures, although one is used for storing frozen products and is kept below 0 C. Therefore, it is not appropriate for storing fresh produce. The dimensions and refrigeration capacity of each room is:

Cooler #1:

- 30 x 20 x 10 feet
- two 12,000 BTU/hr evaporators (2 tons refrigeration capacity)
- temperature maintained at 3 to 4 °C

Cooler #2:

- 15 x 20 x 10 feet
- one 12,000 BTU/hr evaporator (1 ton refrigeration capacity)
- temperature maintained at 3 to 4 °C

Cooler #3 (used as a freezer):

- 30 x 20 x 10 feet
- four 12,000 BTU/hr evaporator (4 tons refrigeration capacity)
- temperature maintained at 0 to –10 °C

None of the cold rooms are equipped with high velocity fans for forced air-cooling. In addition, the refrigeration capacity in each room is minimal. The rooms were not designed with enough refrigeration to rapidly remove product field heat. Therefore, this facility is only appropriate for storage of products already cooled prior to arrival.

Valle de Sébaco
Planta Hortalizas, km 104
Carretera Panamericana
Phone / fax: 622-2206

This facility opened earlier in the year and consists of a 32 x 20 x 10 foot cold room inside an enclosed packinghouse facility. The cold room has two Bohn 1-ton refrigeration units for a total of 2 tons refrigeration capacity (24,000 Btu/hr.). It does not have sufficient ventilation capacity or refrigeration capacity to rapidly remove product field heat. It is currently being run at 8 ºC, as the refrigeration units do not have the capacity to maintain a 1-ºC temperature.

The third APENN cold storage facility is located in the Jinotega area. It was recently opened, but currently is not being utilized to capacity. There is a single cold room with dimensions of 20 x 10 x 10 feet. It has 15,000 BTU/hr refrigeration capacity (1.25 tons of refrigeration). The walk-in cold room is located inside an open-sided roofed building with an adjacent grading / packing area.

Additional room cooling facilities for perishables in Nicaragua include 3 cold rooms in the Carazo area operated by APRONOT. They are used for temporary storage of tropical fruit prior to processing into pulp or juice concentrate.

A single forced air cooler exists at one of the melon export operations. The only other cooling facility is a 1-pallet batch hydrocooler for asparagus at the farm of Agroindustrias Nicaraguenses de Alimentacion, Finca San Jeronimo, km 14 carretera Norte.

The Use and Need for Cooling Technology in the Nicaraguan Produce Industry

The key to success in the highly competitive perishables export business is the ability to provide the market with consistent supplies of high quality product at competitive prices. Proper postharvest cooling and temperature management helps to ensure that product quality is maintained and is an essential part of any successful horticultural crop export business.

Fruits and vegetables are living organisms that continue to respire, ripen, senesce, and begin to deteriorate as soon as they are harvested. To market a high quality product with a shelf life acceptable to the importer and buyer, the Nicaraguan grower and exporter must have the capability to remove the field heat immediately after harvest and hold the product at the proper temperature and relative humidity until it reaches its destination market.

Many fruit and vegetable growers throughout Nicaragua do not utilize proper postharvest cooling and storage procedures. This results in less than optimal product quality upon arrival at the destination market, and in some cases rejected or downgraded loads. Lack of postharvest infrastructure is particularly evident among limited resource, low-volume producers. Many do not understand that export markets require extremely high quality product, quite different than the average or poor quality found in local domestic markets.

Competition for the lucrative North American market is intense. Each year more producers within a given country, and additional countries, export horticultural crops to North American market destinations. Buyers demand a consistent supply of high quality product. If they cannot get it from one country (or supplier), they will source it from elsewhere.

Investment in postharvest infrastructure is often not thought of as an essential component of a horticulture crop export business. Consequently, considerable market share is lost and significant economic losses occur. In order to develop a more sustainable and profitable horticulture industry in Nicaragua, a continuous effort is needed to convince the grower/shipper that investment in cooling and storage infrastructure is as important as any other aspect of the business. Investments to save the marketability of fruits and vegetables after harvest are not expenses. They will pay for themselves many times over. Even a partial reduction in postharvest losses can significantly improve the grower's net return. The axiom, "one must spend money to make money" rings ever so true in the perishables business. However, for many limited resource growers, the investment does not seem justified because of the small volume of product harvested. However, there are available relatively low-cost cooling systems which can be imported or fabricated locally and if centrally located, can be shared and utilized by a number of growers. The objective of this document is to provide appropriate postharvest cooling methodology and infrastructure recommendations to support the continued development of the non-traditional horticulture export industry in Nicaragua. Specific recommendations are made on type of cooling methodology most appropriate for Nicaragua, quantity and capacity of the cooling systems needed, and where to locate the cooling infrastructure.

Appropriate Postharvest Handling Begins With Proper Harvesting

Produce should be picked during the coolest parts of the day and kept in the shade away from direct sunlight. It is very important to keep the product as cool as possible after harvest. Lower product pulp temperature will require less energy for cooling and allow for extension of shelf life.

Smaller capacity refrigerated trucks should be used for product transport to centralized packing and cooling facilities. It is best to move perishable product as quickly as possible to the cooling facility rather than delay the initiation of field heat removal while waiting to fill a large truck in order to make a single trip. Several options exist for facilitating this rapid movement of product to the cooling facility. One consists of procuring a medium sized truck (e.g. 10 pallet capacity) with an enclosed insulated refrigerated box in order to transport the perishables from the farm sites to a nearby centrally located packinghouse/cooling facility. A more extensive cooling infrastructure is desperately needed to significantly develop the export potential of fresh fruits and vegetables. This will supplement APENN's two existing transport vehicles and could be positioned in the Leon-Chinandega area, an underutilized, but potentially strong area for horticultural crops in the future. Another option consists of obtaining mobile cooling systems to be used when and where appropriate, according to season and crop. However, the costs for mobile forced air cooling units are very high and there is not enough critical volume of products available to justify this type of cooling method in Nicaragua at the present time.

Adding additional permanent cooling units in multiple strategic locations throughout the country is the best approach for the Nicaraguan perishables industry. It will allow for significantly improved postharvest temperature management of horticultural crops. The recommended locations include Leon, Sébaco, Jinotega, and the Managua airport.

Cooling Immediately After Harvest Is Essential

Proper temperature management is the single-most important factor influencing postharvest life of a product. Proper temperature management begins with the rapid removal of field heat immediately after harvest. Cooling is essential to preserve market quality of highly perishable horticultural commodities. A few hours delay before starting of cooling can result in irreversible deterioration and product quality loss. An old rule of thumb says that you lose 10 hours of shelf life for every hour the product remains at field temperature after harvesting. The positive benefits of cooling include: retardation in ripening, maintenance of a firm texture, reduction in the growth of decay producing microorganisms, less product wilting, less ethylene production, and preservation of product quality. Cooling generally represents a single controlled handling step after harvest and may be accomplished using several different techniques, including: room cooling, forced-air cooling, hydrocooling, contact icing, and vacuum cooling. All involve the transfer of heat from the commodity to a cooling medium, such as water, air, or ice.

It is also important to remember that the benefits of cooling will be lost if the commodity is not kept properly refrigerated after cooling. 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. The refrigeration capacity needed for fast cooling is substantially higher than for cold storage.

The choice of cooling methods depends on the following factors:

- The nature of the product. Different types of produce have different cooling requirements. For example, strawberries, raspberries, asparagus, baby corn, and broccoli require rapid cooling after harvest to near-freezing temperatures (e.g. 0.5 ºC), whereas bananas, mangoes, and honeydew melons are sensitive to chilling injury and do not require such a rapid rate of cooling and would be damaged by such low temperatures. Likewise, because of disease problems that can be caused by wetting of certain products (i.e. onions, garlic, berries), hydrocooling or icing is not appropriate.
- Product packaging requirements. The package type and design can have an effect on the method and rate of cooling.
- Product flow capacity. If the volume of produce to be cooled per day, or per hour is large, it may be necessary to use a faster cooling method than would be used for lower volumes (or increase the air flow with respect to forced air cooling).
- Economic constraints. Construction and operating costs vary among cooling methods. The expense of cooling must be justified by improved product marketability. When more than one precooling method meets the commodity requirements, the cost difference between cooling types is a major consideration. Likewise, equipment and spare parts availability enter into the decision.

Cooling Methods Used for Perishables in Nicaragua

Several types of cooling methods are currently being used for fruits and vegetables, including room cooling (the predominant method), forced air cooling (used only by the melon exporters), and hydrocooling (used by one asparagus exporter). Icing is widely used in the seafood industry, but not for horticultural products. Vacuum cooling is not available in Nicaragua. A brief description follows of the different cooling methods.

Room Cooling

Room cooling involves placing field or shipping containers of product in to an insulated cold room (usually 0.5 to 1.0 ºC) equipped with refrigeration units and allowing cold air to circulate over the product. Cold air from evaporator coils circulates cool air around the containers and gradually cools the product. Typically refrigerated air is blown horizontally just below the ceiling, sweeping over and down through the containers of the product below. Upon reaching the floor, it moves horizontally into the return vent to be recycled. Room cooling is used by many small vegetable, fruit, and cut flower growers. It is the main method used in Nicaragua. The cookers operated by APENN at the airport, in Sébaco, and in Jinotega are all room coolers.

However, most room coolers, including those of APENN have neither the refrigeration capacity nor the air movement needed for rapid cooling. Air velocities of 200 to 400 ft/min (65 to 130 meters/min) around the containers are required to minimize the length of time required for cooling. APENN's coolers do not have this capacity.

Cartons should be stacked loosely to provide exposure to cool air. The outside of the carton cools first, followed by inner layers of product. It takes much longer than other methods of cooling and is unacceptable for product which is highly perishable. Room cooling requires days for packed products, but can be satisfactory for unpacked products with good exposure to cold air. Room cooling also requires more floor space and labor. The main advantage of room cooling is that it is a low-cost, low-technology system that allows produce to be cooled and stored in a single room, decreasing the amount of handling required and little extra equipment is needed. The main disadvantage of room cooling is that it removes field heat too slowly (taking from 12 to 24 hours) to maintain quality for many crops. For dense products that are packed tightly into shipping containers, room cooling can take 36 to 48 hours) C degrees or more.? to reduce product temperatures 20 A much more rapid cooling rate is recommended for most perishables (usually less than 4 hours) so that product quality is preserved. Unfortunately, faster rates of cooling usually require additional expenditures for machinery and/or equipment. Thus, while room cooling is preferable to not cooling, room cooling is the least desirable cooling method because of the long time it usually takes to remove a sufficient amount of field heat. Increased product moisture loss is also more likely due to greater fluctuations in room temperature and prolonged exposure to high airflows. Sweet onions are one of the few horticultural export crops from Nicaragua that can be satisfactorily cooled using room cooling.

Small room coolers can be constructed by growers, purchased in prefabricated form, or purchased as used refrigerated transport vehicles (e.g. trailers or marine containers). However, refrigerated transport vehicles rarely have enough refrigeration capacity to rapidly precool produce. If rapid cooling is needed, extra refrigeration capacity must be added. Moreover, transportation vehicles are too narrow for the frequent product movement needed in a precooling facility. A separate self-constructed room is much more convenient for precooling operations.

Forced-air (Pressure) Cooling

Forced-air cooling differs from room cooling in that forced-air cooling moves the air around the individual product units (e.g. individual fruits) rather than merely around the exterior of the container. Depending on the temperature, airflow rate, and type of produce being cooled, forced-air cooling can be from 4 to 10 times faster than room cooling.

Forced-air cooling is adaptable to the widest range of commodities and is most often recommended for small-scale operations, which typically may handle several different products. Forced-air cooling achieves rapid cooling by forcing cool air through ventilated containers and across the product. Usually forced air cooling is done in a separate, dedicated area within a cold storage room. However, it is simple to convert a room cooling facility into forced air cooling by adding additional fans and increasing the size of the refrigeration unit to accommodate the

additional cooling load. The fans are normally equipped with a thermostat that automatically shuts them off as soon as the desired produce temperature is reached to reduce energy consumption and water loss from the produce.

The most common method of forced air cooling is accomplished by lining up parallel, palletized stacks of filled ventilated containers, with the parallel stacks of product separated by several feet of open space (usually the diameter of the fan). Then, a heavy fabric cover or tarp is placed over the parallel stacks (centered over the open space between stacks of product). This cover restricts the direction from which air can escape. In effect, you have created a "tunnel" that restricts the direction of the air. The fabric cover extends to a powerful fan placed in the front middle section and centered between the parallel stacks of containerized product. The fan pulls cool air across the product and product cooling is achieved. The fans are significantly more powerful (5 to 20 hp) than the fans used to blow air over the coils in room coolers. They develop high air flow at relatively high static pressure.

Because air is forced through the product packages by the difference in air pressure between the opposite sides, it is necessary to fill the containers properly and stack them in such a way as to minimize voids and openings. Openings between containers allow the air to circumvent the produce, reducing cooling efficiency. Double stacking of pallets should be avoided since even powerful forced-air fans have difficulty pulling air through more than one pallet width (3 to 4 feet) of produce.

Not all fans are designed to move air at the volume and static pressure required for forced-air cooling. (Static pressure in this case is the resistance to air movement presented by the packages of product). Fan curves giving pressure and volume data are available from the manufacturer for most commercial or industrial fans. There is an inverse relationship between pressure and airflow rate. In addition to airflow rate and temperatures, several other variables influence the time required to cool product with forced air, including the size and shape of the product and the configuration and venting of the containers. The area of container vent holes should equal at least 5 percent of the total side panel area. The greater the airflow distance, the greater the pressure drop and the longer the cooling time for a given airflow. The optimum airflow rate and duration for proper cooling vary with the type and amount of product being cooled. An airflow rate of between 1 to 3 cubic feet per minute (1 to 3 liters/sec/kg) per pound of product at 1/2 inch static pressure is the recommended range which will adequately cool all Nicaraguan produce items. An airflow rate of 1.4 cfm/lb Of product is recommended for berry cooling (at 0.5 inches static pressure), while 2,500 cfm per pallet at 1.5 inches static pressure is recommended for larger commodities like melons. A simple way to obtain airflow control is to operate fan motors with a variable frequency motor speed controller that produces a wide range of airflow rates.

It is also a good idea to control the fan with a line-voltage thermostat mounted in the airstream. The thermostat will stop the fan when the produce has cooled to a predetermined point, thus saving energy. It will also reduce the drying effects of the cooling air because it will not allow the fan to keep running for an extended period after the product has cooled.

Axial-flow (propeller) and centrifugal (squirrel cage) fans can both be used for forced-air coolers. Most axial fans are better suited for systems where the fan operates against less than 5 cm (2 in) water column pressure. Centrifugal fans can be selected to operate against much higher pressures and are generally quieter than axial flow fans.
Narrow air-supply and air-return channels in tunnel coolers cause uneven pressure drop across pallets and uneven cooling. The channels should be wide enough so that air speeds (measured with an anemometer) are less than 7.5 m/sec (1,500 fpm). A narrow air-supply channel will cause bottom boxes in pallet loads to cool slower than top boxes, and a narrow air-return channel will cause pallets farthest from the fan to cool slower than pallets closer to the fan.

Besides measuring temperature variation, another way to determine poor air-channel design is to measure the pressure drop (with a pressure gauge) across pallets at various heights in individual pallets and at the same height for pallets at various distances from the cooling fan. Large differences in pressure drop indicate differences in airflow through pallets.

Some growers use refrigerated trailers or used marine containers for cooling produce. These units normally have 2.5 –3.5 tons of refrigeration capacity. This is not enough refrigeration capacity to rapidly remove field heat from a commodity. In addition, they do not have enough air flow (typically 102 m^3/min or 3,600 cfm) to get the cool air in contact with the produce for rapid cooling. Circulation capacity is designed for maintaining, not lowering product temperatures. Air is circulated by a fan in the refrigeration unit and aided by an air delivery chute over the top of the load. Loads must be secured away from rear doors and away from flat side walls to allow air to circulate down over the load. A supplemental fan can be put inside the refrigerated trailer and adapted to increase cooling rate. Many new trailers and marine container vans have vertical, bottom-to-top airflow through the load compartment, making them more effective for cooling fresh produce. They provide better and more uniform product temperatures because they have a more constant and uniform airflow, greater capacity to circulate the air through the load, and shorter air channels through the load. Load patterns should provide the air channels needed to maintain uniform product temperatures in the load. Tight loads restrict air circulation and thus enhance product warming. Air circulation is much greater and product transit temperatures are more uniform in palletized loads or those on wood racks than in on-the-floor loads.

Forced air cooing is an effective method of cooling a wide diversity of fruits and vegetables, including berries, melons, mangoes, pineapples, and most vegetable crops. In addition, it is popular with small-scale producers because it is relatively inexpensive to install and operate.

In additional to controlling the temperature and airflow, it may be necessary to control the humidity. Moving air tends to remove water from the surface of produce, causing wilting, shrinkage, and general loss of quality and value. Most produce items require a relative humidity in the range from 90 to 98 percent if they are to be kept for more than a few hours in cold storage before shipment.

Low humidity may be corrected by various types of commercial humidification systems. Many operators simply hose down the floors from time to time, but this approach may not be consistent with good sanitation nor particularly effective in many situations. On the other hand, excessively high humidity for long periods can also be detrimental because it encourages the growth of molds and fungi.

The most versatile and appropriate cooling method for the Nicaraguan produce industry is forced air. It is the most adaptive method to the widest range of commodities. The other techniques of cooling are either too expensive or are not nearly as versatile as forced-air cooling.

Hydrocooling

When warm produce is cooled directly by chilled water, the process is known as hydrocooling. Hydrocooling is an especially fast and effective way to cool produce, primarily because of the much higher heat transfer coefficient of water than air.

Many types of produce respond well to hydrocooling. Produce items that have a large volume in relationship to their surface area (such as sweet corn, asparagus, cantaloupes, cucumbers, peppers, and many fruits) and that are difficult to cool can be quickly and effectively hydrocooled. Unlike air cooling, no water is removed from the produce. In fact, slightly wilted produce may sometimes be rehydrated by hydrocooling. At typical flow rates and temperature differences, water removes heat about 15 times faster than air. Hydrocoolers are able to cool a large amount of produce rapidly.

Water is chilled by a mechanical refrigeration unit or by having ice placed in it and then being directed to flow across the product through a series of spaced spray nozzles. Water temperature should be kept at 0 to 0.5 ºC. Even chilling-sensitive products can be cooled with 0 ºC water if cooling time is limited.

Water supply should be potable, from a clean well or domestic supply. Water from streams or ponds is rarely clean. Because nearly all coolers re-circulate water, the cooler must be designed to control disease organisms that enter the system from incoming product. Chlorine, a powerful oxidizing agent, is commonly used to disinfect the water. Water near 0 ºC (32 ºF) requires 100 to 150 ppm of available chlorine and a pH near 7.0.

Hydrocooling methods differ in their cooling rates and overall process efficiencies. In addition, hydrocoolers vary in the method of cooling that is used and the method of moving or placing the product so that water comes in contact with it. Hydrocoolers can be separated into two general designs, conveyer versus batch, based on whether or not the product is stationary within the cooler. Conveyor-type hydrocoolers can be further subdivided into shower and submergence types.

Conveyor-Shower Hydrocooler

A conveyor-shower hydrocooler allows the product, either in bulk bins or in cartons, to pass along a conveyor under a shower of chilled water. Warm product is placed on one end of the conveyor, and cooled product is removed at the opposite end. The rate at which the conveyor, and thus the product is advanced through the shower is about 1 foot per minute and may be varied on most hydrocoolers to suit conditions. The length of the conveyer is critical and depends on the volume of product to be cooled and the amount of cooling required (initial versus final product temperature). The conveyor speed can be increased or decreased to adjust for different cooling rates and initial temperatures.

Hydrocooling requires large quantities of water to be passed by the product. Water flow rates of 20 gallons per minute per square foot of active cooling area are recommended (e.g. 800 liters/min/m^2).

Most conveyor-shower hydrocoolers are high production units with large refrigeration systems and heavy-duty components. Because of their relatively high cost, they must be operated for considerable periods each year to be economically justified. These hydrocoolers would need to be used by more than one grower (or with more than one crop) or by a co-op of growers and packers in order to be cost effective in Nicaragua.

Batch Hydrocooler

Batch hydrocoolers are enclosures that do not have conveyors. Cartons or bulk bins of produce are loaded into the enclosure and put directly under a metal water distributor pan with numerous holes. The door of the enclosure is then closed, and large quantities of chilled water are distributed over the top of the produce, collected at the bottom, recooled, and recycled. The product remains stationary during the cooling process. At the end of the cooling period, the pump is stopped, the cooled product is replaced by another load of warm product, and the process is repeated. Batch hydrocoolers need the same water flow rates as conveyor-shower hydrocoolers.

Most batch hydrocoolers can cool only one pallet of produce at a time. These hydrocoolers generally have a smaller capacity than conveyor hydrocoolers. They are generally less expensive and easier to construct. They are better suited for growers with a limited amount of produce who cannot economically justify a larger unit.

Hydrocoolers should be designed so that the distance between the water distribution pan and the top product never exceeds 15 to 20 cm (6 to 8 in). Leafy vegetables and other vegetables such as broccoli and asparagus are subject to water-beating damage if the drop height exceeds this range.

Conveyor-Immersion Hydrocooler

Conveyor-immersion hydrocoolers are large, shallow, rectangular tanks that hold moving chilled water. Crates or boxes of warm produce are loaded into one end of the tank and moved by a submerged conveyor to the other end where they are removed. The primary drawback to submersion is that when the product is held in bulk bins, water movement is greatly restricted. A second problem with submersion is that many plant products have a density less than water, and as a consequence, they float. To prevent floating, some mechanical means of maintaining the product under water is required.

The hydrocooler and mechanical refrigeration units are expensive to purchase, have high operating costs, and are quite energy inefficient. Their major advantage is that they provide rapid, quick and complete precooling for products that can come into direct contact with chilled water.

Enough refrigeration must be supplied to keep the water temperature at about 1 ºC despite variation in initial product temperature. Mechanical refrigerated hydrocoolers are easiest to use, but the initial investment is high. Alternatively, block ice does not require a large initial investment but is more difficult to handle, transport, and use. However, using block ice to chill water tends to be very energy inefficient.

Typical cooling times for hydrocooling range from 15 to 45 minutes. The principal perishable products appropriate for hydrocooling in Nicaragua are asparagus and cantaloupes.

Ice Cooling

Package icing is an old method that involves placing finely crushed ice within shipping containers. It can be effective in cooling products that are not harmed by contact with ice. Sweet corn, broccoli, Brussels sprouts, radishes, green onions, carrots, and cantaloupes are products commonly marketed with crushed ice in shipping containers. Ice rapidly removes heat when applied to produce and continues to absorb heat as it melts. Crushed and liquid ice cooling methods can be used effectively by growers with both large and small operations.

Cooling is accomplished by filling containers with prescribed amounts of ice or a water-ice slurry combination called liquid ice. Cooling effectiveness increases with increasing contact between the ice and product. Rapid cooling occurs with ice, but the cooling rate slows as the ice melts and less ice remains in direct contact with the product. Crushed/liquid ice is placed in the container automatically using an automatic dispensing machine or manually with a shovel. If crushed icing technology is used, it is usually necessary to build and operate an ice storage bin so ice can be stored for later use. Liquid ice gives a much greater degree of initial contact between the product and the ice and it can be applied after the boxes have been palletized. If the produce has been packed and palletized in the field, the water and ice mixture can be alternatively pumped from a hose into the hand openings of each container. This method is fast and effective, and it does not require the cartons be opened or removed from the pallet. With the proper

equipment, two workers can liquid ice a pallet of 30 cartons in about 5 minutes. The liquid ice slurries range in water to ice ratio from 1:1 to 1:4. The liquid nature of the slurry allows the ice to move throughout the box, filling all of the void volume of the container, reaching all the crevices and holes around the individual units of the product. After removal from the icing machine, the water drains, leaving a relatively solid mass of crushed ice in which the produce is imbedded. The principal advantage of liquid icing is the much greater contact between the ice and product afforded by this method. When the boxes are palletized prior to application, proper orientation of the openings is required for an unrestricted flow of ice throughout the load. Heavily waxed cartons with bottom drains or wire-bound wooden crates should be used with ice.

Icing is relatively energy inefficient and an expensive cooling method. One pound of liquid ice will cool about 3 pounds of produce from 29^{o}C to 5^{o}C.

Icing has limited practicality for use on Nicaraguan export crops. Although portable ice makers are available for packing shed or field use, it is very expensive to make ice in Nicaragua. In addition, a primary disadvantage of icing products for which ice can be safely used is the weight of the ice substantially increases the shipping weight. C), the? For relatively warm produce (i.e., 35 additional weight may equal 35-40% of the weight of the product. Perhaps the only export crop in which icing may be useful would be cantaloupe, as some importers require the melon cartons to arrive with ice in them. However, there are better and cheaper cooling methods available. In general, I do not recommend icing for Nicaraguan exports.

Vacuum Cooling

Vacuum cooling is achieved by enclosing vegetables in an air-tight chamber and rapidly pumping out air and water vapor. Water is vaporized in a vacuum chamber under low pressure; thus, cooling is accomplished by evaporation of water from the product surfaces. As the pressure in the chamber is reduced, evaporation continues. If the pressure is reduced to 4.6 mm mercury and evaporation continues for a sufficient time at that pressure, a commodity temperature of 0 ºC (32 ºF) will be reached. At ordinary atmospheric pressure (760 mm mercury), water boils at 100 ºC (212 ºF). However, if the pressure is reduced to 4.6 mm mercury, water boils at 0 ºC. Cooling is accomplished in a vacuum cooler by literally boiling water off the product. The conversion of liquid water to a gas absorbs heat. Because evaporation is a surface phenomenon, products with large surface-to-volume ratios are the most effectively cooled (e.g. leafy crops such as lettuce, cauliflower, brussel sprouts).

The vacuum chambers used vary greatly in size. The small, portable units have a capacity of a few pallets, whereas the large, stationary ones each hold up to two container loads. The principal disadvantages of vacuum cooling are the high initial equipment cost and the need for skilled operators. Vacuum coolers typically need eight to ten months use per year to justify the unit cost. They have only limited application to most types of export crops from Nicaragua. It is not practical to use vacuum cooling in Nicaragua because other less expensive and more versatile cooling options are available. Therefore, I do not recommend vacuum cooling.

Cold Storage

Cooling and storage are two separate operations. The specific requirements for achieving fast, uniform cooling must be considered independently of the cold storage requirements. Refrigeration capacity needed for fast cooling is substantially greater than for cold storage. A combination of rapid cooling and subsequent cold storage and transport of the commodity at its optimal low temperature will maximize the market life potential for that commodity. The cold chain must be continuously maintained after cooling in order to preserve product quality and maximize shelf life. The forced-air cooler can be a part of the cold storage room if adequate refrigeration capacity is provided for both cooling and storage needs. The length of storage for most commodities will be short, since the objective is to send them to the export market as soon as possible.

Determination of Refrigeration Capacity

The refrigeration system must be sized with enough capacity to handle heat removal from a number of different sources. The main source of heat that needs to be removed after harvest is the field heat of the commodity. This is determined by the following formula:

> Btu (heat) = weight (lbs) of product x specific heat (of product) x temperature (ºF) difference between pulp Tº and final desired storage temperature.

The ratio of heat required to raise the temperature of a given weight of fruit or vegetable to that required to cause an equivalent rise in the same weight of water is called its specific heat. It is necessary to know the specific heat of a product to calculate the refrigeration load during the cooling step. It can be estimated from the following equation.

> Specific heat = 0.008 x (percent H_2O in product) + 0.20

For example, the specific heat of strawberries, with a moisture content of 90%, is 0.008 x 90 + 0.20 = 0.92. The specific heat above freezing for various fruits and vegetables is given in the Appendix Tables.

An additional source of heat that needs to be taken into account when determining refrigeration capacity requirements is the heat of respiration (vital heat). All living organisms give off heat during the respiration of carbohydrates to CO_2 and H_2O. The amount of heat varies with the commodity and increases with temperature.

Other sources of heat that add to the total refrigeration capacity requirement include heat leakage through room surfaces and open doors; heat produced by electric motors, lights, mechanical handling equipment, and workers; and heat stored in the empty containers. The refrigeration requirement for these miscellaneous sources of heat is generally considered to be 25% more than the refrigeration requirement to remove the field heat.

The refrigeration load is commonly referred to in tons of refrigeration. One ton of refrigeration is equivalent to 12,000 Btu/hour (12,660 kJ/hour).

The refrigeration requirement during cooling must be based on peak refrigeration load. This peak usually occurs when outside temperatures are high and warm product is being cooled. The peak refrigeration load depends upon the amount of commodity received each day, the temperature of the commodity at the time cooling is initiated, the specific heat of the commodity, the final temperature attained, and the infiltration of non-product heat sources into the cooling environment.
The total refrigeration requirement is determined by summing the BTU's from 1) field heat removal, 2) vital heat (respiration) removal, and 3) miscellaneous heat sources. For example, if we have 1000 lbs of strawberries at a field temperature of 85 ^oF, what will be the refrigeration requirement to cool them to 33^oF.

1) Heat needed to be removed to cool the strawberries to 33 ^oF:
BTU = 1000 lbs x 0.92 (specific heat) x 85^oF - 33^oF
= 1000 x 0.92 x 52
BTU = 47,840

2) Heat needed to be removed due to strawberry fruit respiration:
200 mg/kg/hr = respiration rate at 85^oF
15 mg/kg/hr = respiration rate at 33^oF
200 mg/kg/hr x 220 (factor) = 44,000 BTU
15 mg/kg/hr x 220 = 3,300 BTU

Let us use an average respiration rate of 107 mg/kg/hr for the respiration rate basis (midway between 85^oF and 33^oF)

Therefore:

107 mg/kg x 220 = 21,400 BTU

3) miscellaneous heat removal:

25% of source 1)

BTU = 47,840 x 0.25

BTU = 11,960

Total BTU's needed to be removed:

47,840 + 21,4000 + 11,960 = 81,200

81,200 12,000 BTU 1 hr = 6.77 tons of refrigeration?BTU needed

- Always plan for enough refrigeration capacity to meet peak volume cooling needs.
- Convenient cooling interrelationships include:

- 1 ton of refrigeration requires about 1.5 horsepower of compressor capacity at 32 ºF (0 ºC).
- 1 ton of refrigeration equals about 3.4 kw of refrigeration
- 4 kw of refrigeration requires about 1 kw of compressor capacity.

The cost for a new mechanical refrigeration unit is about $1,500 per ton (12,000 BTu/hr) in the U.S.

Cooler Management

If more than one commodity is to be cooled, it may be necessary to provide more than one cooling room. One room may be kept at 0^{o}C and another at 7 ^{o}C for the different temperature requiring commodities. It is recommended to have available two different storage temperature rooms at the Managua airport. One should be at about 7 – 10 ºC and the other at 0.5 – 2.0 ºC. Cooling facilities should be designed to remove field heat quickly. Refrigeration capacity needed for fast cooling is substantially higher than for cold storage. Cooling and storage are two separate operations that have vastly different refrigeration requirements.

Air circulation inside cold storage room should be sufficient to remove the heat produced during respiration, as well as remove the heat, which infiltrates into the room. Generally from 0.06 to 0.12 m^3/min of air per metric ton of product (20 to 40 cfm/ton) is adequate. This assumes proper container stacking inside the room to allow air movement past one or two sides of each container. It also assumes the product was completely cooled prior to storage.

Plastic strips hung on the inside of the cold storage entrance should be used in addition to commercial refrigeration doors. This will reduce the amount of warm, humid air drawn into the cooler when outside doors are opened for loading. Doors should be open as little as possible. Air leaks around doors or other openings should be sealed to reduce energy costs.

Relative Humidity (RH)

Because all fruits and vegetables are subject to shrivel, a high RH is essential in the storage room. It is recommended that most commodities be stored between 90-95% RH. Exceptions would be onions and garlic. High RH should be obtained by the use of a mechanical humidifier.

A system capable of supplying 4 L of water/hour/ton of refrigeration should be able to maintain 95 percent relative humidity under any reasonable conditions.

Packaging Systems to Maintain the Cold Chain in Transit

Maintenance of low temperatures during transport is a critical factor in maximizing postharvest life. There are several ways to maintain the cold chain during transit of highly perishable air-freighted products (e.g. berries, baby vegetables, cut flowers). The most common methods are to use styrofoam-insulated E-containers with gel packs or thermal blankets as a pallet overwrap.

An E-container is simply a large single or double-wall corrugated fiberboard box lined with at least 18 mm of styrofoam on all 6 sides. Gross weight of the E-container ranges from 250 to 290 lb. (115 to 132 kg). The box should have a bursting strength of at least 275 pounds per square inch. The top is insulated and sealed with a corrugated fiberboard cover. The dimensions of a standard E-container bottom used for berries are 99.6 cm long by 74.8 cm wide by 77.5 cm high. Gel packs are frozen gels enclosed in a plastic bag which are put inside sealed E-containers to maintain the cold chain during transit.

Another option for maintaining the cold chain during transit is to stack the cooled flats on a pallet (with a bottom sheet on top of the pallet) and overwrap and cover the flats with an insulated thermal blanket. Thermal blankets are made of thin insulated polyethylene and foil laminated insulation material. The foil reflects ambient heat from the outside surface while the air pockets inside the insulation material prevent the cool air on the inside surface of the thermal blanket from escaping. They can be purchased to fit a standard 100 x 120 cm pallet. Thermal blankets can maintain a temperature of 3 ºC within the pallet for up to 36 hours.

Transportation Modes for Perishables from Nicaragua to the U.S.

The method of transportation used for fresh fruits and vegetables exported from Nicaragua depends on the degree of perishability of the product. Highly perishable products require air freight, and are all shipped from Managua International Airport. Airlines providing direct service to the U.S. include: UPS/Challenge Air Cargo (via Miami); Fine Air Cargo (via Miami); American Airlines (via Miami); Continental Airlines (via Houston); and Grupo TACA (via San Salvador to Miami, Houston, or New Orleans). Air cargo rates for quantities over 500 kg range from $0.45/kg on American Airlines to $0.55/kg on UPS/Challenge Air Cargo. Lift capacity is adequate at the present time.

Less perishable product like melons are trucked in a container up to Puerto Cortez, Honduras or down to Puerto Limon, Costa Rica to be sent on a container ship. There is currently no acceptable Atlantic-coast seaport in Nicaragua for perishables. Therefore, exporters have to pay an extra $800 - $900 per container just for the inland freight cost to Puerto Cortez or Puerto Limon. Sea-Land / Maersk offers regular bi-weekly service to Miami.

Local Suppliers of Refrigeration Equipment

There are no manufacturers of precooling equipment in Nicaragua. However, there are several companies that act as in-country distributors of the major international brands of refrigeration equipment (i.e. compressors, evaporators, condensers, etc.). A listing of the local representatives and suppliers of refrigeration equipment follows. The companies are concentrated in metropolitan Managua.

Ayre & Cia., Ltda.

Shell Centroamerica
½ Cuadra al Lago
Managua
PBX: 278-3516
Fax: 278-1342
The company represents various manufacturers, including York, Bohn, Tecumseh, and Classic.

Cannica, S.A.
Managua
Telefax: 222-2998
The company distributes refrigeration equipment and cold rooms.

Coirsa
Calle 14 de Septiembre P. del H.
1 ½ Calle al Este.
Managua
Phone: 248-3877
Fax: 249-6473
This company supplies refrigerant gases, copper tubing, capacitators, expansion valves, and compressors. They are dealers of Genetron and Danfoss brands.

Commercial Guerrero & Cia. Ltda.
Shell Ciudad Jardin 80 varas arriba
Casa S-37
Managua

PBX: 249-1360
Fax: 249-9075
This company supplies a diverse line of refrigeration equipment. They distribute equipment from the following companies: Embraco, Tecumseh, Atlas, Ruud, and Alco.

Commercial Mena & Mena Cia. Ltda.
Villa Don Bosco F-329
Costado Este Mercado
Managua
Phone: 248-2603
Fax: 249-1525
This company offers a wide line of refrigeration equipment.

Etienne Refrigeracion
De Los Ranchos 7 calle al Sur
75 Varas Abajo, Altagracia

Managua
Phone: 266-4393
Fax: 266-1023
This company supplies cold rooms and a wide diversity of refrigeration equipment. They are distributors of York brand.

Nicafrio
Managua
Phone: 278-6343
This company distributes Artic brand room coolers.

Refricentro
Ciudad Jardin L-3 de la Gasolinera Shell
3 ½ Calle al Sur Avenida Central
Managua
Phone: 244-0175
Fax: 249-7740
This company offers a full line of refrigeration equipment for commercial and domestic needs. They distribute Tecumseh, Copeland, and Embraco brands.

Refryaire T & T Cia. Ltda.
Iglesia Santa Ana
1 ½ Calle al Lago
Managua
Phone: 266-0252
Fax: 266-0251
This company distributes Copeland, Tecumseh, and Embraco brands of refrigeration equipment. They also supply cold rooms.

Sernisa
Clinica Las Palmas
1.5 Calle al Noroeste
Managua
Phone: 268-1149
Fax: 266-0517
This company distributes Sabroe and Danfoss refrigeration equipment. They supply compressors, cold rooms, water coolers, and ice machines.

Fogel de Nicaragua, S.A.
Carretera Norte km 5 ½,
(semaforo Portezuelo)

300 m al Lago
Managua
Phone: 249-6330
Fax: 249-0810
This company supplies cold rooms and small commercial refrigeration units.

Regional Suppliers of Refrigeration Equipment

COSTA RICA

Consorcio Poder del Mar, S.A.
Barreal de Heredia
Heredia
Phone: 506-239-3233
Fax: 506-239-3087

Ersa
San Jose
Phone: 506-443-2315
Fax: 506-442-9142

This company supplies cold rooms for industrial purposes.

Mycom Centroamerica, S.A.
Apdo Postal 167-4003
San Jose
Phone: 506-391-1316
Fax: 506-220-1667
This company supplies compressors, condensors, evaporators, ice machines, and designs cold rooms. The company manufactures and designs a diversity of refrigeration equipment.

Refrigeracion Polaris
Barrio Pilar Guadalupe
San Jose
Phone: 506-225-5258
Fax: 506-225-1878

GUATEMALA

El Artico, S.A.
Calz A. Batres 40-68
Zona 11

Guatemala City
Phone: 477-3804
Fax: 477-3805

HONDURAS

Refri-Trans S.A.
Km 8 Cr a La Lima
Frente Cerro El Polvorin
San Pedro Sula
Phone: 559-8062
Fax: 552-8389

International Suppliers of Cooling and Refrigeration Equipment

Due to the highly specialized nature of precooling equipment for perishables, it is often easier to procure the components directly from the foreign manufacturer. There are a number of specialized companies throughout the world that manufacture cooling equipment and facilities for fruits, vegetables, and floriculture crops. However, due to the physical proximity near Nicaragua and the easy accessibility, the focus among international suppliers will be on U.S.

manufacturers. A listing of the principal U.S. companies with cooling equipment and services appropriate to Nicaragua is listed below.

Cool Care, Inc.
4020 Thor Drive
Boynton Beach, Fl 33426
Phone: 561-364-5711
Fax: 561-364-5766
Cool Care is a leading manufacturer of both forced air and hydrocooling systems. It is a global leader in the production of modular forced-air (pressure) cooling units which are shipped pre-assembled and ready to install inside an existing cold room. The Century refrigeration units contain the plenum, heat exchanges and air handler all in one module. The units are made of sheet metal and use R-22 as the refrigerant. Their smallest modular unit (MPC-6) is designed for forced air cooling of 6 pallets(3 on each side of the plenum). It has 15.7 tons of refrigeration capacity and comes with a 30-inch diameter 16,200 cfm centrifugal fan at 2-inches static water pressure. The complete unit costs $28,000. This is an appropriate size for installation in the recommended new cooling rooms in Nicaragua.

They also manufacture hydrocooling systems. Their 1-pallent shower-type hydrocooler with 10 tons of refrigeration capacity costs $30,000.

Cool Care also makes a completely mobile 40-foot container forced air cooling unit. It is easily transported to any cooling site. The unit has 40 tons of refrigeration capacity at a high delivery

rate of 30,000 cfm. It can cool up to 25,000 pounds or 10 pallets of products at a time. This mobile unit costs $ 75,000.

TRJ Refrigeration, Inc.
1617 Pacific Ave.
Suite 118
Oxnard, CA 93033
Phone: 805-240-3434
Fax: 805-240-3430
TRJ manufactures modular forced-air cooling units completely pre-assembled for easy installation inside existing cold rooms. Their high capacity fans have a 2-speed motor. Their smallest unit (model SF-32) has 22 tons of refrigeration capacity and comes with a 15 horsepower fan capable of providing 21,600 cfm air movement at 2 inches static water pressure.

The company also manufactures liquid ice injection coolers for cartons of produce stacked on a pallet. Their model PJ-1000 is capable of injecting liquid ice in 400 to 700 cartons per hour.

The company also makes conveyor-type shower hydrocoolers for produce packed in bins, bulk, or palletized. Capacities range from 5,000 to 60,000 pounds per hour.

Eltec Remote Refrigeration Systems
P.O. Box 262584
Houston, TX 77207
Phone: 713-926-7300
Fax: 713-926-9300
Eltec manufactures both forced air coolers and hydrocoolers and also constructs cold storage rooms. Their RHX-26 model forced air (pressure) cooler is designed to accommodate 12 pallets. It is equipped with 15 tons of refrigeration and a 15 horsepower fan capable of providing 34,000 cfm of air. Each unit is able to cool 12 pallets to their desired temperature in 45 to 60 minutes.

Grainger Export
2255 NW 89th Place
Miami, FL 33172
Phone: 305-591-2512
Fax: 305-592-9458
This is a large wholesale industrial supply company with offices worldwide. They serve customers in Central America from their Export Distribution Center located in Miami. They have a complete line of walk-in cooler units, fans, and accessories. They stock climate control brand refrigeration units. The largest size they stock is in a low temperature unit, with electric defrost is one that provides 28,000 Btu/hr (2.33 tons of refrigeration). The catalogue price for this unit is $2,417.

Mobile Forced Air Cooling Services, Inc.
5436 North Sunrise Ave.
Fresno, CA 93722
Phone: 559-276-0442
Fax: 559-276-8420
This company manufactures mobile forced air cooling systems. They are specially made 40-foot containers equipped with 72 tons of refrigeration and 5 front wall mounted high velocity fans capable of delivering a total of 45,000 cfm air velocity. This high humidity unit can cool up to 20 pallets of product at a time. It rests on a truck chassis and can be moved from one packinghouse to another. Total system cost $90,000 per unit.

Barr, Inc.
1423 Planeview Dr.
Oshkosh, WI 54904
Phone: 920-231-1711
Fax: 920-231-1701
This company supplies used refrigeration equipment to worldwide destinations. Barr has the world's largest inventory of ready to ship cold rooms and mechanical refrigeration equipment. All used equipment is reconditioned and sold with a warranty. Cold storage buildings are blue

printed for easy assembly by the purchaser, and range in size from 80 to 10,000 square feet. They are polyurethane panel units. They stock refrigeration units for room coolers ranging in size from 3 to 120 tons of refrigeration capacity. The used refrigeration units are manufactured by well-known companies such as Copeland, Carrier, Krack, Larkin, Bohn, Heatcraft, etc. In general, the price of a complete system consisting of an insulated cold room equipped with appropriate refrigeration capacity costs about half of that of a new system.

Inventory changes quickly, but a 13.5 x 48 x 14 cold room (648 square feet) equipped with a 10 ton refrigeration capacity unit was offered for a total of $15,300. Another cold room of 24 x 31 x 10 foot dimensions equipped with a 15 tons of refrigeration capacity cost $16,000.

Kelly Container, Inc.
Phone: 413-788-0917
Fax: 413-785-1955
This company retrofits used marine containers into cold storage rooms. They offer both 20 x 8 x 8,5 foot containers and 40 x 8 x 8.5 foot containers with 3 tons of refrigeration capacity. A 12,000 cfm centrifugal fan mounted in the front of the container blow air over the top of the load of produce. They use all electric carrier “Transcold” refrigeration units.

A custom-made roof mounted refrigeration unit of 5 tons capacity is available for $13,500 in a 40-foot length. These are their standard units. The 20-foot container sells for $8,400 and the 40-foot container for $9,400. They are insulated with 2 inches of Styrofoam and made out of water-tight steel.

BTU Corporation
P.O. Box 860
Meridian, ID 83680
Phone: 208-884-8070
Fax: 208-887-1467
This company manufactures a range of industrial grade centrifugal humidifiers. Their model 10 will easily maintain a 90 – 95 % relative humidity in 30 x 20 x 10 cold storage rooms. It sells for $597 and is a compact almost maintenance free unit which delivers a microfine mist. It can be installed anywhere in the cold rooms and only requires a water source and electric power.

Jaybird Manufacturing, Inc.
2595-B Clyde Ave.
State College, PA 16801
Phone: 814-235-1807
Fax: 814-235-1827
This company manufactures a series of humidifiers using a fog generating fan system. They use a unique process of atomizing liquid into ultra-fine fog. Units are capable of rapidly producing high humidity environments, with minimal wetness. The recommended model XE-100 for small room coolers of 30 x 20 x 10 feet can produce the recommended 0.3 to 0.5 gallons per hour of

mist and comes with a floor stand and adjustable boom. It sells for $129. It is capable of maintaining the desired internal storage room relative humidity (typically 90 – 95% for produce) if wired to a humidistat. The model H2 – 240 humidistat sells for $249.

Energy Panel Structures, Inc.
102 East Industrial Park
Gravettinger, IA 51342
Phone: 712-859-3219
Fax: 712-859-3275
This company manufactures cold storage rooms refrigerated buildings, and insulated panels. Their Tuffy pre-fabricated buildings feature aluminum walls and plywood material laminated to an expanded polystyrene core. Due to the unique strength characteristics of the wall panel system, no structural steel is required for the building. Their 'Energy-Look' insulated panels feature expanded polystyrene insulation bonded to a facing of galvanized steel. A 4-inch thick panel has an R-value of 18. A 30 x 20 x 10 foot pre-engineered Tuffy cold storage building costs $ 14,168.

Amerikooler
Miami, FL
Phone: 305-884-8384
Fax: 305-884-8330

This is a leading manufacturer of walk-in coolers and refrigerated warehouses. They stock large industrial refrigerant units. A 156,000 Btu/hr (13 ton refrigeration capacity) unit costs $18,705. This includes the complete system (evaporator and condensing unit), but is a dry coil type.

A walk-in aluminum walled insulated with 4 inches (10 cm) of polyurethane panels with dimensions of 30 x 20 x 10 feet costs $12,146. This includes a 5 x 8 foot sliding horizontal door. However, this does not include the cement floor.

Aluma Shield
405 Fentress Blvd.
Daytona Beach, FL 32114
Phone: 904-255-5391
Fax: 904-257-2523
This company manufactures foamed-in-place urethane panels for cold storage buildings.

Thermo King Corporation
314 West 90th Street
Minneapolis, MN 55420
Phone: 612-887-2200
Fax: 612-887-2615

Thermo King is arguably the world's leading company in transport temperature control. They manufacture a wide range of refrigeration units for trucks and marine containers. Refrigeration capacity ranges from 6,000 Btu/hr (0.5 tons of refrigeration) in small van type trucks to 42,000 Btu/hr (3.5 tons of refrigeration) in large 48 foot marine containers.

Supreme Corporation
P.O. Box 463
Goshen, IN 46527
Phone: 800-642-4889
Fax: 219-642-4540
Supreme is the only truck body manufacturer in the U.S. that offers a complete line of refrigerated vehicles. They custom-build the van bodies according to the buyers needs. The van bodies typically are made of aluminum walls insulated with 4 inches of polyurethane foam.

Industrial Insulations, Inc.
1011 Walnut Ave.
Pomona, CA 91766
Phone: 800-551-0277
Fax: 909-517-1085
This company provides insulation covers to wrap over pallets in order to maintain the cold chain during air transport. The recommended materials to use for maximum protection is the 'Cool Guard Light' material. It costs $32 per pallet overwrap, and includes 5 sides and the bottom, along with sealing tape.

RECOMMENDATIONS

Nicaragua does not currently have sufficient cooling infrastructure available to ensure the export of consistent supplies of high quality fresh fruits and vegetables. There is only one forced air cooling facility, located at a melon export operation. There is only one small batch hydrocooler, located at an asparagus export operation. There is no ice cooling or vacuum cooling facilities for horticultural products. The facilities of APENN at the Managua airport, in Sébaco, and in Jinotega are room coolers and do not have the refrigeration capacity or air movement capability of rapidly removing field heat. They would be adequate for cold storage of previously cooled product, but since there is no other availability of cooling equipment, the APENN facilities serve as both 'coolers' and cold storage rooms. As previously discussed, room cooling is the least effective method of removing the field heat from a perishable product. In addition, these cold rooms are rather small in size and will not be able to accommodate a significant increase in export product volume. Therefore, in order to accommodate the future growth in perishable product volume out of Nicaragua, it is recommended that APENN / USAID expand the existing facilities in Managua, Sébaco, and Jinotega, along with adding additional cooling infrastructure in Leon. Specifically, it is recommended to add one additional cold storage room of 30 x 20 x 10 foot dimensions at each of the above 3 locations along with a 30 x 20 x 10 foot room in Leon. Each of these 4 cold rooms should be equipped with a forced air cooling system which has 15 tons of refrigeration capacity and a fan capable of delivering 16,000 cfm air movement at 1.5 – 2 inches static pressure. Each room will be equipped to serve as a forced air cooling facility and a cold storage room. There will be adequate space to simultaneously cool 6 pallets and store an additional 4 to 6 pallets at one time. Each individual 30 x 30 x 10 foot insulated storage room can be obtained for around $ 14,000. The total cost for 15 tons of refrigeration and a 16,000 cfm fan capacity is about $ 29,000, including a humidifier. Therefore, the total cost for a 30 x 20 x 10 foot cold room equipped with a forced air cooler capable of rapidly removing the field heat from 6 pallets of perishable products with enough storage room to hold an additional 6 pallets will be approximately $43,000. With delivery and installation, the final figure will likely be around $50,000. I recommend installation of a total of 4 units (Managua airport, Sébaco, Jinotega, Leon). These new facilities, along with utilization of the existing cold rooms, should provide an adequate infrastructure to serve the needs of the expanding horticulture industry in Nicaragua and allow a number of new growers to participate in the export process.

Regarding the existing cold rooms of APENN at the airport, I recommend one room (e.g. cooler # 3) should be set at 0.5 to 1 ºC for highly perishable commodities not subject to chilling injury and the other room (cooler # 1) should be set at about 7 ºC for storage of chilling-sensitive items. I recommend adding another 5 tons of refrigeration's capacity to each room to better maintain the low temperature conditions. Cooler # 2 could be converted to a freezer by adding additional refrigeration. However, it may be necessary to construct an additional 30 x 20 x 10 foot room in another part of the warehouse in order to have sufficient storage area for frozen items.

The physical location and accompanying packinghouse in Sébaco makes this a logical site for adding a forced air cooling room along with upgrading the current refrigeration capacity in the existing cold room. The Sébaco Valley lies in the heart of a nearby vegetable growing region

and this facility should be used as a centralized receiving / cooling / storage area for both domestic and exported produce. The refrigeration capacity in the existing cold storage room should be upgraded with an additional 5 tons (60,000 BTU/hr). The availability of two potential cold rooms in the Sébaco Valley is important to accommodate the future expansion of the produce industry in the area. In addition, the two cold rooms will allow for separate storage of chilling sensitive warm season vegetable crops (to be stored at 7 to 10 ºC) versus chilling insensitive cool season vegetables (to be stored at 0.5 to 2 ºC).

The refrigeration capacity in the existing 20 x 10 x 10 cold room in Jinotega should be increased by another 5 tons in order to operate at 0.5 to 1.0 ºC. This is necessary to temporarily store the many cool season, low temperature requiring vegetables and fruits grown in the area. A good forced air cooling facility in the Jinotega area coupled with additional cold storage capacity would well serve the limited resource fruit and vegetable growers in the area.

SUMMARY

Only through proper postharvest temperature management will the Nicaraguan fruit and vegetable grower be able to provide the buyer with consistent supplies of high quality product. Proper postharvest technology is an essential ingredient to realizing success in the international trade of horticultural products.

Forced-air cooling is the most widely adaptable cooling method for a diversity of fruits and vegetables. Most perishable commodities can be effectively cooled with this method and it is the recommended method for the Nicaragua produce industry assistance program under the USAID/ARAP Project. A total of 4 new cold rooms equipped with forced air cooling and located in 4 different locations throughout the country will significantly support the development of the fresh fruit and vegetable export industry.