Agricultural Competitiveness and Enterprise Development Project

TECHNICAL INPUT FOR IMPROVED COLD STORE OPERATIONS IN THE REPUBLIC OF MOLDOVA

AGRICULTURAL COMPETITIVENESS AND ENTERPRISE DEVELOPMENT PROJECT (ACED)

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Contents

Summary

The main objective of this mission was to assess the current state of cold chain development and management in Moldova's fresh produce sector and recommend specific strategic practices and actions in the cold storage sector for the ACED project to pursue. The ultimate goal is to increase the operational efficiency of existing cold store facilities and provide advice and strategies for the design and development of new facilities to service producers of a wide range of fresh produce including apples, table grapes, peaches, cherries, plums, tomatoes and others. To achieve these goals we met with project stakeholders, farmers, storage operators, wholesalers, industry associations, and several supporting members of the produce industry. There were a number of visits to growers, existing and new cold stores, cold store designers and equipment designers and suppliers. Conclusions and recommendations summarized in this report were provided in collaboration with ACED staff and other members of the industry. A discussion of results and proposed steps to be implemented was shared with USAID staff and project stakeholders. In this work we defined the strategy based in four segments:

1. Analysis of the current state of the cold chain for postharvest management of produce;
2. Recommendations for improvement in the short term (lower cost investments);
3. Recommendations for improvement in the long term (higher cost investment);
4. Guidelines for future starting from ground investment of different infrastructure and logistic systems in the cold chain.

Generally, we found Moldova in an early stage of building a solid cold chain that may support production of high-quality produce, but given recent investments and the strategic location of the country the opportunity for growth is positive.

General <u>short-term improvements</u> must be directed toward:

- Contract with proven experts to provide a comprehensive Cold Chain Education Plan including Train the trainers for all aspects of the value chain, followed by trainings to final users and employees. Utilize examples and studies of financial savings/gains where possible to impact the message, as well as invite at least 1 native expert who has been vetted to deliver a course (e.g. Andrei Cumpanici, Food Safety Specialist at ACED, or Sergiu Caldari - Design);
- Development of GAPs and GMPs programs, and "plain language guide" kits should be developed as soon as possible. Contract with STTA to develop and provide a comprehensive package which addresses all links in the Value Chain;

- Emphasis on pre-harvest and harvest practices (e.g. disease control and good schedule of harvests) should be done at this stage to prevent losses that do not require high investment in facilities. Provide proven, effective documentary guidance as well as face-to-face help;

- Use of tools to retain moisture and mitigate ethylene content in storage are affordable additions to the operations, which may include: Modified atmosphere package (MAP), cooling with controlled high relative humidity, rapid movement of product from field to coolers, ethylene evacuation;

- The project should support the continuous advancement of the "Cold Chain" Association in Moldova in different areas including training and collaboration with international entities. Identify opportunities to help strengthen or develop a new "Association";

- Record keeping should be implemented at this stage for variables of interest as to provide the basis for future development of traceability systems. Contract with STTA to aid in the development of a comprehensive traceability package, including operational document examples, and explanations of the need for and the use of the documentary system.

Aside from this we warn that some mere pre-harvest actions are needed to reduce large amounts of losses at harvest (e.g. we estimated losses above 25% at harvest in a peach orchard due to diseases).

<u>Long-term investment</u> in new or pre-existing facilities and operational systems should include:

- Focus upon pre-cooling rooms or hydrocooling for various fruits will be important for the overall strength of the value chain. In addition to pre-cooling, an increased focus on multi-link logistics, as well as product flow within the facilities will be necessary as the industry grows;

- Humidifying equipment must be included in future projects. Also, adding ethylene reduction methods, particularly in high-producing fruit storage rooms (e.g. apples) will be an asset for long term storage and long distance transportation to market;

- Usage of engineering "questionnaires" designed to obtain any/all data sets available for the appropriate design of an effective, long term facility will be a good start for the discussion between builders/cooling system suppliers and customers/growers;

- Assess opportunities to aid and be involved in the development of a logistics/ distribution center near Chisinau;

- Investigate opportunities to obtain assistance from International, private, or government agencies of Moldova.

We have identified a pattern in the facility design practices, which tend to follow a “cart before the horse” principle. Often customers will approach designers with a basic idea of what they think they want, with very little if any data to support their assumptions, beyond the size of land, and their current yields. Appropriately, design practices should begin with a field data collection process, wherein all business inputs, processes, and outputs are forecasted, which in turn allows the facility to be designed based on current business needs, with some consideration for future changes and flexibility. To this end, a “Facility Design” basic data sheet is provided in the attachments to be used when starting new business, or a new component of the chain. The main goal is to use the most efficient technology to maintain the appeal of produce in the high end or demanding markets, with maximum shelf life and free of harmful pathogens. Most of this list centers around the handling during the first two days after harvest, a stage where we observed a number of aspects that may be improved to more effectively compete in foreign markets.

Finally, we have summarized our assessment of future industry value chain growth considerations in section VI, which require large capital, government activity/sponsorship, international cooperation, or collaboration across multiple sectors. In this report each section ends with a bulleted segment that summarizes the most important findings and recommendations for the specific section.

INTRODUCTION

When developing a cold chain for handling produce the aims are to extend their shelf life, slow the aging process, maintain their quality and taste, maintain resale value, reduce losses while complying with safety standards that prevent contamination of the edible products, and create or increase revenues throughout the value chain. Building upon these realized goals, and introducing marketing strategies, a more viable domestic and export market can emerge.

With these concepts in mind, it is significantly valuable to develop traditional food chains into a modern “cold chain” methodology. The development of cold chain systems would be a significant economic injection to the agricultural sector (both local and exports) of Moldova, serve as a new employment sector in the country, especially in the rural traditionally agro-economic areas, will aid in the mitigation of food borne illnesses and will prolong product value and shelf life with the subsequent raise of image of Moldovan products.

Cold storage warehouses are an essential supporting component impacting nearly every produce value chain. Traditionally referred to as the “Cold Chain”, it can be reduced to its most basic elements as follows:

1. Harvesting
2. Pre-Cooling
3. Processing, (Sorting, Grading, Value Added Services)
4. Cold Storage (commonly includes humidity and other controls for produce)
5. Cold Transportation
6. Wholesale/Retail

In a modified version that may lower costs while keeping a robust cold chain, many of these components are shared or merged within a single facility, operation, or process. A typical cold chain that presents this scheme, as observed in recent years, will include:

1. Harvesting, Pre-Cooling, Sorting and Grading
2. Wholesale, Cold Storage, Cold Transportation
3. Retail

Cold storage operations with modern technology are a recent addition to the food supply chain of Moldova. Based on our visit with stakeholders, producer associations, government officials and various supporting members of the produce industry and observation of practices and facilities we are in a position to develop a platform of analysis and recommendations that can add higher value and sustainable growth to the produce industry in Moldova.

The main objective of this assignment of the ACED project was to assess the current state of cold chain development and management in Moldova's fresh produce sector and recommend specific strategic practices and actions in the cold storage sector to be pursued in future stages of the project. The ultimate goal is to increase the operational efficiency of existing cold store facilities and advise the design and development of new facilities to service producers of a wide range of fresh produce including apples, table grapes, peaches, cherries and others.

CURRENT STATE OF THE PRODUCE HANDLING SYSTEM & COLD CHAIN

Moldova has a good number of resources and infrastructure bases already in place. Many of the latter were built or repaired in the last few years. Adding to this, repairing, and further support of these areas can lead to an increase in production of agricultural commodities, and increased economic opportunities, which will naturally stem from them. The country has a viable climatic opportunity for a variety of agricultural commodities, has an extensive transportation network, and has linked most agricultural areas to traditional infrastructures, such as water, energy, telephone, etc. The primary highway arteries are in place and in good repair, thus moving commodities to transportation and logistical hubs should be efficient. Secondary highways and roads however, are in need of attention and currently add to the damage that produce incurs when being transported.

High quality produce exports are an opportunity market for Moldova. To seize this opportunity, there are several infrastructure and support areas, which need to be addressed before being considered a viable competitor in the international market, particularly the EU markets. First, losses at harvest and rapid pre-cooling, and product management must be efficiently managed and better understood, both at farm and buyer level. Second, the roads leading from agricultural areas to collection/infrastructure must be sufficiently smooth and wide to ease the movement of product. Third, the new port facilities in the South need to be ascertained as a strategic export point.

It is evident that currently product loss is occurring at and during the hours immediately after harvest. A wide variety of cold storage and produce farming operations were visited in Moldova, providing a well-rounded understanding of the complexities and difficulties the industry is faced with, as well as the opportunities that are being presented to it. One of the most consistent observations made is the state of the refrigeration equipment in most of these operations; it is very modern, and is well designed for its purposes. Particularly because there have been many improvements and new construction during the last few years. With the proper training, volume opportunity, and ability to repair and replace vital components, the Moldovan cold chain can rapidly gain through the advancement and promotion of the cold storage operations. Cold Storage buildings tend to be less consistent, while there are modern designs in existence, there remains several “soviet era” buildings which continue to serve as the centers for cold storage. In almost all of these older buildings, they are in need of insulation, deep-cleaning, and in some instances, complete abandonment, as a result of the potential for dangerous, or toxic substances coming in contact with produce.

Another critical deficiency observed is the lack of pre-cooling. Given the fact that water safety is not regulated, forced-aired cooling is recommended. We discussed this with stakeholders and demonstrated the importance of having humidifiers in both pre-cooling rooms and standard storage cold rooms. Moreover, we realized more advanced cooling systems with large coil surface area and suction pressure control are being offered. This suction pressure should be increased to the highest possible level to yet provide appropriate refrigeration power. Very importantly, air speed in these cases should be minimized to reduce moisture loss while still maintaining uniformity of atmosphere throughout the room. Even in the latter case humidity needs to be added, and controlled, a topic we stressed in this visit, more so if the package used for handling the product is wooden made, which absorbs more water than corrugated board.

Virtually all produce cold storages in USA and Europe closely control humidity. There are many humidification systems, methods and equipment in use. Some operators simply run the condensation from the coils onto the floors and add extra water during the temperature pulldown period in an attempt to provide additional moisture to saturate wooden bins, however, this method is unreliable and nearly impossible to control to exacting standards. Some have installed low-pressure nozzles in front of the evaporators, others use small diameter, high-pressure nozzles that run at pressures of up to 10 atmospheres. With most of these systems, the droplets are large enough to get the bins and the fruit near the ceiling wet, although this does not seem to cause any problems. More modern systems use an air compressor to inject air into the nozzles to break up the moisture into smaller droplets. In cases of cold-CA rooms it is important that air is re-circulated out of the room to avoid bringing in any oxygen. Nozzles, especially those with small orifices, are subject to plugging and corrosion. Malfunctioning can be a problem, especially with hard water, thus frequent maintenance is required. Some rotary-type humidifiers break up the water into a fine mist with shear action, thus they can operate on low pressure; also, they do not need small diameter orifices and are less likely to malfunction. In the case of hard water, water softening equipment should be added to protect the equipment and reduce maintenance problems.

A general guideline used by many in the produce industry is providing 1.5 L water/hr (0.35 gal/hr) of fruit. Higher amounts are used during the first three to four weeks in storage to help saturate the dry wooden bins (if that’s the case). These bins can increase in weight from 5 to even 15% depending on conditions. A practice to force saturation of wooden packages is not used in Moldova, reason why we suspect a good amount of moisture released from produce is absorbed by the package or pallet during long-term storage.

Humidity sensors are currently not in use to monitor and control humidifier operation. They should be periodically checked for accuracy by placing psychrometers in the room. Humidifiers should be run only when the RH must be increased. The sensors should be located in the cooling air stream, about 3 meters from the coils, a little to one side and should be placed approximately 2-3 meters from floor height, depending on the height product is stacked in the room.

Many people voiced their willingness and excitement at being "partners" or in some other way, affiliated and tied to the ACED project in a more formal manner. It is clear that these specific individuals are eager to learn, grow their businesses, aid their fellow industry members, and are willing to ask for help. These should be considered as candidates for the "Pilot Program" addressed in the "Conclusions and Recommendations" section. They can be used as key players in a dissemination plan across the nation, and serve as the foundation for change in the industry.

The other most consistent observation is the lack of general knowledge regarding cold storage operations, refrigeration basics, refrigeration repair and maintenance, logistics, postharvest handling science and methodology, and a general lack of business acumen, especially in the business development (marketing) arena. Furthermore, as indicated, parallel to the physical components of a cold chain, we observed the majority of the industry is overlooking essential aspects of a solid scheme to manage fresh horticultural products and access high demanding markets:

a) Good agricultural Practices (GAPs) and Good Handling/Manufacturing Practices (GHPs/GMPs) are not followed. In fact, for several decision makers we visited, this is not really a priority in the short term. While most fruits are not immersed in water after harvest, there are practices that may pose a risk such as: 1) chemical application with contaminated water; 2) handling with contaminated hands; 3) boxes/totes/containers contaminated with feces of wild animals. These three examples are not far from what could be happening in certain scenarios in this country, according to our perception. There is a chance some growers may implement hydro cooling in their operations which consequently raise risks for water to either contaminate directly the product or serve as a vector for cross contamination (from produce exposed to contamination to clean produce). Clearly, hydrocooling is more efficient than forced-air pre-cooling in some cases (e.g. peaches) but water must be monitored for contaminants, and be able to prevent cross contamination that may be in the surface of some fruits. Cold water may introduce pathogens inside fruits and grow in the pulp while in storage.

b) Harvest index and practices to reduce losses at harvest may require more attention. For example just in one peach field we observed waste equivalent to 1/3 of the entire production of the orchard. This needs to be addressed before anything. While diseases due to *Monilinia* sp. (we could not verify what species was as it could have been *Monilinia lax*, *M. fructigena* or even *M. fructicola*) is a worldwide problem, based on what we observed it suggest this issue is already draining potential profits.

   Another producer mentioned that he would prefer harvesting immature grapes (resulting in less flavor) than to harvest grapes suffering from water loss. This solution is not going to add to a value chain, as costumers appreciate both visual quality and flavor, and is completely unnecessary with current cold chain methodology and technology. With grapes the main problem we observed is the complexity around its packaging. Wooden crates may work in some quality markets, but the local industry must understand that the risk for lower valued product resulting from physical damages is higher and as indicated before the wood tends to absorb water released from the fruits during storage.

c) Modified atmosphere is almost non-existent. Bags and films are not used. While this is not essential, clearly, it can help product to retain moisture and reduce respiration rate by reducing oxygen in the headspace. This, however, needs to be implemented carefully, as bagging may cause condensation, which can result in faster microbiological decay.

d) Appropriate packaging is a real challenge at this point. We learned that what the local industry is doing is to copy boxes used in other markets. It happens that in many cases, in the world, the boxes are poorly designed. Proper packaging training is needed, at least for trainers and decision makers. What is the role of packaging? A package should efficiently protect, contain, inform and sell. With protection it is understood that the product will need to sustain natural shock and vibration issues during handling and transportation. Contain, involves grouping the right amount in a way that can be stored, allowing appropriate cooling and handling. Pre-cooling and cooling both can be significantly affected by a bad design of a package. We observed this several times in this mission. Finally, packaging is clearly a tool to enhance the attributes of a good product, this is the reason why a professional designer is needed for market development. Food industry is one where markets are sometimes saturated with product offers and suppliers need to come with innovative ways to distinguish their products

e) Traceability is currently not addressed in the supply chain. Thus, a true Value Chain cannot be formed until this issue is met and programs of traceability are implemented and strictly adhered to. Both traceability and information systems well in place are required to add value. Without information systems it is difficult, though not impossible, for the flow of information between various links in the chain and have good control of what the next member in the chain does or requires in the case of consumers.

f) New technology to prevent physiological and microbiological decay needs to be accessed. For example in the case of grapes we noticed essentially all facilities are conducting a single fumigation during the early stage of the storage. However, the effect of this fumigation will dissipate with time. There are two types of SO_2 releasing pads encouraged for use. One is a slow release design and the other a two-stage system. Slow release design is for grapes that have been SO_2 fumigated at least once before shipment (which is the case of most Moldovan grapes). The other system provides an initial rapid release of SO_2 then it continues with slow release for long-term storage. It is also possible to release SO_2 into a truck using liquid container. This will simulate an initial fumigation.

However, in this case grapes need to be re-fumigated once every seven days during storage. In another example we observed ethylene control is not performed in any of the rooms. This practice can prevent aging of some fruits (e.g. cherries, grapes) but particularly in the case of apples can lower the risk for scald and physiological decay. The most important to have success in controlling ethylene in apples is to start with harvesting fruits prior to the non-climacteric peak which needs to be defined for each variety. Moreover, ethylene scrubbers may be used in storage rooms (CA rooms included). In order for an ethylene scrubber to be effective it must remove all of the ethylene from the storage environment. Ethylene must be kept at 1 ppm or below. There are currently several ways to scrub or prevent ethylene accumulation. Heated catalytic scrubbers are commercially available, some coming from the European Union. The second type of ethylene scrubber uses potassium permanganate, which oxidizes ethylene very effectively. Another common tool is to use filters containing potassium permanganate in small beads of aluminum silicate (alumina). Activated carbon scrubbers remove some ethylene from CA rooms, but cannot be relied upon to remove sufficient ethylene for low ethylene storage. Other attempts (yet not well disseminated in the market) has been the use of sachet with ethylene scrubbers (potassium permanganate, palladium base remover) or inhibitor such as 1-methylcyclopropene (SmartFresh).

g) Basic principles of cleaning and sanitizing cold rooms are rarely followed. It is well known and a basic industry standard of the importance of maintaining cold rooms in a clean and sanitized condition. Particularly rooms where grapes are stored or produce that tend to be sensitive to mold, proliferation needs to be addressed through constant cleaning and sanitizing, besides the fact that cleaning allows removal of further ethylene accumulation. This cleaning process should involve an initial step applying firm scrubbing or brushing of surfaces with water and detergent, followed by disinfection with a wide-broad impact sanitizer such as quaternary ammonium at up to 800 ppm which may eliminate risk of *Listeria monocytogenes*, a pathogen of great concern in cooling facilities as it can grow in cold temperatures. Alternatively chlorine at 1000 ppm may be used. A clear Standard Sanitizing Operation Procedure (SSOP) for cleaning rooms should be in place. In the US it is customary to have weekly procedures that include cleaning of ceiling, floors, drains and equipment. Cooling units are cleaned semi-annually according to the manufacturer's instructions. Coolers are emptied, cleaned, rinse and sanitized at least three times a year (depending on seasons and rotation).

Chapter Summary: *Consider these important items*

- **Cold storage facilities of modern design have recently been built or are currently in construction across Moldova. Lack of humidity control, non-existence of pre-cooling rooms, little attention to ethylene accumulation in rooms and inappropriate loading docks patios are the most noticeable issues with these facilities.**

- **GAPs and GMPs are not a priority in the produce operations in Moldova, which combined with the fact that traceability and information systems are not yet on the horizon result in reduced ability to develop a value chain in a high-demand market. Notably a better understanding of the impact of water quality is needed to prevent risk of contaminated produce, especially if economical hydro coolers are utilized.**

- **Basic concepts in pre-harvest (e.g. disease control, appropriate pruning to avoid wind damage, logistic organization to avoid excess increase of temperature in harvested tissue) are not necessarily followed, producing great amount of losses at harvest or during the first few hours after harvest. One common misperception about pre-cooling and cold storage is that it acts as a "fountain of youth" for the product. The fact remains, the lower the stability and value of the product is going in, the lower it is coming out of the value chain**

STRATEGY FOR THE SHORT TERM

We believe that a focus on "the basics" is very important and that a short-term strategy should involve addressing some of the most important (burning) issues that prevent growth of the industry while doing it through affordable investment. Based on this we formulate below what we think should come next in this project.

Technical training and a basic understanding of refrigeration systems and operation, product handling, and operational design concepts is missing and must be addressed in the near-term, to allow for the proper use, and protection of the product, equipment, and facilities in the quest for a more valuable cold chain. Further, warehouse operations management training must be initiated to aid the businesses in reaching a positive return on investment, and to aid the industry in moving forward with efficiencies and higher standards of care. Though opportunities exist for robust use of the new cold storage facilities, a lack of both marketing expertise and cold chain operations knowledge related to agriculture is apparent. Further training and support should be leveled at this issue. Since this is an issue that does not carry as much investment as construction or purchase of equipment, plus it provides a solid base for a cold chain it is clearly the most urgent need in the short term. Training is dramatically important at this stage of the development of a solid cold chain for produce handling, and effective training and consistency is fundamental. After training the trainers and decision makers, training of personnel should continue. Effective training of these people with short sessions should be developed. It is known that a series of 15 minute "mini-sessions" is more efficient than long-term sessions that are only provided periodically.

As previously indicated we observed a number of practices are overlooked, which may significantly reduce the shelf life of produce. The primary produce examples observed in need of immediate attention are: Apples, grapes, peaches, plums, and cherries, for which we have provided in the appendices general information sheets for handling these products, developed by the University of California-Davis. Though this report can and should be considered for all perishable products in Moldova, we will continue to focus on these examples for the sake of efficiency and clarity. Fortunately all those fruits with export potential may be stored at similar temperature (0-2^0C with relative humidity above 90% at least). We do warn that cherries and grapes however, should not be stored with the other fruits because while these are not known for being high ethylene producers may have moderate sensitivity to ethylene. Moreover, grapes may be stored in a more special fashion as it is often fumigated with SO_2 and with temperature as low as -1^0C (assuming control of temperature is extremely accurate), two factors that make grapes non-compatible with the other fruits. Leafy greens may be stored at similar temperatures as those fruits above but are sensitive to ethylene so they should be stored in separate rooms. Other vegetables we observed produce in great volumes such as tomato should be stored above 7^0C, with some variability among varieties.

One example that shows poor attention to specifics of storage is the non-existence control/monitoring of ethylene in apples. The long storage with subsequent accumulation of ethylene is producing major losses of Granny Smith Apples even in the most modern facilities (Codru-ST SRL). It is not known what levels of ethylene are present in long-storage rooms. Ethylene control should be included in the facilities that are already running for long-term storage. As mentioned, all members of the supply chain from farmers, to transporters, to cold stores, wholesalers, retailers and consumers should be educated to the basic “longer life” standards available for these products. Thus, the use of “kits” containing plain language guides should be made available and easily accessible to all players in the entire value chain, including their availability on websites and in printed form. Examples of these plain language user guides and other documents can be found as attachments to this report.

A grower needs to know well how a product behaves after harvest. Also, there is a need to understand what is happening at different times during the season. For example, a grower should know what the weight loss is during the period between field and packinghouse, as this loss, sometimes inevitable (even in the most ideal conditions) help to understand viable volumes in a high-demanding market. Also, and as important, most produce develop symptoms of water loss or dehydration at above 4.5%. Thus, a grower is in a race to avoid this cumulative water loss before the consumer notices a decrease in product value/”freshness”, a concept that certainly is relative, but it is a true marketing tool. A grower also, needs to know exactly what fruit is causing more problems and when. Early harvest and or very late harvest normally produces different shelf lives, one case are apples that are harvested early in the season, which often produces lower quality for long term storage. It is apparent that some already obtained this information empirically, but the grower needs to understand that constant monitoring, testing, documentation, and data analysis inside the company is needed every season to consistently improve profits and quality for himself.

Elements of the principles of food safety have been provided to growers as part of USAID Agribusiness Development Project. However, growers continue with some practices that put their businesses at risk. For example, the cleaning of cold rooms is currently being done with just water. We verified most of the rooms have accumulations of biofilm (bacteria) and mold. SSOPs need to be developed so that the two step process of cleaning indicated above is followed. Likewise, cleaning of packaging materials and trucks should be performed efficiently. This is a relatively inexpensive practice and will add to the solid platform needed to develop a true Value Chain.

Recording data is vitally important to the long term sustainability of product and business revenues. Recording data upon receipt, while in process, in storage, and during shipment will aid the business owner in operating the business, proving his statements, as well as allow him to learn and reassess his business management and processes. Simple instrumentation to aid in recording important data (temperature, relative humidity, ethylene, free chlorine and pH for any water used in the facility with direct contact to produce) should be acquired. Many manufacturers offer numerous high quality, inexpensive, measuring instrumentation. For example a recommended source for temperature and humidity recording and monitoring devices is *Taylor Precision Products*, though we observed that many of these devices are available in Moldova. Following are links to specific devices:

a) Commercial Anti-Microbial Instant Read Thermometer

Temperature range -40°C to 230°C.

Anti-microbial plastic storage case inhibits growth of pathogens.

Waterproof

Recalibratable - complies with HACCP requirements.

http://www.taylorusa.com/5-commercial-anti-microbial-instant-read.html

b) Sling Psychrometer

Measures the wet and dry bulb temperatures of the surrounding air and permits conversion of the readings to a relative humidity percentage on the "slide rule" scale built into the case

Range 10 to 100% RH.

http://www.taylorusa.com/pocket-sling-psychrometer-1.html

c) Wall Mounted Hygrometer

Metal hygrometer measures relative air moisture.

Range 0 to 100% humidity.

Weather-resistant finish.

http://www.taylorusa.com/4-round-hygrometer.html

d) Ethylene Scrubbers (ethylene gas removal)

http://shop.ne-postharvest.com/Ethylene-Scrubbers_c9.htm

e) Free chlorine kit analyzer (test for any chlorinated water in contact with produce) http://www.hach.com/cl17-free-chlorine-analyzer/product?id=7640295880

f) Temperature and Humidity Data Loggers

http://www.omega.com/ppt/pptsc.asp?ref=OM-40&ttID=OM-40&Nav=

Technology that may be considered in the short term should include use of humidifiers and bagging to reduce water loss of product. It is clear to us that most of the producers are losing money directly by allowing weight loss of the products, but also by allowing product to diminish in quality due to high transpiration rate. This is a Direct attack against the Value Chain, and completely unnecessary given available and relatively inexpensive technology.

Finally, at this first stage of the project, we consider it prudent to promote the inclusion of leading industry members (production and supporting industries) to leading or global associations. Moreover, all links in the food supply chains and cold chains should be constantly trying to join or develop industry associations, designed to further their economic interests, provide training and technical knowledge, aid in the development of marketing and other business materials, and to serve as knowledge pools and network links to the global food industry. Meeting with various members of the industry, and the Director of the association involved with Refrigeration Technicians in Moldova, it was clear that there is a disconnection between members from various links in the cold chain, and that more must be done in regard to linking the members of the cold value chain. Though nearly seventy-five percent of the association membership represents the technical or services sector of the industry, and the remaining twenty-five percent represent producers, in total the association is very small (17 member companies) in relation to the total number of the cold chain which should be members. This is an area which can and should be exploited as soon as possible, to help drive the value chains growth and effectiveness. Further, as the association grows, it can and should become one of the leaders in the nation regarding linking academia, private sector, public sector, and adjacent associations. The opportunities which stem from a strong membership association supported, led and contributed to by the members are too numerous to list here, but which have been proven in country after country historically. In several cases we heard of improper capital investments completed because of the reliance on the “help of a colleague” that was in another country who perhaps observed, assumed, or overheard that a particular technology should be used. This, however, would not be a problem with sufficient analyses of pros and cons by local, experienced experts, which would normally be the case wherein the industry members were more tightly integrated.

Chapter Summary: *Consider these important items*

- **Contract with proven experts to provide a comprehensive Cold Chain Education Plan including Train the trainers for all aspects of the value chain, followed by**

trainings to final users and employees. Utilize examples and studies of financial savings/gains where possible to impact the message, as well as invite at least 1 native expert who has been vetted to deliver a course (examples: Andrei Cumpanici, Food Safety Specialist at ACED, or Sergiu Caldari - Design);

- **Development of GAPs and GMPs programs, and “plain language guide” kits should be developed as soon as possible. Contract with STTA to develop and provide a comprehensive package which addresses all links in the Value Chain;**

- **Emphasis on pre-harvest and harvest practices (e.g. disease control and good schedule of harvests) should be done at this stage to prevent losses that do not require high investment in facilities. Provide proven, effective documentary guidance as well as face-to-face help;**

- **Use of tools to retain moisture and mitigate ethylene content in storage are affordable additions to the operations, which may include: Modified atmosphere package (MAP), cooling with controlled high relative humidity, rapid movement of product from field to coolers, ethylene evacuation;**

- **The project should support the continuous advancement of the “Cold Chain” Association in Moldova in different areas including training and collaboration with international entities. Identify opportunities to help strengthen or develop a new “Association”;**

- **Record keeping should be implemented at this stage for variables of interest as to provide the basis for future development of traceability systems. Contract with STTA to aid in the development of a comprehensive traceability package, including operational document examples, and explanations of the need for and the use of the documentary system.**

STRATEGY FOR THE LONG TERM

Developing a Value Chain requires innovation. Unlike the traditional supply chain, that is supply oriented (e.g. assuring Apples from Moldova during a extensive period of time of the year), with value chain management the producers need to identify the value of their product. This can only be done by learning what consumers look for, then target this particular desire with innovation. Clearly, packaging is one tool that allows both improved power to keep quality for extended time, save energy and communicate with the buyer/consumer. We realized developing a new packaging system takes time and investment, thus, we have considered this issue to be a step after the most burning points denoted in the previous sections.

Some considerations for corrugated board packaging are the following:

- Double-faced corrugated fiberboard is the predominant form used for produce containers. It is produced by sandwiching a layer of corrugated paperboard between an inner and outer liner (facing) of paper-board. The inner and outer liner may be identical, or the outer layer may be preprinted or coated to better accept printing. The inner layer may be given a special coating to resist moisture. Heavy-duty shipping containers, such as corrugated bulk bins that are required to have high stacking strength, may have double- or even triple-wall construction.

- Corrugated fiberboard manufacturers print box certificates on the bottom of containers to certify certain strength characteristics and limitations. There are two types of certification. The first certifies the minimum combined weight of both the inner and outer facings and that the corrugated fiberboard material is of a minimum bursting strength. The second certifies minimum edge crush test (ETC) strength. Edge crush strength is a much better predictor of stacking strength than is bursting strength. For this reason, users of corrugated fiberboard containers should insist on ETC certification to compare the stackability of various containers. Both certificates give a maximum size limit for the container (sum of length, width, and height) and the maximum gross weight of the contents. Prove for these certifications were not found in any of the corrugated board boxes observed in Moldova. Thus, the grower (perhaps in the form of an association or in collaboration with this project) need to try to have other type of tests done so that he/she can be assure a box at the bottom of a pallet can sustain a number of boxes on top, during transit and high relative humidity.

- One of the most visible mistakes we observed with corrugated board boxes made locally was the lack of enough perforation to allow airflow upward and horizontally. Ventilation at the bottom of the boxes are needed as well as perforations on the walls that allow a good match with other boxes in the pallets regardless of the way boxes are placed in the pallet.

- Corrugated board boxes are either used as primary or secondary packaging. For the fruits of interest in Moldova, and when targeting export markets, it would be ideal that the corrugated board boxes (or alternatively well designed wooden boxes) are used as secondary packaging. This is suggested because using other materials as primary packaging (directly touching the product) reduce the damages for friction between fruit-to-fruit surfaces and reduce water loss. For example, we discussed with different people of the benefits of using perforated bags for grapes. However, we also warned that any time a film is intended to be used, testing need to be performed as bagging also increase chances of condensation. Similarly, individual wrapping or tray that separate apples may be used for high-demand markets.

In the long-term, we consider the development of a traceability program of great importance. This program can be combined with the improvements on packaging systems. An efficient traceability program will involve both logistic organization and investment in technology. Ideally, codes for traceability should match those used eventually by the buyers in the export market. The traceability program should at least in the first stage indicate date of harvest (which in fact is connected with field practices including chemical use), date when product leaves the storage facility (which is subsequently linked to any event that occur during certain time, including faulting electrical power), and a step further will indicate the lot where the product was gotten from, particularly if the product is a vegetable.

Another point to have in mind in the horizon is the use of cushioning systems in trucks that carry product from field to packinghouses, particularly, in remote areas where it is evident that product suffers even before it is stored in cold temperature. Ideally roads should be improved, but at least, the cushioning may aid with this problematic issue.

We understand improvements to existing facilities may be costly, which is why we consider this point a long term issue.

Control of relative humidity and perhaps pre-cooling systems are however two factors that once addressed can pay back in the short term. Other factors may be addressed at a later stage or when considering new facilities. Among these factors it will be important to consider: a) acquisition of diesel generators of a size that is capable of supplying power needs for at least all the refrigeration rooms (excluding lights) for at least 12 hours; b) consider designs of storage facilities that do not assign inbound and outbound loads on the same place (in many US facilities for example waste product or rejections leave the plant from different side of the building in relation to inbound product from field and from product shipped to the market); c) refrigeration should be included in all places once the product arrives to the facility as even rapid movements of product from low temperature to high temperature (e.g. corridors without refrigeration) may produce condensation on the surface of the product that may create an ideal substrate for pathogen proliferation. In this issue of new design of packing facilities it is remarkably important that product is always considered to be selected and classified before cold storage. A product that will be later rejected should never use space and energy in a cold facility.

We found it relevant that academia is not involved in almost any step of the developing Cold Chain. It was learned that the “Cold Chain” Association has some collaboration with some faculty from the Technical University of Moldova. However, there is no known postharvest physiologist, food scientist or agricultural engineer faculty working close in this effort. Indeed, it was brought to our attention as a genuine weakness in the industry; we wholeheartedly agree with this assessment. Undoubtedly, our experience during the last two decades allows us to state that a solid national program to enhance quality and presence in international markets should involve the academia, so that research can eventually look for opportunities to innovate and add value to the chain.

At one point between what we consider short-term strategy and long-term strategy a Pilot Program with leading members of the industry should be started. Clearly, the Pilot Program will start sooner if choosing “big players” that are ready to take the challenge. While the social impact will be more direct with associations of small growers, we have learned that implementing an initial foundation for a solid national Cold Chain is usually faster with collaborators that are more vertically integrated. Beyond the recommendations given for the short term, several other areas can be considered for inclusion as well sometime in the short to long term. These “Next Steps” should be considered as minor in operational importance, or take lesser priority under the recommendations, but can nonetheless be effective controls, tools, and leveraging opportunities for the advancement of the ACED goals, both near and long term.

Step 1

Immediately define the basic parameters of the Pilot Program and prepare to meet with the participating program members to arrive at agreed upon deliverables from both sides. At a minimum, operators must agree to maintain daily, weekly, monthly, and seasonal documentation for specific operating areas as noted herein. Also, operators must agree to share financial and other information related to the operation, including but not limited to:

- Cost of produce purchased from farmers or other, and all other costs of the operation;
- Revenue related to produce sales, and all other revenues of the operation;
- Ancillary services costs and revenues (example, processing, grading, sorting, etc…)

Step 2

Contract with and retain an external technical consultant for limited technical consulting guidance related to the approaching harvest season, technical guidance related to the pilot program, and guidance with specific technical, operational, or business related questions from operators. This consultant can provide documentation needed in operations, and serve as a sounding board or respond to technical questions on a daily or weekly basis.

Step 3

Develop a Kit containing "Plain Language Guides" both printed and electronic versions to be provided to all cold storage providers and related food supply chain members.

Step 4

Develop a local consortium of interested participating actors associated with the supply and servicing of the cold supply chain. To put this into context the reader should view it as a mini association, loosely developed for the mutual benefit of all parties. Examples of participants in this "consortium" are the following:

- Refrigeration and humidity maintenance companies in Moldova
- Refrigeration and humidity parts suppliers in Moldova
- Refrigeration and humidity tools suppliers in Moldova (thermometers, hygrometers, etc.)
- Refrigeration and humidity education providers in Moldova
- Produce export, brand management, and, business development (Marketing) consultant
- Pre-cooling service companies
- Cold chain transportation companies
- Corrugated box design companies
- Refrigerated building supplies company (plastic strip curtains, insulation, low-heat lighting, etc.)

Chapter Summary: *Consider these important items*

- **Develop appropriate packaging systems that enhance qualities of the product, protect, allow efficient cooling, and promote sales.**

- **Begin the development of a comprehensive traceability program based on the expected built data compilation programs suggested for previous steps, and meets the standards of export trading countries and customers**

- **New buildings should include refrigerated ambient in all areas, including corridors between rooms.**

- **More aggressive market development effort should be done upon addressing suggestions for the short term, particularly where comparative advantages exist for Moldovan fruits.**

- **Develop a "Pilot Program" with a small and selected group of members of the industry that can bring leadership throughout the nation.**

ASPECTS TO CONSIDER FOR NEW BUSINESSES, FACILITIES, OR LARGE MISCELANEOUS INVESTMENTS

The average cold storage facility has clearly modernized in recent years in terms of building construction, refrigeration, humidity and material handling equipment in use. Going forward, an initial focus upon pre-cooling rooms for various fruits will be important for the overall strength of the value chain. In addition to pre-cooling rooms (forced air), an increased focus on logistics and product movement through the facilities will be necessary as the industry grows, and volumes of various products begin to choke the available storage facility capacities. While new storage space is designed and built, there must be a reliance on logistics management to augment the storage space requirements. In other words, moving product more efficiently through the use of newer equipment, process flows, training, personnel management, and reduction of waste/non-conforming product will enable higher volumes to flow through the existing facilities, without increasing storage or cooling space, thus avoiding unnecessary, burdensome capital costs related to new construction/expansion.

As forced air pre-cooling measures are appropriate for the early stages of the cold storage industry in Moldova, and as space, and storage spaces become increasingly filled, there may be a need to look toward hydro cooling of some species and varieties to increase the pre-cooling process speed, which will allow a more rapid overall process, and make available storage space previously used in the forced air cooling process. Finally in regard to pre-cooling, processes should be reviewed at harvest locations as well (orchards and fields) to begin the pre-cooling process immediately upon harvest. Of the various harvest scenes toured, there was no evidence of field cooling usage. Product was never placed out of direct sunlight under tents, tarps, or other shade, no airflow intentionally directed through boxes of picked produce, or other low cost/no cost solutions were in use. Globally, 5% to as much as 40% reduction in waste/spoilage has been observed among post harvests where such field management of harvested produce was used.

Humidifying equipment is generally not in use including the more modern facilities built in Moldova. Also, there is a general lack of knowledge of the importance of the need for exacting measurements of humidity in storage to maintain quality of product, shelf life, and product weight. To support the importance of this observation, it should be noted that during numerous discussions of this issue, it was customary to be engaged in argument over the issue. Generally, the argument was that the new Dutch equipment could maintain adequate humidity percentages, or, by spraying water on the floors in the coolers, humidity could be maintained. When questioned whether anyone had hygrometers to measure humidity, all admitted they did not. It should be noted that with produce, water = weight = revenue. Stated another way, when the humidity levels are reduced in storage, the produce will lose water weight, which directly affects the weight of the sold bulk product, reducing the revenue stream to the seller. Moreover, the absence of consistent humidity controls negatively impacts the shelf-life and quality of the value chain.

Education of Value Chain and Cold Chain Management

Management and personnel training in postharvest handling of produce, cold storage operations, equipment maintenance, marketing, and value chain management should be a priority to ownership, management, and NGOs related to the produce value chain. As noted before, a general lack of knowledge exists in all of these arenas, and in most cases this lack of knowledge is severe, which equates to double digit losses in the value chains' revenue stream. When a consistent, comprehensive knowledge transfer (education) platform for this value chain is provided, the national averages in these quality and value chains, and direct revenues will be positively impacted. Empirically, the positive change should be double digit percentages in the first 24 months of insertion, followed by greater than 5 percent per year for the following several years, as the knowledge base becomes commonplace in the national industry.

Organizations such as the World Food Logistics Organization (WFLO) are well known globally for providing these educational series' targeted toward emerging and developing food value chains. Their compendium of educational options range from one-day seminars, one-week workshops, to comprehensive long term educational series which include specific course work titles for each of the areas noted above. It is critical to place this type of training and knowledge transfer in the hands of actual industry organizations such as the WFLO because failure would prove disastrous in the long term for the industry, as distrust of the knowledge transfer platform would become rampant and of little impact when re-introduced later. Contracting with a proven, effective partner is of the highest priority. The traditional outcomes of these educational series have proven very effective at reducing losses of product and revenue, increased energy efficiency and cost savings, and the elevation of standards in the global industry to best handling practice increases in food safety and efficiency.

New Facility Design and Construction

Reviews of cold storage facilities designed or under design have met with general approval. Primarily, most of the basics of modern cold storage design and construction are being met, with consistent and reasonably reliable construction techniques and final delivery. Again, as noted above, there appears to be a general misunderstanding or lack of knowledge within the engineering and design profession regarding the interrelationship between temperature and humidity, as well as the importance of pre-cooling, and automated, cleaning, sorting, grading, and packaging equipment and products.

The specific planning of a new facility must take into account the current needs as well as the long term needs of the operation, as far out as 10 years without the need to significantly re-engineer or add on to the physical operation. The input data required for this type of planning are numerous. Receiving volume, timing of product receipts, time to pre-cool, time in storage, time to prepare for shipment, scheduled shipping, and work process time estimates are all important data sets to consider when designing a storage facility. Though initially one can view the cold storage facility as simply a “box” in which to store something, the realities are that one can’t put more in the box than it can hold at any given point in time, and it can’t cool product faster than the cooling equipment, personnel, transportation, building design and material handling equipment will allow. Therefore, it is quite important to develop a substantial questionnaire or “field data sheet” for “customers” to answer these and other questions to very exacting detail.

Previously, we discussed the need for appropriate packaging materials, from bulk containers for harvest, to unit sized bags and boxes destined for final delivery to retail. Entire industries have been built around the specific sciences related to these issues. The corrugated and wooden box industries, as well as the “plastic” bag industries have very specific and exacting applications for foods, the size of the food packaging, varieties, etc. In the long term, it will be very beneficial to align with various industry suppliers and develop business relationships with them to gain the knowledge and products necessary.

As previously mentioned, large scope new projects are generally conducted in areas which provide the greatest opportunity for success; where certain advantages can be leveraged to reach stated goals and objectives. Regarding the need of modern distribution centers for perishable products, the greater Chisinau area provides such an opportunistic platform. The infrastructure requirements of roads, rail, electricity, water and sewer are consistently available, land availability appears to be sufficient, and a large target market is readily available. The target market of consumers, retailers and wholesalers in Chisinau have a higher demand for quality than that of the rural areas.

There are a number of ways in which to develop this type of facility. A private entity from either inside Moldova or a foreign entity can finance and operate it, government funding can be leveraged, either locally or nationally, credits may be available, and in many cases US government funding or international financiers may be available to provide funding. We recommend a thorough and dynamic feasibility study be conducted to review this opportunity. Again, the use of knowledgeable consultants well versed in distribution centers and logistics be contracted for a feasibility study.

Strengthening Local Markets for Improved High Quality Export Culture

In several countries of the world it has been proven that a governmental/international aid effort toward improving consumerism will dramatically establish a more solid step toward a new culture for handling produce. In those countries (e.g. Chile, Thailand, Costa Rica) prior to their strengthened market presence, a producer and its corresponding labor workers would not distinguish between their own production habits and desires versus the desires of the customers in the foreign country who were buying the product. Whereas now in a more enlightened business environment, many of those same producers/countries produce fruit and/or vegetables that they have no consumer or first-hand knowledge of, but are growing and producing "what the customer demands, "the way the customer demands it, such as Asian vegetables grown in the Dominican Republic for the US market. The technology for postharvest management of many products may be copied from other countries. However, innovation will be required to truly adapt technology and more importantly, but the way a worker handles a product cannot necessarily be "cloned" in the short term as it is the result of consistent training and efficient enough to change a culture. We believe a project that can benefit standards of living of local consumers, standard of living of country side communities and the economy overall are enough justifications for seeking funding in several forums.

Chapter Summary: *Consider these important items*

- **Focus upon pre-cooling rooms for various fruits will be important for the overall strength of the value chain. In addition to pre-cooling rooms (forced air), an increased focus on logistics and product movement through the facilities will be necessary as the industry grows.**
- **Humidifying equipment must be included in future projects. Also, adding ethylene reduction methods, particularly in high-producing fruit storage rooms (e.g. apples) will be an asset for long storage and long distant markets.**
- **Usage of engineering "Questionnaires or Field Data forms" designed to obtain any/all data sets available for the appropriate design of an effective, long term facility will be a good start for the discussion between builders/cooling system suppliers and customers/growers.**
- **Development of a logistics/distribution center near Chisinau.**
- **Obtaining funding from international, private, or Government of Moldova.**

CONCLUSIONS AND RECOMMENDATIONS

We have outlined a diagnosis of what we found in Moldova. It is clear that Moldova is rapidly increasing its capability to store more produce. In virtually every case outlined above and below, an ongoing and strategic focus on education will be paramount. The insertion of new ideas, processes, technology and equipment will undoubtedly fail in the aggregate, without a sound investment in the education of the practitioners in the industry. To this end, we found most investment in this area to be appropriate, however regarding pre-cooling and humidity, it is clearly common practice in the industry to largely ignore the importance of these two requirements, if not dismiss them completely. Where humidity is addressed, it is uncommon to be measured or controlled. Where pre-cooling has been introduced, it is with a lack of process control, and little to no understanding of the role pre-cooling serves in the overall value chain, or definable process outcomes.

Regarding packaging, in most cases the use of boxes, bags, crates, bins and other conveyances is very rudimentary and allows physical damages and inefficient cooling. Fact based scientifically measured systems are now in use throughout the world, including the EU for the use of specific, effective packaging, but this needs to be well selected as mistakes are also committed throughout the world. We also have to be clear that any cold chain or value chain management must be built upon solid bases of: Food safety programs and efficient production that prevent losses in the field, two areas that in many cases in Moldova are extremely weak. Therefore a solid foundation of education and training are paramount to the execution of a high quality, profitable value chain. To be clear, food safety is often misunderstood as a requirement that offers no value to the chain; this is an incorrect assumption. Food safety practices, when administered correctly, provide for the careful handling and processes which ultimately serve to protect the shelf life, quality, taste, and safety of the food product, which is a direct influence on the actual product value.

The general advantages of an industry association include rapid and sound technological advice; access to equipment and service professionals; statutory and standards information, latest technological advances; shared knowledge of best practices, etc. All these offerings ultimately lead to a higher value group of final products, increased revenue margins, consistent market presence and the opportunity to compete at a higher level on the world stage. The refrigeration association in its present state fails to address the needs of the cold chain, and is focused almost exclusively on the technicians in the industry. The current association must either re-focus on a larger audience and deliver to their needs, or a new association must be launched. The GCCA may be of aid in this situation.

As a summary, the following recommendations are presented as opportunities for improvement in the education, reform, handling, standards, efficiency and profitability among the cold supply chain, primarily through the effective increase in quality centric, value based processes and ideology.

Recommendation 1: Intensive Targeted Training

Conduct educational workshops as soon as possible for "Pilot Program" members (details follow below) and ALL other industry members and interested parties. Included in the education workshops should be the following bodies of knowledge:

- Harvesting Operations
- Postharvest handling
- Pre-cooling
- Processing
- Grading
- Sorting
- Packaging
- Facility, Materials, and Equipment Design
- Cold Storage Operations
- Cold Storage Management
- Refrigeration Equipment Maintenance
- Cold Supply Chain Marketing
- Association Building at all levels
- Economics of Technology Investment

This training, as indicated before, should be a holistic/sustainable program that will initially include trainers but should also include all members of the industry. The ultimate goal it to change the regional/national culture for one that aims production of high quality with efficient technology and logistical operation.

Recommendation 2: Peak Season Operational Analysis and Review

Utilizing the same experts conducting the educational series in Recommendation 1, conduct an on-site "hands-on" review of the operations during the operational season, to evaluate the processes, equipment, assets and business operations with the management of the facilities, and consult them where necessary with new ideas, concepts, and approaches to solutions. This can be scheduled to immediately follow Recommendation 1. Analysis during harvesting and packaging of the most financially promising fruits will result in additional, "next level" recommendations.

Recommendation 3: Cold Supply Chain Pilot Project

Conduct a 3 Phase Pilot Program aimed at creating "Model" cold storage operations, to be used as Benchmarks, and Platforms for future cold supply chain infrastructure linkages, as well as serve as model operations for further cold storage business growth.

Phase I*, prior to the harvest season of the reference year*
Cold Storage Management are trained in workshop(s) in the basics of Cold Storage Operations and Postharvest Handling, including refrigeration equipment, building design, document and data control, temperature and humidity monitoring, cost benefit analysis, food safety, and business management. Pilot participants are selected for inclusion from among this workshop group and further screened to verify their operating status and to determine whether they are capable and willing to produce reliable information targeted for data collection via survey(s). This first phase is merely a screening questionnaire used to improve survey efficiency; it does not contribute to the user data files greatly. Of primary importance here is to determine the accuracy and willingness of the operators to store and share business related data with ACED, including financially sensitive data.

Phase II*, conducted in the busy (harvest) season of the reference year*
Randomly selected operating Cold Storages from Phase I are interviewed to collect information on their training, operations, business acumen and management skills and practices. Phase II data are collected at the individual operational unit level. Phase II is a series of surveys conducted to obtain physical, management, and economic data on operational inputs/outputs, management practices, document & data controls, training retention and costs of operations.

ACED will provide personnel from selected operations to refrigeration, mechanical, and management trainings, as well as provide management of selected operations, with Cost Benefit Analysis Tools, Marketing strategies, access to experts among various fields including operations management, marketing, mechanical maintenance, product and post harvest control specialists.

Phase III*, conducted in the following busy (harvest) season the year after the reference year*

Selected operating Cold Storages from Phase II are again interviewed to collect information on their operations and management practices. Phase III mirrors the former Interviews and Surveys of Phase II. Phase III data are collected at the individual operational unit level. Phase III is also a series of commodity surveys conducted to obtain physical and economic data on operational inputs/outputs, management practices, document & data controls, training retention and costs of operations. Then assessed, measured and studied against the Phase II collections of data.

Recommendation 4: Marketing Programs Consultancy

Obtain consulting advice and programs from a Produce and Cold Chain Marketing Specialist, with experience in the specific concerns, obstacles, opportunities, and specific knowledge of markets similar to Moldova, seeking to gain new export opportunities. If possible, this Marketing Specialist should also be utilized in conjunction with Recommendations 1 and 2 above. We find important that a market specialist targets both local and international markets, as a solid program to improve postharvest handling across the nation requires the pressure in local market for improved quality. It has been shown in several places that the higher the quality standards requested by grocery stores the higher the pressure to reduce losses at harvest and physical damages during the hours after harvest.

Recommendation 5: Knowledge Transfer Training

Contract with consultant experienced with ACED project to research, write, and produce a comprehensive "Plain Language User Guide" series, in addition, also contract for a ***Cold Storage "Basic Operations" Manual (including Postharvest Handling and Good Handling Practices for produce of interest and local varieties)*** to be the property of ACED, and to be used as a primary educational component and deliverable to cold storage operations management, as well as adjacent cold supply chain partners interested in the basic requirements of operating a cold storage business.

Academic tools for calculation of cold storage needs are also available. One example is the software Coolsys (http://www.feagri.unicamp.br/agripaginas.php) developed by the State University of Campinas, Brasil. Likewise the Information Network on Post-harvest operations by FAO (http://www.fao.org/inpho/en/) can be of use, particularly, for developing systems in small enterprises. We find key the involvement of researchers to develop specific outreach information sheet for some local products. The link between the academia or research institution with industry developmental program is needed to identify more opportunities for value of products.

Recommendation 6: Develop a "Select Line" of High Value, High Quality Produce

Targeted at the HRI Industry in Chisinau, this HI-Value/Hi-Quality Food Chain project serves as the platform to press farmers, cold stores, transporters, and wholesalers (the entire produce food chain in Moldova) to rapidly advance the ideology and implementation of a higher quality perishable produce food chain.

A certain level of Marketing and Branding will be required to augment this project, and perhaps the usage of the USAID logo, or another highly valued logo can serve as a lure to the targeted players. To start, the "high end" produce market Hotel, Restaurant, Institution (HRI) customers in Chisinau must be contacted and met with to bring them into the project. As a direct result of receiving a "Select Line" of the highest quality Moldovan Produce available, they must agree to a higher cost base of the targeted products such as apple, plum, cherry, and peach.

Next, farmers, cold storage suppliers, transporters, and wholesalers must be met with, and evaluated for consideration. Undoubtedly these players will evolve from the members of the Pilot Program noted above. Again, strategic, specific applications, work instructions, documentation, and data must be applied, managed and stored by these players to protect this "Select Line" of product. As a direct result of being selected for inclusion, these specific chain members will receive the highest rates for the high quality product they deliver to exacting standards.

With intense scrutiny and management, this "Select Line" can be leveraged and marketed, and in time will be sought after by other retailers. This growth in demand can serve as the catalyst to encourage other farmers and food chain players to raise the level of product quality and care. The use of the external cold chain consultant, and the marketing consultant will be of considerable value here. This model for increased quality can easily be copied and used in other industries as a growth tool for those specific industries.

APPENDIX

POSTHARVEST HANDLING INFORMATION OF TARGETED FRUITS

Apple: 'Gala'

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Maturity Indices

- Ground color change from green to light-green or white may be the most useful indicator of maturity for harvesters.
- Beginning of starch degradation may also indicate harvest time.

Quality Indices

- Firmness, crispness, lack of mealiness.
- Flavor, including soluble solids, titratable acidity and flavor volatiles.
- Freedom from defects such as bruising, decay, stem or blossom-end cracks, bitter pit, insect injury, etc.
- Percent blush on the apple (visual quality only).

Optimum Temperature

0° ± 1°C. Cool rapidly, this apple softens quickly

Optimum Relative Humidity

90 to 95%

Rates of Respiration

6.5 to 8 ml/kg·hr at 0°C

To calculate heat production multiply ml CO_2/kg·hr by 122 to get kcal/metric ton/day.

Rates of Ethylene Production

4 to 12 µl/kg·hr at 0°C

Responses to Ethylene

Ethylene can accelerate senescence and loss of firmness. A reduction in ethylene concentration may reduce susceptibility to scald.

Responses to Controlled Atmospheres (CA)

The following atmospheres have been successful for Gala apples:

- 1 to 2% carbon dioxide (1.5 to 2% oxygen)
- maintains firmness and acidity
- reduces susceptibility to bitter pit and storage scald
- can store up to 4 or 5 months in CA
- Additional research may determine more optimum atmospheres.

Physiological Disorders

Storage Scald. Information is incomplete; however, Gala appears to be slightly to moderately susceptible to scald. DPA may be needed for storage in air for longer than 2 months. CA storage reduces scald incidence.

Bitter Pit. Bitter pit has been observed on Gala apples. Large fruit from young, vigorous trees are most susceptible. Preharvest calcium sprays are most effective to reduce bitter pit. Postharvest calcium dips are also beneficial.

Calcium Rates for Postharvest Dips

- 2 to 3% solid flakes (77% $CaCl_2$).
- 1.5 to 2% calcium chloride ($CaCl_2$).
- 0.5 to 0.8% calcium ion (Ca^{+2}).

Pathological Disorders

Gray Mold, Blue Mold.

- avoid fruit injury

- sanitize water systems with chlorine

- cool fruit quickly

Mucor rot. Some orchards have Mucor fungus in the soil. Sanitation to keep soil out of drench water is important. Do not place fruit from the orchard floor into storage bins. Chlorine will not effectively control this organism and there are no effective fungicides. Mucor continues to grow slowly even at 0°C.

Sanitation of Water Systems

Sanitation of water systems used to handle apples is important to prevent spread of disease organisms to healthy fruit. Chlorine at 50 to 100 ppm is very effective but the level of available chlorine and solution pH (7.0) must be monitored frequently and adjusted. Sodium will accumulate when liquid sodium hypochlorite is used and can burn apple tissues. We recommend water systems be changed once a day to reduce the risk of burn to apple skins. Gala is very sensitive to sodium burn.

Apple: 'Granny Smith'

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Maturity Indices

Average starch score for a sample of 30 apples equal to or greater than 2.5 on a 0 to 6 scale (California Granny Smith Apple Starch Scale), based on the percentage of the core and cortex areas stained dark blue when dipped in the iodine - potassium iodide solution.

Preparation of Iodine-Potassium Iodide (I2KI) Solution for Starch Staining: Dissolve 58.1 g of potassium iodide (KI) in about 150 ml of distilled water, then add 14.5 g iodine (I2) and mix well until completely dissolved. Then complete the final volume to 2 liters with distilled water. Store in a brown bottle or aluminum foil covered bottle.

Quality Indices

- Flavor, including soluble solids (12% or higher), titratable acidity (0.75% or lower) and flavor volatiles.
- To improve eating quality, early season fruit can be conditioned with an ethylene treatment at 100 ppm for 24 hours at 20°C (68°F) for immediate marketing.
- Freedom from defects such as bruising, stem or blossom-end cracks, bitter pit, insect injury and watercore.
- Deep green color and absence of blush and/or sunburn (yellow or brown spots).

Optimum Temperature

0.5 ± 0.5°C; highest freezing point is -1.5 °C

Some reports indicate that 0°C can result in low temperature (chilling) injury in some seasons.

Optimum Relative Humidity

90-95%

Rates of Respiration

2 to 4 ml/kg·hr at 0.5 °C. To calculate heat production multiply ml CO_2/kg·hr by by 122 to get kcal/metric ton/day.

Rates of Ethylene Production

1 to 6 µl/kg·hr at 0.5°C

Responses to Ethylene

- Ethylene can accelerate senescence and loss of firmness.
- Removal of ethylene may reduce susceptibility to scald.

Responses to Controlled Atmospheres (CA)

The following atmosphere has been successful for Granny Smith apples: 1.5% oxygen + 1.0% carbon dioxide:

- maintains firmness and titratable acidity
- reduces susceptibility to bitter pit and storage scald

Physiological Disorders

Storage Scald. Granny Smith apples are very susceptible to storage scald especially when grown in hot dry climates such as much of California. Diphenylamine (not registered in the Republic of Moldova) drench before storage is recommended, especially for storage beyond 3 months. CA storage can reduce scald incidence and severity, and reducing ethylene levels in storage also reduces scald development. The lower the oxygen concentration used, the better the scald control (be sure to determine fruit tolerance to low oxygen first). Early season or low maturity fruit is more susceptible to scald.

Bitter Pit. Granny Smith apples are very susceptible to bitter pit. Large fruit from young, vigorous trees are most susceptible. Preharvest calcium sprays are most effective to reduce bitter pit. Postharvest calcium dips are also beneficial.

Calcium Rates for Postharvest Dips

- 3 to 4%- solid flakes (77% $CaCl_2$)
- 2 to 3%- calcium chloride ($CaCl_2$)
- 0.7 to 1%-calcium ion (Ca+2)

Pathological Disorders

Gray Mold, Blue Mold. These decay-causing pathogens can be controlled by avoiding fruit injury, sanitizing water systems with chlorine and cooling fruit quickly.

Mucor rot. Some orchards have Mucor organisms in the soil. Sanitation to keep soil out of drench water is important. Do not place fruit from orchard floor into storage bins. Chlorine will not control this organism and there are no effective fungicides. Mucor continues to grow slowly even at 0°C.

Sanitation of Water Systems

Sanitation of water systems used to handle apples is important. Chlorine at 50 to 100 ppm is very effective but the level of residual chlorine and solution pH (7.0) must be monitored frequently and adjusted. Sodium will accumulate when liquid sodium hypochlorite is used and can burn apple tissues. We recommend water systems be changed once a day to prevent burn to apple skins. Granny Smith is moderately sensitive to sodium burn.

Table Grape

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Maturity Indices

In California, harvest date is determined by Soluble Solids Concentration (SSC) of 14 to 17.5% depending on cultivar and production area. In some situations, the SSC/titratable acidity (TA) ratio of 20 or higher is used to determine maturity for early maturing cultivars from early production areas. For red and black colored cultivars, there is also a minimum color requirement.

Quality Indices

High consumer acceptance is attained for fruit with high SSC or SSC/TA ratio. Berry firmness is also an important factor for consumer acceptance as are lack of defects such as decay, cracked berries, stem browning, shriveling, sunburned or dried berries, and insect damage.

Optimum Temperature

Berry storage at -1.0 to 0° C is recommended.

The highest freezing point for berries is -2.1° C, but freezing point varies depending on SSC. A -2.0° C stem freezing point has been reported.

Optimum Relative Humidity

90-95% RH and an air velocity of approximately 20-40 feet per minute (FPM) is suggested during storage.

Rates of Respiration (of grape clusters, i.e. berries + stems)

Temperature	ml CO_2 /kg·hr*
0° C	1-2
5° C	3-4
10° C	5-8

20° C	12-15

Stem respiration rate is approximately 15 times higher than berry respiration.
* To calculate heat production, multiply ml CO_2 /kg·hr by 122 to get kcal/metric ton/day.

Rates of Ethylene Production

<0.1 - l/kg·hr at 20° C

Responses to Ethylene

Table grapes are not very sensitive to ethylene. However, exposure to ethylene (>10 ppm) may be a secondary factor in shatter.

Responses to Controlled Atmospheres (CA)

CA (2-5% O_2 + 1-5% CO_2) during storage/shipment is not currently recommended for table grapes because its benefit is slight and SO_2 used for decay control.

Effects of Genotype on Market Life

Market life varies among table grape cultivars grown in California and is also strongly affected by temperature management and decay susceptibility.

Physiological Disorders

Shatter. (loss of berries from the cap stem) In general, shatter increases in severity with increasing maturity, i.e., the longer the fruit remains on the vine. Berries of seedless cultivars, are usually less well attached to the cap stem than seeded cultivars. Shatter varies considerably from season to season, and there is a large difference among varieties. Gibberellin applied at fruit set weakens berry attachment. Shatter occurs mainly due to rough handling during field packing with additional shatter occurring all the way to the final retail sale. Shatter incidence can be reduced by controlling pack depth and fruit packing density (cubic inches per pound), using cluster bagging, gentle handling and maintaining recommended temperature and relative humidity

Waterberry. Waterberry is associated with fruit ripening and most often begins to develop shortly after veraison (berry softening). The earliest symptom is the development of small (1-2 mm) dark spots on the cap stems (pedicles) and/or other parts of the cluster framework. These spots become necrotic, slightly sunken, and expand to affect more areas. The affected berries become watery, soft, and flabby when ripe. In California, this disorder has been associated with a high nitrogen status vine, canopy shading, or cool weather during veraison and fruit ripening. Avoid over fertilization with nitrogen. Foliar nutrient sprays of nitrogen should be avoided in waterberry-prone vineyards. Trimming off affected berries during harvest and packing is a common practice, although labor intensive.

Pathological Disorders

Gray Mold. (*Botrytis cinerea*) Gray mold is the most destructive of the postharvest diseases of table grapes, primarily because it develops at temperatures as low as -0.5° C and grows from berry to berry. Gray mold first turns berries brown, then loosens the skin of the berry, its white, thread-like hyphal filaments erupt through the berry surface, and finally masses of gray colored spores develop. Wounds near harvest also provide opportunities for infections. No wound is required for infection when wet conditions occur.

Botrytis infection can be reduced by removing desiccated, infected grapes of the previous season from vines, leaf-removal canopy management, preharvest fungicides, trimming visibly infected, split, cracked, or otherwise damaged grapes before packing, prompt cooling and fumigation with sulfur dioxide (100 ppm for one hour) or use of continuous release SO_2 pads.

Peach and Nectarine

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Maturity Indices

In California, harvest date is determined by skin ground color changes from green to yellow in most cultivars. A color chip guide is used to determine maturity of each cultivar.

A three tier maturity system is used in California
1) US-Mature (Minimum Maturity)
2) Well-Mature
3) Tree Ripe.

Measurement of fruit firmness is recommended in cultivars where skin ground color is masked by full red color development before maturation. Maximum maturity: The flesh firmness at which fruits can be handled without bruising damage is measured with a penetrometer with an 8 mm- (5/16") tip. Bruising susceptibility varies among cultivars.

Quality Indices

High consumer acceptance is attained on fruit with high soluble solids content (SSC). Fruit acidity, SSC/acidity ratio, and phenolic content are also important factors in consumer acceptance. There is no established minimum quality standard for peaches and nectarines.

Fruit with 2-3 pounds-force flesh firmness is considered "ready to eat". Fruit below 6-8 pounds-force measured on the cheek are more acceptable to the consumer.

Optimum Temperature

-1 to 0°C. Freezing point varies depending on SSC from -3 to -2.5°C

Optimum Relative Humidity

90-95% R.H.; an air velocity of approximately 50 CFM is suggested during storage.

Rates of Respiration

Temperature	0°C	10°C	20°C
ml CO_2/kg·hr	2 - 3	8 - 12	32 - 55

To calculate heat production multiply ml CO_2/kg·hr by 122 to get kcal/metric ton/day.

Rates of Ethylene Production

< 0.01-5 µl/kg·hr (range)* at 0°C, 0.02-10 µl/kg·hr at 5°C, 0.05-50 µl/kg·hr at 10°C and 0.1-160 µl/kg·hr at 20°C

*The lower end of this range is for mature but unripe fruit; higher values are for ripe fruit.

Responses to Ethylene

In general peaches and nectarines harvested at Well Mature (higher than US-Mature) will ripen properly without exogenous ethylene application. Ethylene application to fruit harvested at the US-Mature maturity will only ripen the fruit more uniformly without speeding up the rate of ripening. A few cultivars may need to be exposed to ethylene to ripen properly.

Responses to Controlled Atmospheres (CA)

The major benefits of CA during storage/shipment are retention of fruit firmness and ground color. Decay incidence has not been reduced by using CA 1-2% O_2 + 3-5 % CO_2. CA conditions of 6% O_2 + 17% CO_2 are suggested for reduction of internal breakdown during shipments, but the efficacy is related to cultivar, preharvest factors, market life and shipping time period.

Effects of Genotype and Cultural Practices on Postharvest Life

There are approximately 350 peach and nectarine cultivars in California. Market life varies among them and it is strongly affected by temperature management. Maximum market life is obtained when fruit is stored at approximately 0°C (32°F). Maximum market life varies from 1-7 weeks for nectarine cultivars and from 1-5 weeks for peach cultivars. Because internal breakdown is the main limitation to market life, minimum postharvest life occurs when fruit is stored at 5°C (41°F). Cultural practices have an important role in determining fruit quality and storage potential. Leaf nitrogen content between 2.6-3.0% is advised to obtain high red color development and maximum storage performance. Small size fruit grown in the outside canopy position have a longer market life than large size fruit grown in the inside position.

Physiological Disorders

Internal Breakdown or Chilling Injury. This physiological problem is characterized by flesh internal browning, flesh mealiness, flesh bleeding, failure to ripen and flavor loss. These symptoms develop during ripening after a cold storage period, thus, are usually detected by consumers. Fruit stored within the 2.2-7.6°C(36-46°F) temperature range are more susceptible to this disorder.

Inking (Black staining). It is a cosmetic problem affecting only the skin of peaches and nectarines. It is characterized by black or brown spots or stripes. These symptoms appear generally 24-48 hours after harvest. Inking occurs as a result of abrasion damage in combination with heavy metals (iron, copper and aluminum) contamination. This occurs usually during the harvesting and hauling operations, although it may occur in other steps during postharvest handling. Gentle fruit handling, short hauling, avoiding any foliar nutrient sprays within 15 days before harvest, and following the suggested preharvest fungicide spray interval guidelines are our recommendations to reduce inking in California.

Pathological Disorders

Brown Rot. Caused by *Monilia fructicola* is the most important postharvest disease of stone fruits. Infection begins during flowering and fruit rot may occur before harvest but often occurs postharvest. Orchard sanitation to minimize infection sources, preharvest fungicide application, and prompt cooling after harvest are among the control strategies. Also, postharvest fungicide treatment may be used.

Gray Mold. Caused by *Boyrytis cinerea* can be serious during wet spring weather. It can occur during storage if the fruit has been contaminated through harvest and handling wounds. Avoiding mechanical injuries and good temperature management are effective control measures.

Rhizopus Rot. Caused by *Rhizopus stolonifer* can occur in ripe or near ripe stone fruits kept at 20 to 25°C (68 to 77°F). Cooling the fruits and keeping them below 5°C (41°F) is very effective against this fungus.

Plum

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Maturity Indices

In most of the cultivars growing in California, harvest date is determined by skin color changes that are described for each cultivar. A color chip guide has been designed to determine maturity for each cultivar.

A three tier maturity system is used in California
1) US-Mature (Minimum Maturity)
2) Well-Mature
3) Tree Ripe

Measurement of fruit firmness is recommended for cultivars where skin ground color is masked by full red or dark color development before maturation.

Maximum maturity: Flesh firmness, measured with a penetrometer with an 8 mm-tip, can be used to determine a maximum maturity index, which is the stage at which fruit can be harvested without suffering bruising damage during postharvest handling.

- Plums are less susceptible to bruising than most peach and nectarine cultivars at comparable firmness.

Quality Indices

High consumer acceptance is attained on fruit with high soluble solids content (SSC). Fruit acidity, SSC/acidity ratio, and phenolic content are also important factors in consumer acceptance. There is no established minimum quality standard based on these factors. Plums with 2-3 pounds -force flesh firmness are considered "ready to eat".

Optimum Temperatures

-1.0 to 0°C. Freezing point varies depending on SSC.

Optimum Relative Humidity

90-95% R.H; an air velocity of approximately 50 CFM is suggested.

Rates of Respiration

Temperature	0°C	10°C	20°C
ml CO_2/kg·hr	1-1.5	4.2	8.2

To calculate heat production multiply ml CO_2/kg·hr by 122 to get kcal/metric ton/day.

Rates of Ethylene

Temperature	0°C	5°C	10°C	20°C
µl/kg·hr	< 0.01-5*	0.02-15	0.04-60	0.1-200

* The lower end of this range is for mature but unripe fruit; higher values are for ripe fruit.

Responses to Ethylene

Most of the plums harvested at the California Well-Mature stage (higher than US-Mature) will ripen properly without exogenous ethylene application. Ethylene application to fruit harvested at the US-Mature maturity will only ripen the fruit more uniformly without speeding up the rate of ripening. However, for the slow ripening plum cultivars, expgenours application of ethylene (100 ppm for 1-3 days at 20°C / 68°F) is needed for even ripening. These cultivars are Angeleno, Black Beaut, Casselman, Late Santa Rosa, Kelsey, Nubiana, Queen Ann, Red Rosa, and Roysum.

Responses to Controlled Atmospheres (CA)

The major benefits of CA during storage/shipment are retention of fruit firmness and ground color. Decay incidence has not been reduced by CA of 1-2%O_2 + 3-5 %CO_2. CA conditions of 6% O_2+ 17% CO_2 are suggested for reduction of internal breakdown during shipment, but its effectiveness depends on cultivar, preharvest factors, market life and shipping time.

Effects of Genotype and Cultural Cultivars in California

Market life varies among cultivars and it is strongly practices on affected by temperature management. Maximum market life is obtained when fruit are stored at approximately 0°C (32°F). Maximum market life varies from 1-8 weeks. Because internal breakdown is the main limitation to market life, minimum postharvest life occurs when fruit is stored at 5° C (41°F).

Physiological Disorders

Internal Breakdown or Chilling Injury. This physiological problem is characterized by flesh translucency, flesh internal browning, flesh mealiness, flesh bleeding, failure to ripen and flavor loss. These symptoms develop in plum and fresh prunes during ripening after a cold storage period. Thus, these symptoms are usually detected by consumers. Fruit stored within the "killing temperature range" 2-8°C (36-46°F) are more susceptible to this problem.

Pathological Disorders

Brown rot. Caused by *Monilia fructicola* is the most important postharvest disease of stone fruits. Infection begins during flowering and fruit rot may occur before harvest but often occurs postharvest. Orchard sanitation to minimize infection sources. preharvest fungicide application and prompt cooling after harvest are among the control strategies. Also, postharvest fungicide treatment may be used.

Gray Mold. Caused by *Boyrytis cinerea* can be serious during wet spring weather. It can occur during storage if the fruit has been contaminated through harvest and handling wounds. Avoiding mechanical injuries and good temperature management are effective control measures.

Rhizopus Rot. Caused by *Rhizopus stolonifer* can occur in ripe or near ripe stone fruits kept at 20 to 25°C (68 to 77° F). Cooling the fruits and keeping them below 5°C (41°F) is very effective against this fungus.

Sweet Cherry

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Maturity Indices

Skin color and soluble solids content (SSC) are the main criteria used to judge fruit maturity. Minimum maturity in California requires that the entire cherry surface have a minimum of light red color and/or 14 to 16% SSC, depending on the variety. The red mahogany stage is recommended for harvest of Brooks, Garnet, Ruby, Tulare and King varieties.

Quality Indices

Taste is related to SSC, titratable acidity (TA) and the ratio of SSC/TA. Freedom from cracks, bird pecks, shriveling, decay or misshapen fruit (doubles, spurs). Green fleshy stems are often associated with freshness and quality.

Optimum Temperature

-0.5 ± 0.5°C

Optimum Relative Humidity

90-95%; high humidity is particularly important to maintain green stem color.

Rates of Respiration Production

Temperature	0°C	5°C	10°C	20°C
ml CO_2/kg·hr	3 - 5	5 - 9	15 - 17	22 - 28

To calculate heat production multiply ml CO_2/kg·hr by 122 to get kcal/metric ton/day.

Rates of Ethylene

< 1 µl/kg·hr at 20°C

Responses to Ethylene

Cherry response to ethylene is minimal. Ethylene does not accelerate cherry ripening.

Responses to Controlled Atmospheres (CA)

CA reduces respiration rate and thereby increases postharvest life. Elevated CO_2 suppresses decay development. Modified atmosphere packaging within boxes has been very successful. Successful atmospheres are generally within the following ranges:

3 to 10% O_2
10 to 15% CO_2
< 1% O_2 can result in skin pitting and off-flavors
> 30% CO_2 can result in brown skin discoloration and off-flavors.

Flavor volatiles may be reduced following several weeks of CA storage resulting in fruit of good visual quality but poor sensory quality.

Physiological & Physical Disorders

Pitting. An indentation in the surface of the fruit caused by the collapse of cells under the skin. Thought to result from impact injury.

Bruising. Results from compression and impact of the fruit.

Postharvest life is closely related to respiration rate. Respiration rate increases as a result of increased temperature and physical injury.

Pathological Disorders

Brown Rot. Caused by *Monilinia fruticola*, disease can begin in the orchard or postharvest. Pre and postharvest control measures are necessary.

Grey Mold. Caused by *Botrytis cinerea*, a fungus that continues to grow slowly at 0°C (32°F).

Rhizopus Rot. Caused by *Rhizopus stolonifer*, a fungus that is found in fruit exposed to temperatures of 5°C (41°F) or greater.

Proper temperature management (rapid cooling to optimum storage temperature) can completely control Rhizopus Rot and significantly reduce Brown Rot and Grey Mold. Eliminating injured and diseased fruit from the packed box is important. Fungicide treatments, pre and postharvest are often beneficial.

"FACILITY DESIGN" BASIC DATA SHEET

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HARVESTING AND HANDLING PEACHES

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Harvest and conveyance of ripe fruit to the packing house concludes the orchard management phase of peach production. It initiates a new phase of management that requires its own unique skills. A series of systematic quality oriented harvest and post-harvest operations, beginning with harvest and ending when the consumer utilizes the product, is a key to success in any peach operation. Managers must assess fruit maturity to balance between the optimal quality of a truly tree-ripe peach and retention of resilience and durability required to harvest, transport, grade, package, and market fruit. Each time the fruit is handled or moved is a step that should be analyzed as an individual componentto optimize fruit quality. An understanding of fruit physiology pre- and post-harvest and of conditions that maintain fruit quality is essential.

Harvesting

Proper Maturity at Harvest

Peaches must be picked at a stage of development that is advanced enough to allow the fruit to ripen to high culinary quality, yet early enough to minimize bruising and premature softening during storage and transit. Deciding when to pick is difficult. Selection of picking dates is as much art as science. Variability in maturity, quality, and anticipated durability after harvest place a premium on experience and decision-making. Although every tested variety has an estimated ripening date relative to that of Elberta, the grower must adjust to annual fluctuations in ripening. Excessively green fruit or soft fruit are undesirable, and over-mature fruit will be subject to rapid deterioration. Harvest workers should be trained to select for size and maturity. Green and undersized fruit should be left on the trees until they reach shipping maturity.

Multiple pickings are usually required for each variety to cope with the variable ripening of peaches. Picking must be selective, removing only those fruit mature enough to ship. Color and firmness are the two factors most employed in selecting fruit for picking. Environmental factors such as chill or frost can affect color, size, occurrence of soft tips, or striping of peel color. Parameters for judging maturity will continue to change with the releases of new varieties. Level of acceptability is a sliding scale that changes within each season by variety.

Ground color is the best field indicator of peach maturity. Considerable research effort has been given to the development of harvest standards based on color. The ground color of a peach approaching maturity is light green. A break in color toward yellow is the first definite indication of maturity. Brightening of the red over-color of the skin is another, though less reliable, index of maturity. Red color is typically dull prior to the green to yellow break. When the underlying ground color breaks to yellow, the red brightens and can easily be selected. Color judgments are reliable with many older varieties, but new highly colored varieties with higher percentages of red over-color have diminished the usefulness of color in maturity determination.

Varietal tendencies must be understood to make proper picking decisions. Some varieties can hang on the tree longer when ground color has broken to yellow, although others may have so much red over-color that the green to yellow break is hard to detect.

With highly colored varieties, firmness and size are key determinants of ripeness. Some varieties are firm when mature, while others begin to soften as soon as ground color breaks. Firmness may vary year-to-year on the suture, opposite the suture, and at the tip. These variations limit the value of objective pressure testing by instruments. Day-to-day picking judgments must be made for each variety. Many newer varieties are firmer at eating maturity and can hang on the tree longer. As breeding efforts introduce non-melting flesh into the germplasm, estimation of maturity will become even more challenging and quality parameters of acidity and soluble solids may become more important. Clearly, orchard history and the grower's experience are critical to the proper determination of fruit maturity.

Experience and the General Rule.

A break in ground color and a perceptible cushioning of firmness are frequently the best indicators of maturity. Growers and picking crews must be sensitive to changes in fruit shape and size as the fruit moves through its final swell to packing maturity to minimize soft tips, sutures, and shoulders.

Orchard to Packing House: Optimal Fruit Handling to Reduce Handling Injury.

Injury from rough handling is a key cause of fruit quality reduction. Bruises, cuts, punctures, compression, and abrasion injuries can be found on almost any fruit in a retail display. Consumers consistently avoid damaged fruit if undamaged fruit are available. The physiology of fruit is altered dramatically by wounding: (1) respiration increases with a corresponding decrease in shelf life; (2) ethylene production increases, which accelerates deterioration of the wounded fruit and adjacent sound fruit in the container; (3) undesirable color changes, such as flesh browning, occur; and (4) open wounds are a point of entry for pathogens, leading to decay. An important objective for any crew or packing house manager is the reduction of handling injury during harvest and post-harvest operations. Handling injury is cumulative. When several steps in the handling system wound fruit, injuries accumulate, sometimes to the point fruit are down-graded or unmarketable. Picking is step one in harvest and post-harvest management. Ideally, picking should be done in early morning when temperatures are lower. Rapid conveyance to the packing house and shading harvested fruit will reduce overheating and slow the post-harvest ripening. The hands of harvesters are the most important hands that touch the fruit. A single careless step in harvesting can injure a peach and render it unmarketable. Workers should not have long, sharp fingernails. Gloves are desirable. Workers should not drop or toss the fruit. They should be taught to empty their bags, boxes, or buckets carefully, especially if the receiving container is empty. They should not overfill any container that might later have another container stacked on top. Picking bags, bins, buckets, boxes, trailers, and all other field containers should be frequently examined for sharp edges, protruding nails or staples, and sand or gravel that could cause injury to fruit. Padding should be used in containers whenever possible to reduce impact and abrasion injuries. An often-cited harvest management study by Ramsey in 1912 highlights common-sense steps to improve quality. Decay was less when: smaller picking bags were used; the manager did not harvest, but was free to manage the harvest crew full-time; and the manager took time to randomly inspect product piece by piece for harvest injury as well as proper maturity. Farm roads are seldom smooth surfaces and are difficult to maintain. Moderation in transport speed, use of shock absorbers on trailers or flatbed trucks, and the use of plastic rather than wooden bins are all steps that help reduce fruit injury.

Published Quality Standards in the U.S.

U.S. Department of Agriculture Standards must be met for each of the four grades if classified by the U.S. Department of Agriculture.

U.S. Fancy requires that the peaches have at least 1/3 of their surface showing blushed pink or red color and that at least 90% of them meet this color standard. U.S. Fancy has a 2% allowance, or tolerance, for soft or overripe fruit at destination.

U.S. Extra No. 1 requires that the peaches should have at least 1/4 of their surface showing blushed pink or red color and that at least 50% of the fruit meet this color standard. As with U.S. Fancy, 2% are allowed to be soft or overripe at destination.

U.S. No. 1 peaches do not have a color standard, but should be mature with a 2% allowance for soft or overripe peaches at destination.

U.S. No. 2 has no color standards and it allows for a greater percentage of fruit that are poorly shaped. As with all USDA grades, the tolerance for soft or overripe fruit at destination is only 2%.

California Well Matured fruit are mature enough to complete the ripening process without additional ethylene exposure. The over-blush is usually 90% of total for a given variety. Ninety percent of the lot must meet the color standard. There is a non-severe open suture tolerance of 25%.

U.S. Mature covers all U.S. No. 1 peaches, stipulating that fruit are mature enough to complete the ripening process without additional ethylene exposure. There is a non-severe open suture tolerance of 25%.

Physiology of the Peach After Harvesting

Peaches are climacteric fruit, they can be harvested when they are still firm but physiologically mature, which means they will continue to ripen after harvest. This is analogous to the "California Well Matured" grade. A harvested peach is alive, and is physiologically active as it ripens and eventually becomes senescent. If the fruit is injured by storage at inappropriate temperatures or improper handling, its senescent phase is advanced, significantly shortening shelf life. In peaches, advanced senescence brings unfavorable mealy flesh textures and undesirable flavors, particularly the absence of typical peach flavor volatiles. Flesh discoloration and internal browning can be initiated by improper storage conditions. Temperature and humidity are the key post-harvest environmental factors influencing the quality and shelflife of the harvested peach.

Softening of a harvested peach is prompted by cell-wall-degrading enzymes that become active during the final stages of ripening. Softening occurs more rapidly in freestone fruit than in cling peaches. The levels of ripening enzymes vary from one variety to the next, which affects their natural flesh firmness. Higher temperatures increase the activity of ripening enzymes. In general, a peach will ripen as much in a day at 70°F as it will in a week at 32°F. Obviously, refrigeration is an effective way of slowing the rate of ripening. During the ripening process, respiring fruit utilize oxygen and metabolize sugars, converting sugars by enzymatic action into heat, chemical energy, carbon dioxide (CO2), and water. Heat is given off by the fruit into the environment; the chemical energy is used to maintain cell and fruit integrity, to support enzyme activity, and for synthesis of ripening compounds; the CO2 is expelled into the atmosphere; some water is used for enzyme activity, some accumulates in the tissues, and some evaporates. The production of energy from sugars is called respiration. Under proper conditions, respiration keeps the fruit in a fresh and constantly changing condition. Eventually, sugars and other stored components are depleted, which reduces flavor. Respiration can be slowed to prolong ripening. As respiration slows, fruit produce less heat, softening by enzymatic reactions is retarded, and flavor changes due to metabolism of sugars are reduced.

Temperature reduction slows enzymatic action, as do reduced oxygen and increased CO2, which in turn reduces respiration rate. A 10°C (18°F) increase in temperature increases peach respiration 2 1/2 times. Respiration peaks when fruit go from optimal ripeness to over-maturity or senescence. This physiological watershed between under ripe and overripe is referred to as the climacteric. To maintain fruit quality, peaches must be picked early enough to reach the consumer before the fruit becomes overripe. The climacteric is easily reached in peaches stored at 50°F or above, which accelerates the progress toward fruit senescence, and deterioration of flavor and texture.

Temperature is the most important determinant of the shelf life of fruit. Uncooled fruit can deteriorate more in 1 hour at 90°F than in 1 day at 40°F or in 1 week at 32°F. Most of the physiological processes associated with fruit deterioration operate more rapidly at high temperatures. Understanding the relationship between temperature and fruit senescence is required in order to properly handle peaches during the post-harvest period.

During refrigerated storage of peaches, air exchange is required to dissipate CO_2 and heat of respiration. Slightly elevated CO_2 may reduce the respiration rate, but levels above 5% can induce flesh browning around the pit. Any interference in gas exchange that restricts oxygen absorption and causes internal build-up of CO_2 shortens the storage life of peaches and promotes development of off-flavors. Even heavy wax on the fruit surface may cause undesirable internal conditions (anaerobic respiration) that will cause the formation of alcohols detected as an off-flavor. The heat of respiration must be constantly dissipated. Warm peaches in an inadequately cooled and ventilated truck may actually grow warmer while in transit. It is very important to thoroughly cool fruit before shipping or storage.

Challenges to Meeting Quality Standards

The many fruit choices available to consumers mean peaches must be attractive, flavorful, and free of internal breakdown to sell competitively. The difficulties with harvesting southeastern peaches at tree-ripeness have been recognized for decades. The region's uneven growing conditions increase variability in maturity at harvest, with corresponding variability in the rate of softening.

Studies in South Carolina and Georgia have documented variability in firmness at harvest. Puncture pressures varied from 5 to 22 pounds. This great a range of firmness at harvest dramatically increases the range of firmness throughout storage, in the supermarket, and in the consumer's refrigerator. In the same studies, temperatures varied from 38° to 51°F over 5-day storage periods; storing peaches in this temperature range is very detrimental to quality. University of California studies have shown this temperature range encourages mealiness, internal browning of the flesh, and inconsistency of ripening. Fruit held at ambient temperature (roadside market conditions) soften at a rapid rate. If these fruit are sold by the second day after harvest, the consumer will have a fruit of nearly perfect eating quality. By the third or fourth day, the fruit will be completely soft, so fruit picked at a tree-ripe maturity must be moved virtually overnight if they are held without cooling.

Temperature Management

Pre-cooling is the rapid removal of field heat to reduce fruit temperature. Ideally, the internal fruit temperature is reduced to the desired range (32° to 37°F) for shipment within 24 hours of harvest. Peaches are generally pre-cooled by hydro-cooling or forced-air cooling. In the Southeast, the traditional method of choice has been hydro-cooling. Simply placing the fruit in a refrigerated storeroom does not constitute pre-cooling. For the grower who is still flexible in the selection of cooling method, there are a variety of theoretical and practical considerations that should be reviewed.

Heat is removed from the pit and interior pulp to the surface by a process known as conduction and from the fruit surface to the cooling medium by convection. Cooling or heat transfer can be achieved through air or water flow. The rate of fruit cooling is influenced by the fruit's temperature at harvest, the thermal conductivity of the peaches, the temperature difference between the peach surface and the cold water or air, and on the heat transfer efficiency between the fruit surface and the cooling medium. Because water conducts heat more quickly than air, hydro-cooling is more rapid than forced-air cooling. It is important to continuously maintain the cooling medium close to the target temperature for the fruit, especially during the last portion of the cooling period.

Cooling time is influenced by product diameter, with larger fruit requiring more cooling time. Internal fruit temperature should be monitored every 30 to 40 bins to assess the effectiveness of cooling. Cooling schedules usually are designed to achieve seven-eights cool (Figure 1). Typically, peaches with an average temperature of 90°F should be cooled to at least 40°F before storage or shipment. Hydro-cooling provides very rapid cooling (Table 1). Refrigeration capacity, Btu's/hr, required for hydrocooling is therefore greater for hydrocooling than for other, slower cooling methods. Table 1 lists the refrigeration heat loads and refrigeration requirements for hydro-cooling 100 bushels of peaches per hour at typical temperature reductions. Forced-air cooling is slower, so the refrigeration capacity required is proportionately less. However, more cooled space is required to cool a similar volume of fruit. Hydro-cooling is popular because of its efficiency and speed. The heat transfer coefficient from the surface of peaches to water is up to 20 times greater than to air, depending upon the relative flow rates of the two cooling mediums. With hydro-cooling, 15 to 30 minutes is generally sufficient if the water is 35°F.

The chief weakness of hydro-cooling is potential contamination and spread of decay-causing organisms to clean fruit. Hydro-cooler water should be changed frequently and kept at a chlorination level which provides surface sanitation of the fruit.

Criteria for Efficient Hydro-cooling

(1) In shower-type coolers, water flow over fruit in shallow, single bin layers should be 7 to 10 gallons per minute per square foot (gpm/ft2) of cooling area. In double-stacked pallet bins, with about 4 ft. of product depth, flow rates should be 20 to 25 gpm/ft2.

(2) Hydro-coolers should be designed so that the water never falls more than 8 inches before reaching the fruit. A water-drop of more than 8 inches can cause surface injury. If the hydro-cooler water must fall more than 8 inches, bins should be covered with perforated lids to reduce effective water-drop height.

(3) Interference with contact between fruit and cooling medium, for instance, containers, films, or tight fill, reduces cooling effectiveness.

(4) Although it is difficult in actual practice, water temperature should be ideally kept at 32° to 33°F.

(5) For adequate water flow through the package, containers must have top and bottom venting.

(6) In addition to bin design for free flow of water, bins should be kept free of leaves or other debris that block vents and cause water channeling.

(7) Use potable hydro-cooler water that is clean and free of decay-causing organisms to prevent spread of decay throughout the lot of fruit.

(8) Maintain chlorine levels of 50 to 150 ppm at a pH of 6.5 to 7.0. At lower pH levels, equipment corrosion problems and release of toxic chlorine gas can occur, and metals such as iron are more soluble and prone to cause inking. The hypochlorite ion that is formed above pH 7.5 is not very germicidal. Refer to hydrocooler water sanitation section for more recommendations.

(9) Change cooler water daily or more often depending on hydro-cooler usage.

(10) Cooler design should allow easy inspection of the water distribution pan for plugged holes. Remove debris and sediment from the reservoir frequently. Self-cleaning trash screens should be used.

(11) Unless all metal surfaces are stainless steel, maintain them with adequate paint coverage to reduce the corrosive effects of chlorine and contamination of hydro-cooler water with iron.

Forced-air cooling is commonly used in the western growing areas of the United States. Packaged fruit in vented containers are stacked in patterns with air baffles to channel cold air that is drawn or forced through the containers. With forced-air cooling, a tunnel is formed by bins or pallets of fruit. Air is pulled through the stacks of fruit by a fan. A slight pressure drop is formed across containers when the cooling tunnel is tarped. The movement of cold air across warmer fruit results in a more even, efficient form of room cooling. **Air flows of one to three cubic feet per minute per pound of fruit are recommended. A minimum of four hours is suggested to cool fruit by this method, but in practice six to eight hours are more likely required to accomplish the task.**
The chief disadvantage of forced-air cooling is the requirement of a larger refrigeration system and more cooled space to compensate for the increased cooling time compared to hydro-cooling. The greatest advantage of forced-air cooling is its low propensity to spread fruit rots. Preconditioning is a delay in cooling fruit to the target shipping temperature in order to allow the ripening process to begin prior to shipment. Some western shippers have adopted the practice, but it is not commonly employed in the Southeast.

Container Design Requires water resistant containers. Package design for adequate air flow.
Speed Fast thermal transfer through water. Slow thermal transfer through air.
Space Much less space required because fruit are moved through in less than one hour. High volume capacity required to cool a similar amount of fruit in a packing facility.
Fruit Dehydration None May be reduced by short cooling periods and 80% relative humidity.
Tendency to Increase Fruit Rots
Water sanitized to reduce rots. Even with sanitation, use of water cooling medium increases prevalence of rots. Slower field heat removal lowers overall tendency to rot compared to hydro-cooling.
Energy Efficiency 3.5 times more energy efficient than forced-air. Difficult to optimize and maintain at highest efficiency. Easier to optimize and maintain at most energy-efficient conditions possible with forced-air.

Packing

A peach packing line is a tightly integrated series of individual operations designed to off-load, convey, wash, sort size, and package fruit with minimal damage to the fruit. Additional steps may be incorporated into the packing line: a cooling operation (either before the line or integrated in the line) and fruit waxing to improve fruit appearance and reduce water loss. A post-harvest fungicidal treatment can be considered to prevent fruit rots and may be more advisable if rots are abundant. The packing line should package well-graded, attractive peaches, and it is the manager's responsibility to do so economically and without over-handling of fruit. Each element in a packing line is an opportunity to improve fruit quality or prevent its deterioration. Growers operating orchards of 100 acres or less are typically well advised to arrange for packing of their crop at other packing houses if commercial shipments are desired. Packing house layout demonstratively impacts efficiency, and planning begins with analysis of present and future hourly packing rates. Decisions on operational steps are needed to establish the specific sequence in fruit handling. Equipment selection and design of the layout are done simultaneously to optimize efficiency. A representative layout rated for a capacity of 350 bushels packed fruit per hour would often include the operations illustrated in Figure 2. The greatest cost in packing line construction is its length. Generally, packing designs that accomplish volume movement with wider conveyors cost less to build and operate than those that do so with longer conveyors. Conveyor velocity and width should be designed to accommodate fruit packing during peak loads.

The packing line itself can be a significant source of fruit injury, but it is one of the easiest areas in which to diagnose problems and implement solutions. Transfer points, where the fruit move from one machine to the next, are the most common problem areas. Strategic use of deceleration curtains and padding can virtually eliminate bruising in the packing house. Such modifications are inexpensive and effective.

Dumping of fruit from field bins onto the packing line must be accomplished with as little bruising and abrasion as possible. In the eastern United States, both wet and dry dumps are in use. The dumping operation is one of the most troublesome areas for impact injury. If fruit are dumped onto a dry surface, look for ways to minimize the distance that the product is dropped and utilize padding on rigid surfaces. The use of water dump tanks (tank capacities range from

500 to 1,500 gallons) can help reduce the shock of emptying fruit, but carefully manage the water quality to minimize the spread of fruit decay. Fruit are lifted from the dump tank water by simple

conveyors, roller conveyors being the most common. Conveyor sides should be covered with padding to minimize fruit abrasions.

Pregrading for removal of trash, particularly leaves, along with removal of undersized or damaged fruit, follows dumping. This process can be accomplished on an apron conveyor or sloping belt trash eliminator, supplemented with hand separation to remove rots or splits.

Defuzzing is a standard practice in most peach packing houses. Defuzzing is usually combined with a wash. Fuzz is removed using wet knives, high-pressure streams of water, or by brushing. High-pressure water defuzzing uses highpressure water sprays against fruit rotating on metal rollers. The spray pattern is flat and fan shaped and the force of the spray removes peach fuzz. This method reduces the hazard of brush abrasions, but does not produce the close and uniform defuzzing action of brushes. Brush defuzzing is generally done by moving fruit along banks of transverse rotating nylon brushes washed by fresh water sprays. If the flow of fruit is interrupted, fruit should be manually raked across the brushes to avoid excess brushing**. Surface moisture can be removed from peaches by use of polyurethane or sponge rollers. Rollers should be well washed in detergent before mounting and as part of the daily packing line maintenance to reduce the risk of purple or black discoloration.**

Peaches are sorted and sized by manual, mechanical, and electronic options. Mechanical devices effectively accomplish sizing, although in smaller packing houses manual sizing is practical. Dimension and weight sizers are the most frequently used equipment. Dimension sizing is based on moving fruit over a series of conveyors or tapered rollers with progressively larger openings. The small fruit removed at the narrow end are generally the less mature.

Electronic systems for sizing and, in some cases, color sorting are also used. Most electronic sizing systems sort by weight, but newer optical technology is being developed to sort on the basis of spherical size. Electronic color sorters split the line into two or three conveyors based on hue properties of the fruit surface.

Control of fungal pathogens in peaches is an indispensable aspect of peach crop management. A good pre-harvest integrated pest management program of well-timed fungicidal applications is necessary. Water quality management and temperature are very important components of the decay-control program. Supplemental decay control is often desired. Packing line application of fungicidal compounds is the next line of defense for rot control. When post-harvest fungicides are used, they are introduced after the pre-grading and may be mixed with wax. Waxing peaches can be an important cosmetic enhancement that reduces water loss from the fruit and has the additional value of providing a carrier for post-harvest fungicide application. A variety of commercially manufactured waxes employ either water-soluble paraffin base waxes or emulsifiable mineral or vegetable oils. If post-harvest fungicides are used, they can either be premixed into wax concentrates or can be sprayed onto the fruit prior to waxing.

Wax is best applied over a bed of brushes. As with any brushing operation, fruit must be manually raked through the waxer if there is an interruption in flow or if mechanical rakes malfunction.

Grading occurs in an initial or pre-grading step, followed by a detailed grading, normally after sizing. Good fruit presentation on well-lit, flat-belt conveyors materially improves the quality sorting. Overripe, misshapen, or blemished fruit are removed in this operation. In the southeastern United States, peaches are generally placed into 1/2 bushel (25 lb.) boxes by volume. Mechanical fillers normally handle eight to twelve boxes per minute. Volume filling can bruise fruit. Impact forces as much as four times the acceptable force have been measured at some fillers. Fruit bruising during box filling can effectively be minimized by elimination of excess impact force by shortening drops; use of well-placed curtains to slow fruit velocity; employing sloped box fillers to reduce drop distance; and use of box cushioning to allow transfer of impact force from the fruit to the cushioning device.

After check weighing on an over-under scale, boxes are lidded and conveyed to the stamp and labeling machine. Lidded and labeled boxes are then palletized before cold room storage or placement onto trucks for transport. Proper placement of boxes on the pallet facilitates efficient air movement when the fruit are stored prior to and during shipment.

Storage

Successful storage of peaches, whether for two days or two weeks, requires proper refrigeration and high humidity. Most sound and well-matured peaches can be stored for two weeks at 31° to 34°F and 90% relative humidity with no significant loss in dessert quality. Some freestone varieties and most clings may be held for longer periods. If the peaches are underripe or if temperatures range from 36° to 50°F, some deterioration of flavor and texture occurs. Freezing occurs at 30°F or lower. At relative humidity lower than 90%, weight loss and shriveling occur.

Internal breakdown of peach pulp is expected to occur from 36° to 50°F. Packing house storage facilities have been seen to fluctuate in this range. Maintaining cold room temperature below 36°F is difficult, but important. Doors in coolers must be opened frequently to move fruit into or out of the rooms and even with well-maintained, flexible curtains, excessive air exchange often occurs. Also, warm fruit often is placed in the same room with chilled fruit, which makes it harder to maintain proper fruit temperature. Finally, adjustment of the delivery air to a lower temperature that can compensate for the heat load creates a risk of freezing fruit. Ideally, rooms should be equipped with very large heat exchange coils and effective thermostatic control systems to meet these challenges. Although southeastern peaches are seldom stored long enough for internal breakdown symptoms to become apparent, there is considerable interest in prolonging storage times to buffer the impact of poor prices. If storage is to be used in this way, temperatures must be consistently maintained in the 31° to 34°F range.

Refrigeration systems are expensive to install and costly to operate. Consult a professional refrigeration engineer in an analysis of any refrigeration project. The major refrigeration equipment requirements for cold room storage are the evaporator, compressor, and condenser. In addition, fans, valves, gauges, switches, and liquid refrigerants are required. The equipment must be compatible and capable of meeting the refrigeration requirements of the storage room **during peak loads**. Evaporator surfaces must be large enough to function with no more than a 2°F dry bulk temperature difference between the refrigerant temperature and the room air temperature. The compressor must have enough unloader capability to reduce capacity when peak loads are over.

Key factors in a properly constructed cold storage room are the vapor barrier and insulation. The vapor barrier consists of a watertight resin or polymer coating or a metal foil or plastic fiber placed on the cold side of the insulation. This barrier prevents the movement of moisture through the walls, which will saturate insulation and lessen its ability to insulate. The insulation should be three to six inches of materials of expanded polyurethane or polystyrene, or a urethane coating foamed on site. A well-designed vapor barrier and insulation system permits economical temperature control and the maintenance of the high humidities required for the storage of peaches. Cold room layout should consider placement of palleted loads or stacks of bins so fruit can be efficiently cooled through ventilation slots in the fruit boxes or forklift openings in bins via forced-air cooling. Periodic, scheduled cleaning of the storage facility is imperative to reduce the level of disease inoculum that accumulates in cold rooms. Cleaners should have both cleaning and disinfectant properties.

Loading and Shipping

Prior to loading any trailer, inspect it for cleanliness. Require drivers to thoroughly clean and disinfect trailers after transit of unsanitary products. Pre-cool trailers prior to loading. Peaches should be loaded so they are protected from physical damage caused by container shifting and from overhead weight and vibration. Use stacking patterns that will promote adequate air circulation through the load to uniformly maintain flesh temperature. Facilitate airflow through the use of loading patterns that provide lengthwise air channels through the load so heat can be removed by the refrigeration system. To provide maximum access openings to all air channels, a starter stack should be placed against the front bulkhead of the trailer (Figure 3). Subsequent stacks should be loaded in a 7 x 6 pattern (Figure 4) that will provide air channels in alternating layers. So that airflow in the air duct will not be restricted, boxes should be loaded to a height that will be no closer than 10.5 inches from the ceiling of the trailer. One row of "floaters" may be loaded adjacent to the sidewall to within one inch of the ceiling of the trailer. All boxes should be loaded tightly from the front to the rear of the trailer, neither loosely spaced nor flush with the rear door. Boxes should not protrude beyond the extruded flooring at the rear of the trailer, as this hinders airflow and circulation.

When space remains between the last stack and the rear door of the trailer, an end gate or other type of load-securing device should be placed against the rear face of the last stack in the load to prevent load shifting and to maintain the alignment of the boxes and loading pattern. Under no circumstances should peach boxes be loaded beyond their stacking strength limitations. Generally, boxes with combination board weight strengths of only 350 lbs. for the body and 275 lbs. for the cover should not be stacked more than seven layers high.

Highway trailers should be loaded with 750 to 1,500 1/2 bushel boxes, depending on trailer length. Stacking of 8 or more layers high is excessive and may lead to crushing and damage.

Trailer temperatures should be maintained at 32° to 34°F. Growers should be familiar with the truck driver, intended route and timetable, and the likelihood of mixed loads. Other horticultural commodities that have requirements compatible to peaches may be shipped with peaches in mixed loads.

Wholesale and Retail Handlers

Managers of wholesale warehouses and retail outlets are important participants in a peach quality program. Of special importance is temperature management. If peaches have been produced, packed, and shipped in a process that is well integrated and managed to assure uniformity of fruit condition, then the wholesale and retail managers may be able to manipulate temperature so that the fruit is ready to eat at the point of sale. **Everyone who handles peaches has a responsibility to the consumer to deliver the best possible quality.**

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