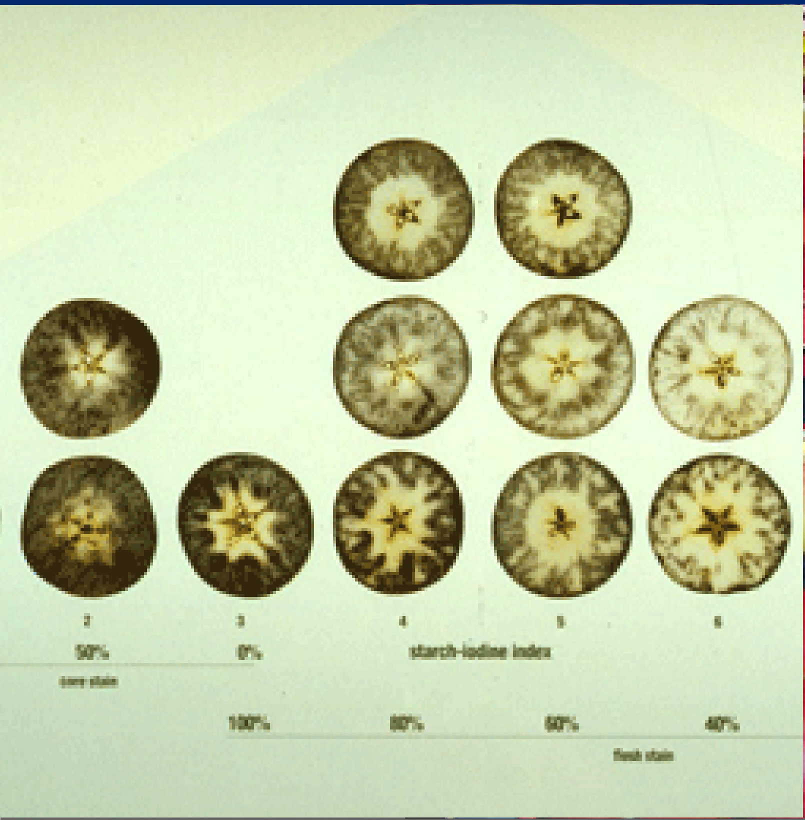
ALBANIAN AGRICULTURE COMPETITIVENESS

USAID FROM THE AMERICAN PEOPLE

ALBANIAN APPLE PROJECT

POSTHARVEST QUALITY, STORAGE AND SUPPLY CHAIN ANALYSIS



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EXECUTIVE SUMMARY

The AAC program aims to stimulate growth in Albania's agricultural sector, which will contribute to achieving sustained, broad-based economic growth and poverty reduction in targeted rural areas. This will be achieved by providing technical assistance and training to producers and other value chain actors to improve productivity and competitiveness. This specific project concentrated on the expanding apple industry in the Korce area, with a focus on postharvest operations.

The purpose of this mission is to ensure that the fledgling supply chain from orchard to storage unit is efficient and cost-effective by using the latest technologies and management techniques.

Three new coolstores erected in 2008, and one that had operated for 3 years, were visited in Korca along with a number of grower clients of AAC who stored apples in clamps (covered heaps on the ground) or in sheds (called warehouses locally). In addition coolstores operators in the Divaja, Berat and Lushnja areas were visited, including one in the process of being built. A greenhouse operator was visited; he provided vegetable transplants to growers and was planning to erect a precooling coolstore for postharvest treatment of melons for export to the UK.

ACHIEVEMENTS:

The STTA completed all tasks according to the SOW.

- STTA undertook a review of existing postharvest facilities of selected ACC clients in the Korca, Divaja and Berat regions in order to understand existing systems and recommend changes required to enhance fruit quality, using internationally accepted apple industry technologies and protocols.
- STTA met with apple grower clients who stored apples in clamps (heaps on the ground), in warehouses/sheds and in coolstores to observe both production and postharvest operations;
- STTA met with 4 coolstore operators in Korce, and three in the Divaja, Berat and Lushnja areas, discussed their operation, answered questions relating to operational problems, and indicated some areas of potential concern including optimum fruit maturity at apple harvest and temperature and humidity management (temperature 0-2^{o}C; relative humidity 90-95%) for maintaining fruit quality in coolstores.
- Prepared a technical presentation for a workshop at Korce to which coolstore operators and one grower were invited. Critical issues addressed were regularity of annual production through minimising biennial bearing, optimising fruit size, reducing bitter pit incidence by crop load manipulation and regular calcium sprays to trees and fruit, and harvesting fruit at the correct maturity (as determined by the starch/iodine test in combination with other maturity indices) for the desired market
- Prepared a presentation for debriefing the USAID representative in Tirana and the AAC project team identifying the major issues facing the apple industry now and in the near to medium term future.
- Prepared a final report that included a review of operations, identified the major issues, outlined recommendations for action and included appendices of important relevant information, much of which will have to be translated into Albanian for local usage.

OUTPUTS AND OUTCOMES

1. An overall description the harvest and storage elements of the value chain including constraints and solutions. The STTA reviewed the supply chain with visits to growers, field and shed storage facilities, coolstores, wholesale markets, retail markets and supermarkets. The supply chain is long with many intermediates – there is a need to shorten the chain to enhance profitability of participants. Local infrastructure in some areas is limited (poor roads, electricity outages) and much fruit is transported from the field to accumulation centres in horse/donkey drawn sprung trailers. Plantings are increasing at about 400ha per year at present; this will produce an additional 2,000 tonnes of fruit within 5 years. Coolstore facilities comprise ~2,000 tonnes in Korce for a current harvest estimated to be 30,000 tonnes. In general fruit was harvested too mature for long term storage, and those coolstores in operation were set at too high a temperature – 6-8oC, rather than 0-2oC.

2. Workshop materials developed and presented on key issues in preharvest, harvest, post harvest and storage. The STTA prepared materials that identified key issues that need to be considered in the apple improvement plan. This included a description of preharvest factors that affect postharvest quality, as well as operational aspects of coolstore management. This was presented to invited participants at a workshop in Korce. However because three of the 4 coolstore operators in Korce had only just commenced the storage operation, they had not experienced any major issues at the time of the visit. It is likely that this will be different after the season; I recommend that there be a follow up visit by the international expert after all fruit has been sold in 2009.

3. Individual audits and list of recommendations for selected AAC client operating cold storage units. At each of the coolstores visited (as well as the shed storage units), the operation was described, discussed and analysed with the STTA; this was followed by an analysis of any problems the operators had confronted this season. Recommendations were then made as to how these might be overcome. All issues that were observed at the four coolstores in relation to operation and fruit quality were covered in the subsequent workshop in Korce.

4. Suggestions for next steps. The following are recommendations for the AAC project team to consider for incorporation into their future work plan.

- That the AAC project teams in the different regions develop strong links with local Albanian personnel, in particular those with postharvest knowledge and experience, for example; Professor Tokli (Tomas) Thomai from the Agricultural University of Tirana (who was educated to the PhD level in postharvest physiology and technology under the leadership of Professor Evangelos Sfakiotakis, a world famous postharvest scientist); the professors at the local university in Korca, the Ministry of Agriculture Extension Service, all of whom will have some responsibility to continue to provide scientific, technical and outreach advice to the apple industry when the current AAC project is completed in July 2012.

- That the AAC project organise two study tours during the next 4 years of the project to enable a selected group of industry personnel with potential to change the business of apple production, postharvest, marketing and education and training to visit Greece within 8 months, and Italy in 2 years time to study the more advanced apple industries in those countries.

- That the AAC project team convene a meeting of apple coolstore operators for a debriefing meeting after the current season has ended and all the fruit has been sold. This might occur in late March/early April and would probably take place in both Korca and in Lushnja. If possible this should include the international postharvest expert (Prof. Hewett will be in Europe on other business at that time) and the local postharvest expert Professor Thomai, who should have a major responsibility for postharvest research and education in Albania on completion of the project.

- That the staff at the Korca office, undertake a small project with selected growers and coolstore operators to formulate their own starch pattern charts for their own fruit grown in their own region. This may have to be created over 2-3 years to ensure that it a consistent pattern is obtained.
- That the AAC purchase a few basic but important books on apple production and postharvest science that will serve as ongoing reference material during and after the project.
- That the AAC purchase a set of tools that can used to evaluate apple quality and also tools for monitoring coolstore conditions.
- That the AAC team continue to explore ways in which local growers can be encouraged to work together in groups in order to strengthen their position in the supply chain. Through unity comes strength and by working together they should be able to negotiate with input suppliers, with traders, with packaging suppliers to obtain better terms; by having greater volumes available they may find better market opportunities. (NB> at least two traders indicated strongly that would prefer to negotiate with a group of growers, rather than many individual growers in the same locality – efficiencies would be introduced and time saved.

5. Orchards operators will have a practical guideline fact sheet to guide them in pre-harvest, harvest, and post harvest activities. Practical information has been provided for the AAC office that can be translated into material for growers. This includes fertilizer recommendations for major and minor elements, critical fertilizer levels for apple trees, information on starch iodine test to determine optimum harvest maturity; and information on thinning trees to minimise periodicity (biennial bearing). Recommendations have been made to the AAC office for simple procedures that should improve fruit quality for growers who store fruit in warehouses/sheds or in clamps.

6. Cold Storage operators will have practical guideline fact sheet to guide them in orchard practices, post harvest handling, transport, pre cooling, and proper storage methods. They will receive practical training and a customized audit report from the consultant. Fact sheets for storage of the major apple varieties grown in Albania have been provided for the AAC team to translate into Albanian. In addition instructions for developing a harvest maturity starch iodine chart have been provided, as have design for the building of a portable precooling unit for using in different coolstore rooms. Several key web sites that provide additional postharvest information have been provided as well as several titles of books that the project might consider purchasing for reference.

7. The STTA team will debrief the Mission with their findings and recommendations. STTA Hewett will complete a final report including protocols for proper post-harvest handling and storage within two weeks after departing Albania. The STTA Dr Hewett, prepared a presentation to debrief the USAID representative and members of the Korce and Lushnja team's, at the Korce office. The final report has been prepared and dispatched electronically to DAI in Washington and to the DAI office in Tirana.

IMPORTANCE OF THIS ASSIGNMENT

If the apple industry in Albania is to change then there is a need to improve production systems, increase coolstorage capacity and shorten the supply chain from orchard to consumer. AAC has made a good start in this project by developing a client base of growers and coolstore operators who are risk takers, who are prepared to adopt new systems and processes to enhance their profits. All clients visited were keen and eager to discuss new technologies for growing and storing fruit to optimise quality.

AAC is to be commended for attempting to establish groups of growers who should be able to pool resources and skills in order to take greater control of their affairs and relationships with a range of supply chain firms and individuals, including traders, input suppliers and perhaps ultimately buyers from supermarkets (that will continue to increase in Albania). Currently apple plantings are being made without cognizance of the market needs for fruit in the future. There are no clear lines of communication along the supply chain for growers; any information they receive is from traders who in turn may be isolated several steps from the ultimate consumer.

This visit highlighted the shortcomings of several key issues concerning apple quality. These include: preharvest nutrition, especially calcium application to reduce bitter pit incidence (a physiological disorder that normally develops in coolstore), balanced nitrogen application to avoid over vigorous vegetative growth and an imbalance between fruit and shoot growth, crop load management to optimise yields and minimise biennial bearing, harvest maturity – all fruit observed were harvested overmature and would have a very limited storage life; and conservative coolstore temperatures – most were running at 6-8oC – when they should have been at 0-2oC. Lack of satisfactory packaging and variation of container shape and size are an issue that needs to be resolved. AAC attempts to foster manufacture of appropriate plastic crates, wooden boxes or cardboard cartons is commended; eventually as supermarkets purchase a larger share of the fruit then they will dictate package type and size.

TASK 1

A RAPID ASSESSMENT OF THE HARVEST AND POST-HARVEST HANDLING PRACTICES CURRENTLY IN THE APPLE VALUE CHAIN.

ASSESSMENT

The supply chain for apples in Albania (value chain as described by Tom Lenaghan, DAI, August 2008) is very diverse and convoluted (Fig 1). At present about 30,000 tonnes of apples are produced each year, yet there is only about 2,000 tonnes of coolstore capacity in the Korca region. While there is a ready market for fresh apples in Albania from the commencement of the harvest season, and while a certain proportion of the annual crop can be sold soon after harvest, international best practice postharvest systems would recommend that the majority of the fruit should be cooled immediately after harvest to maintain quality. This means that a large proportion of the ~28,000 tonnes of apples will continue to be stored using traditional systems that include placing fruit into clamps (heaps in the orchard), as well as placing fruit into warehouses (sheds, barns) that have no control of environmental conditions and thus compromise fruit quality

Development of a coolstore ‘industry’ has the potential to be the beginning of a new era in apple industry of Albania. With the ability to harvest fruit at the correct maturity and to maintain quality in coolstores for longer periods than hitherto possible, the potential exists to supply quality fruit to the domestic market over a much longer period of time than is currently possible. This should lead to a probable increase in returns to both coolstore operators and to their client growers, being greater than in the past. They have the potential to make the price, ameliorated by market demand, rather than simply take any price that is offered by itinerant traders.

However plantings of apples in the Korca region is increasing rapidly; more than 400 hectares were planted during the past season alone, and this planting increase is likely to be continued. Lenaghan (2008) indicated that the average production per hectare from the estimated 12,500 farmers in the region was 20-25 tonnes per ha; some of the more progressive growers would achieve higher yields than this (estimated to reach up to 40 tonnes per ha). Assuming the average yield, then the new plantings in 2008 alone would result in the production of an additional 8,000 tonnes within 3-5 years as the trees come into full production. Thus even if new coolstores are erected in the Korca region over the next few years, there will still be a shortfall in storage capacity and an inability to maintain consistent volumes available for the Albanian market over the period January to April/May. The additional apples produced will still have to be sold in the peak period of October to December. This will result in large supplies of fruit available; causing pressures on prices received and reduced grower returns. The marketing issue is something that growers and coolstore operators will need to consider, and AAC should endeavour to encourage growers and coolstore operators to work together in formal or informal groups so that they wrestle to control the destiny of their apple producing, coolstorage and marketing enterprises. The impetus for such a movement must come from the industry itself; it should not be imposed on them by Government or external agencies. Thus the AAC project will have to adopt a facilitating and advisory role in this process.

At present the majority of apples are stored in very primitive conditions with no control of the storage environment. Fruit is currently harvested at an advanced stage of maturity; this will limit the storage life even when maintained at low temperatures in coolstores. Knowledge of coolstore operation, including optimum storage condition, is limited and coolstore operators were maintaining fruit at 6-8oC, well above the recommended temperatures of 0-2oC used elsewhere in the apple producing world for the major varieties Red (Starking) Delicious and Golden Delicious. While all coolstore operators were advised of the optimum storage conditions, they will only be able to evaluate the material properly after experiencing one season's operation. It will be necessary to continue an ongoing education and training program, including a de-briefing session at the conclusion of the current season.

A number of simple changes were suggested to make marginal improvements to fruit quality of those fruit currently stored in clamps and farm sheds. These include: covering fruit in clamps with white or light colored materials to reflect the sun rather than dark materials that will absorb the heat from the sun; build small tents over the clamps, using locally available materials to allow air to flow over the shaded apples (Fig.2). This system could be replicated easily by other growers. Inside sheds/warehouses fruit is exposed to very low relative humidity (RH) especially during September and October when day temperatures are high. Apples shrivel when they have lost ~5% moisture and this detracts from quality. It was suggested that attempts could be made to increase RH by hanging water absorbing material over windows or on walls in the shed and regularly spraying them with water (avoiding spraying of fruit) to achieve evaporative cooling and an increase in the RH of the air. This may provide a marginal enhancement in fruit quality.

FIGURE 1: APPLE VALUE CHAIN IN KORCA (AFTER LENAGHAN, 2008)

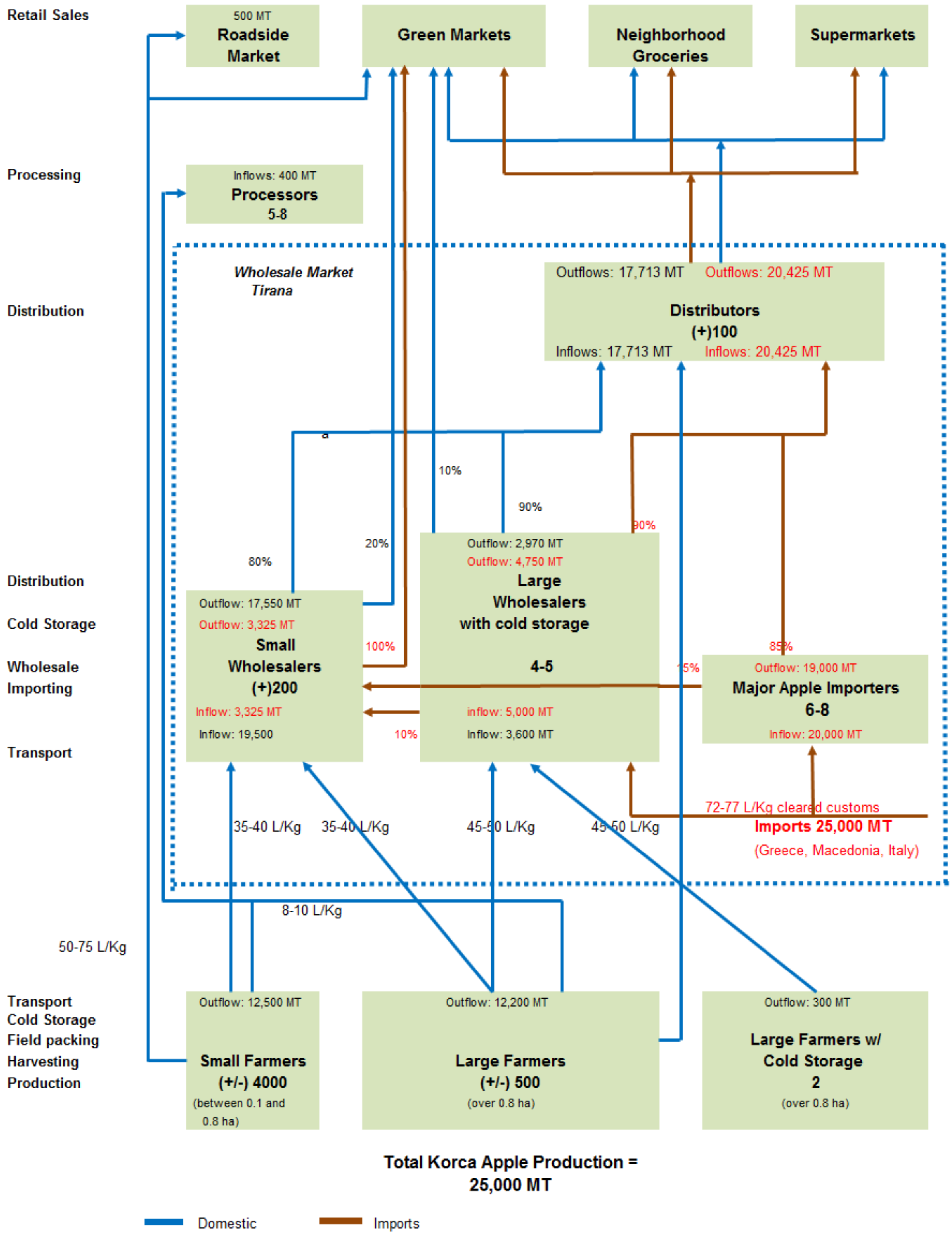


FIGURE 2: SIMPLE TENT STRUCTURE ERECTED USING IRRIGATION PIPES AND LIGHT MATERIAL TO COVER GOLDEN DELICIOUS APPLES.

From left: Lefter Turtulli , regional AAC officer for korce, STTA Dr Hewett and Kico Dudo, orchardist from Polene who devised the tent structure.

In addition it was suggested that a small experiment be undertaken in conjunction with AAC staff to enclose fruit on the floor or on shelves, in perforated plastic sheets to reduce moisture loss. The experiment should be undertaken with fruit the grower can afford to lose, and fruit condition should be monitored closely regularly as this technique might enhance development of postharvest rots.

IN THE ORCHARDS OF APPLE PRODUCERS SUPPLYING COLD STORAGE OPERATORS:

IDENTIFY THE MATURITY DATE FOR OPTIMAL HARVESTING FOR STORAGE (NOT FOR IMMEDIATE CONSUMPTION).

ASSESSMENT

Fruit is being harvested at a range of maturities, determined by the grower, and based essentially on fruit firmness and % sugar content. Neither of these is a good indicator of fruit maturity, as fruit firmness may vary from year to year depending on weather conditions, and sugar content is an indicator that the fruit has already commenced ripening. The majority of the fruit that I saw was far too ripe for medium to long term in coolstores; in fact it was either ready to eat with many fruit tasted being overmature with flesh becoming mushy in texture and juiciness reduced compared with the crisp juicy fruit demanded by most consumers in European, and American markets.

It is important to harvest the fruit depending on the physiological state of the fruit and this cannot be determined using the methods currently employed in Korca. There are a range of tests that are used internationally to determine when to harvest the fruit, but the final decision is usually based on market requirements.

At each orchard visited, preharvest aspects of management that might impinge on at- and postharvest fruit quality were discussed in detail. Relevant technical material was made available to the AAC team at Korce for translation of appropriate documents for provision to growers.

ACTION:

- Outlined the principles of the starch/iodine test at the workshop including pictures of the starch patterns in the major varieties grown in Korca (Golden Delicious and Starking Delicious), describing the reasons for utilizing the starch index pattern and the affect on storage life and quality of fruit after storage. The actual decision of when to harvest will depend on the length of time that the fruit will be stored and the requirements of the market at that time.
- Provided the AAC project offices in Korca and Tirana pictures of starch patterns and suggested harvest times for different varieties and market conditions.
- Recommend that the staff at the Korca office undertake a small project with selected growers and coolstore operators to formulate their own starch pattern charts for their own fruit grown in their own region. This should be done in conjunction with local postharvest specialists, such as Professor Thomai and scientists at the local Korce University should also be included in such a project.
- Optimum harvest maturity will be determined using a range of tools to supplement the starch iodine test. These include monitoring the days from full bloom, the color of the seed (they should always be black); the background color (see color chart for Golden Delicious in Appendix 2), flesh color, and firmness of fruit. Relationships of these maturity components must be ascertained locally to take account of local growing, soil and climatic conditions

FIGURE 3: APPLICATION OF THE STARCH IODINE TEST FOR DETERMINING HARVEST TO DETERMINE MATURITY OF APPLES

IDENTIFY PEST AND DISEASES ON THE APPLES AND DETERMINE HOW THEY MIGHT IMPACT STORAGE QUALITY.

ASSESSMENT

Fruit inspected at the coolstores, in farmer warehouses, in clamps in the orchard, and in both wholesale and retail markets was of very variable quality. Physical, physiological, pathogenic (fungal) and insect was seen on many occasions but again was variable and varied from excellent to poor across growers.

Main pest and disease problems observed:

- codling moth damage – incidence varied among growers and overall did not constitute a major % loss, but this is a serious pest that has the potential to cause substantial fruit damage and it should be possible to control easily using recommended AgriNet spray program;
- apple scab (black spot) – a ubiquitous world-wide fungous disease caused by Venturia inaequalis. Growers were aware of the methods of controlling this disease from their input suppliers, but the regular periods of wet warm conditions during the growing season meant that control was not good in the 2008 season. Growers must be aware of the conditions leading to critical infection periods and apply recommended fungicides accordingly.
- various saprophytic rots – ubiquitous fungi that exist in the environment and are not normally pathogenic, infected the apples through cuts, slices, and abraded fruit surfaces caused by physical damage.

Main physiological disorder observed:

- Bitter pit – a serious physiological disorder that can be very severe in some varieties of apple including Mutsu, Golden Delicious and sometimes Starking Delicious and Granny Smith (Fig. 4). It is caused by a calcium deficiency in the fruit itself (not necessarily in the tree) and cannot be controlled by soil applications of calcium fertilizers or lime. This disorder is often not apparent at harvest, except in some years, but appears within 2 weeks after harvest as well as in coolstores. This disorder was severe in some Mutsu apples seen at one coolstore, but was observed in most lines of Golden Delicious fruit seen in clamps, warehouses, and coolstores.

Each of the coolstore operators were advised on methods to control these problems, as they affected all visited. They were advised to provide technical information to growers to develop management practices to minimise such problems. Technical material has been left with the ACC team for translation of relevant material.

FIGURE 4: BITTER PIT SHOWING EXTERNAL AND INTERNAL SYMPTOMS.

ACTIONS

- Pest and disease control implementation is being undertaken by AgriNet who are developing recommendations that will allow fruit to be marketed as having being produced under the Integrated Fruit Production (IFP) label (minimum sprays, safe sprays, and environmentally safe production and management practices). I recommend that the AAC project team liaise closely with AgriNet to assist with dissemination of the spray recommendations as they become available. They will be based on the chemicals that are approved in Albania, and that are suitable for protection and eradication of the major pests and diseases indicated above.
- Recommended to growers and coolstore owners that they apply 3-6 calcium sprays during fruit development of susceptible varieties to prevent the development of the disorder bitter pit that is a physiological disorder resulting from a localized Calcium (Ca) deficiency in the fruit. This will require the application of Ca based sprays (details of concentrations and timings have been provided for the several AAC offices) during the fruit season.
- ACC team to follow with both growers and coolstore operators that the technical information made available to them is regularly reinforced through an on-going outreach program.

REVIEW SANITATION OF SITE AND PERSONNEL.

ASSESSMENT

Only one large orchard visit was made although several small orchards in back gardens were observed while making visits to external storage heaps of apples (clamps) and to warehouses and sheds. In general the state of orchards appeared good, with vigorous vegetative growth and healthy looking trees.

Apples stored in clamps have a very limited storage life, as they subjected to fluctuating diurnal temperatures that are warm during the day and a little cooler at night. Apples stored in clamps were generally covered with some variously colored materials that varied according to what was available. Some dark colored blankets were seen; using dark colored material is not good as it absorbs heat from the sun and would result in fruit underneath being slightly warmer than they would have been under a white or light colored material.

FIGURE 5: APPLES STORED ON SHELF IN OPEN SHED.

Rotting fruit was noted in the orchard floor; some had been segregated out during the sorting process when fruit was being placed into boxes for transport to the storage warehouse. Such fruit must be removed entirely from the orchard and destroyed, as it will continue to be a source of inoculums for the fungus as long as it remains around sound fruit.

The same situation existed at several non-controlled warehouses that were visited; attempts had been made to sort fruit that had developed storage rots, but the rotting fruit were left in heaps adjacent to the quality fruit. It should be removed and destroyed.

Some trees observed appeared to have vigorous vegetative growth, reflecting a strong fertilizer and irrigation program. Care has to be taken to ensure that a balanced fertilizer program is used; excess nitrogen application, either with ground or spray application, can cause a nutrient imbalance that has the potential to result in fruit with physiological storage disorders and a reduced shelf life. Application of calcium based sprays to the trees and not the soil, ensuring that fruit are covered during by the calcium solution, should reduce the physiological disorder bitter pit, slightly enhance resistance to postharvest rots, and slightly reduce the rate of fruit softening. Fruit from young trees or from trees with small crops, and large fruit are susceptible to bitter pit.

REVIEW HANDLING AND PACKING PROCEDURES. IDENTIFY POSSIBLE CONSTRAINTS.

ASSESSMENT

Main physical damage observed:

- cuts, slices, bruises, and abrasions that occurred during harvesting, transport and/or handling provided many entry points for the fungus to enter into the fruit and cause rots (see below).
- most fruit is harvested directly into buckets that are in turn emptied into boxes. The hard surfaces of the buckets and boxes require that fruit is placed into them very gently. Most apple producing countries use canvas or plastic picking bags that pickers wear and into which they place fruit gently (see Fig. 5 for an example of picking bags available in the USA). This obviates fruit moving against hard abrading surfaces.

CONSTRAINT:

Availability of suitable containers into which the fruit will be placed after harvest is a major constraint. Growers have to place fruit onto plastic straw in heaps on the ground until they can find suitable containers into which they will load the fruit and transport to the warehouse.

ACTION

- Growers should consider using picking bags instead of buckets in an attempt to reduce physical damage during harvesting (Fig. 5). These are used in all major apple producing countries and should be available for purchase in Greece or Italy. Suggested to both farmers and coolstore operators that they should consider purchasing picking bags for each picker so as to minimise physical damage during the harvesting.

FIGURE 6: PICKING BAG FOR APPLES USED IN WASHINGTON STATE, USA.

- Informed each grower and coolstore operator visited about the importance of handling apples very carefully right from the harvest operation, through loading into boxes or crates or buckets, through loading onto the transport vehicle, during transport form the orchard to the accumulation centre, through unloading, sorting, placing back into containers for the coolstore and all subsequent handlings.
- Emphasised at all visits that every time the fruit is handled there is the potential for sustaining physical damage that is manifested as cuts, slices, abrasions or bruises in the fruit; these all provide entry points for normally saprophytic fungi that will develop as rots during storage. They will develop slower at low temperature than at high temperature, but develop they will. If fruit is dropped more than 12 cm onto another fruit or a firm surface it will be bruised.

REVIEW TRANSPORT PROCEDURES TO THE STORAGE UNITS.

ASSESSMENT

Fruit was transported from the orchards in wooden boxes/plastic crates, depending on what the grower owned or could find. There is a major shortage of plastic crates and wooden boxes and this is a major bottle neck for most growers. Boxes are constructed with thin, flexible rough sawn timber, and thus are likely to cause physical damage to fruit as it is transported to accumulation centres.

Many warehouses and coolstores visited were located some distance from the orchards sites. Roads in many rural areas are atrocious with many deep potholes and asphalt that is breaking up, making extremely rough transport to the accumulation centres. Some orchards were located in relatively remote areas with very rough and dusty tracks/roads as the only means of access. Transport from the orchard to the warehouses and coolstores was done using donkey/horse and cart; where orchards were located closer to highways tractors and small vans were used for transport if the orchardists had access.

Although most carts had springs to soften the ride, the very poor state of the tracks/roads (very many, large potholes – some up to 1 m wide and up to 1-300 mm deep, deep ruts in tracks on farms) meant that the risks of physical damage occurring to the fruit during transit to accumulation areas was very high, no matter how carefully the driver tried to avoid the rough areas. All the people we talked to recognized this problem, but until the local authorities undertake repairs to the roads, there condition will only deteriorate further and thus compromise fruit quality further. Local roads that had been sealed in the past were often in the worst state with continuous potholes over the entire surface as the macadam deteriorated. If they are not to be reformatted and sealed then it would be advisable to grade the tar seal off and revert to graded earth roads for smoother rides.

FIGURE 7: TYPICAL TRANSPORT OF APPLES USING A HORSE (OR DONKEY) PULLING A SPRUNG TRAILER

A relatively high percentage of fruit (~5-15% fruit observed at the accumulation centres) had sustained physical damage of some sort, including cuts, slices, abrasions and bruises. Such damage provides an ideal infection point for fungal pathogens that will lead to storage rots in fruit stored in all of the warehouses and coolstores visited.

I was informed that a major water melon export opportunity for growers near Divaja was lost because the buyer saw the state of the roads over which the water melons would have to travel. He made the decision not to buy the fruit, without even visiting the fields – the potential for physical damage occurring as fruit was transported from the field to the accumulation centre was so high as to seriously compromise fruit quality.

ACTION

- Boxes/crates used for transport should be clean, and have smooth interior surfaces, without any sharp edges or protuberances. The distance between wooden slats should be < 5mm apart, so as minimise the sharp edges against which apples would sit and possibly sustain damage during transport. Loads must be tightly secured on the trailers to prevent movement of the boxes during transit.

- Project teams should encourage local growers/traders/coolstore operators to put pressure on local municipal councils to buy/hire a grader to smooth out the roads. In areas where dust is a problem then a water truck could be used to wet the roads during the season when produce is being transported to accumulation centres to reduce the problem of contaminating dust.

AT THE STORAGE UNIT SITE: REVIEW RECEIVING AREA.

The receiving areas at coolstores varied from neat and tidy to very messy (Fig. 7). It must be remembered that 3 of the 4 coolstores in Korca were brand new and only been commissioned before the apple harvest season. In addition all owners were inexperienced and were having to work out their own protocols under pressure of peak harvest. Without experience they would not have been able to put into place well defined and efficient operating systems.

A major issue was that fruit accumulation, sorting and packing was done outside in the sun. In these conditions fruit would heat up to temperatures that would accelerate the respiration rate and hence the rate of deterioration.

FIGURE 8: ORGANIZED CHAOS AT ONE NEW COOLSTORE. FRUIT STANDING IN THE SUN

While there may have been a system of fruit flow being used from receiving, through sorting, spraying, placement into storage containers (sometimes bins, sometimes crates/boxes – depending on what the coolstore operators had available, such a system was not easily apparent as we noticed messy and crowded working area with full and empty containers, waste plastic sheets, and a person spraying fungicide onto apples (right photo) with no protective clothing. Three of the 4 coolstores in Korca had adequate space for receiving, and one was sorting the fruit in the shade (in a coolstore that was not operating, and in the plenum) one other had inadequate space outside his coolstores for easy handling.

ACTIONS

- All coolstore operators should ensure that the fruit is not left in the sun for any length of time after receipt from the farmers. This can be achieved by erecting a shelter under which fruit can be accumulated as it comes from the field, and which it can be sorted for quality, packed into the storage containers before being transferred into the coolstore.
- The structure could be a temporary tent like structure, constructed in a safe manner, or it could be a permanent structure.
- All fruit with rots should be removed from the accumulation site, no matter whether it is the orchard, warehouse or coolstore, in order to remove the source of future infection

REVIEW SANITATION OF SITE AND PERSONNEL.

All fruit is sprayed with a fungicide before placing into coolstores (Fig. 7). Several fungicides are used including Botran (Botran®75WP is a protectant fungicide with particular activity against Rhizopus. Its low volatility and chemical stability enable it to be used both outdoors and under glass. It is recommended for use as a post-harvest dip and/or preharvest spray to protect against Rhizopus rot in stonefruit, berryfruit, grapes and kumaras) and Bavistan (methyl benzimidazole carbamate) (and there may be others).

The purpose of this postharvest fungicide is to attempt to reduce the incidence of rots developing in fruit in coolstore. Many of the fungi involved (Rhizopus, Mucor, Penicillium spp.) infect fruit through cuts and abrasions on the fruit.

Most EU and other western countries will not accept fruit that has been treated with postharvest fungicides, so any coolstore operator will have to ensure that handling of the fruit through the chain from orchard to coolstore is done very carefully to prevent the occurrence of such physical damage and thus obviate the need for such fungicide treatments.

It was observed that there many rotting fruit present when fruit was being accumulated whether this was in the orchard, at the coolstore prior to entry in storage, near and around, sometimes in warehouses. These fruit have been separated from the main lines during sorting at these different locations. However rots will continue to develop, they will eventually sporulate and provide a source of infection that will put all the fruit I the environment and in the storage facility at risk.

Spraying of fungicide was being done among the people who were involved in sorting and repacking fruit. Minimal safety precautions were being taken to avoid risk of spray drift, and in one case the operator was not wearing any protective clothing.

It may be possible for chlorinated water to be used as a postharvest treatment (dip or spray) to reduce potential development of postharvest pathogens. This is used widely in other fruit industries such as cherries, and a chlorine treatment with 50-150 ppm chlorine at pH 7.0 (see Appendix 7) and should be evaluated for its efficacy in comparison with existing chemicals used.

All containers of fruit, whether used in the orchard, or in the pack house, or in transportation to markets, must be cleaned and disinfected to remove dirt, debris and dried and/or decayed fruit residues to remove any potential source of fungal inoculums. All coolstores must be cleaned at least annually, and prior to the new apple season, to ensure that all sources of potential fungal inoculums that may be present. Proprietary brands of approved food safety sanitizing chemicals should be used; this might include chlorinated water at appropriate concentrations (50-150 ppm) or approved quaternary ammonium chloride compounds.

ACTIONS

- Because spraying will probably continue to be necessary to reduce spread of postharvest fungi during storage it is probably necessary to continue this practice.
- Coolstore operators must develop a separate specified location to treat the fruit with fungicides that is way other workers, where the risk of spray drift is minimized.
- Explore the option of using chlorinated water (50-150 ppm at pH 7.0) as a postharvest dip treatment to reduce incidence of postharvest rots.
- Spray operators should adhere to normal safety procedures in wearing protective clothing while undertaking the spraying operation.
- Surplus spray materials, and the empty containers, should be disposed of in properly authorized by the local authorities.
- Follow up by the AAC team to advise coolstore operators of relevant cleansing operations.

REVIEW PRECOOLING AREA AND PROCEDURES.

None of the coolstore operators were using precooling systems. They were receiving the fruit, sorting, spraying, repacking and placing into coolstores. One grower was concerned about cooling his fruit too fast and thus maintained his store at 6-8oC; this was not necessary.

Precooling is done to remove the field heat from products in a very short time, say 6-12 hours, in order to reduce the rate of respiration and hence deterioration. There are various methods of precooling, the method chosen depending on the nature of the product. The main methods used include: forced air (or pressure) cooling, hydrocooling (mainly for cherries and sometimes nectarines), vacuum cooling (mainly for leafy vegetables like lettuce) and icing (for broccoli). Forced air cooling is the main method used for fruit such as apples, peaches, nectarines, plums and kiwifruit.

Because precooling designed to remove heat from products quickly the refrigeration capacity in rooms specially designed for this purpose is much greater than that required for coolrooms designed to hold temperatures only. Thus such rooms are not usually used for precooling, unless small volumes only are being cooled.

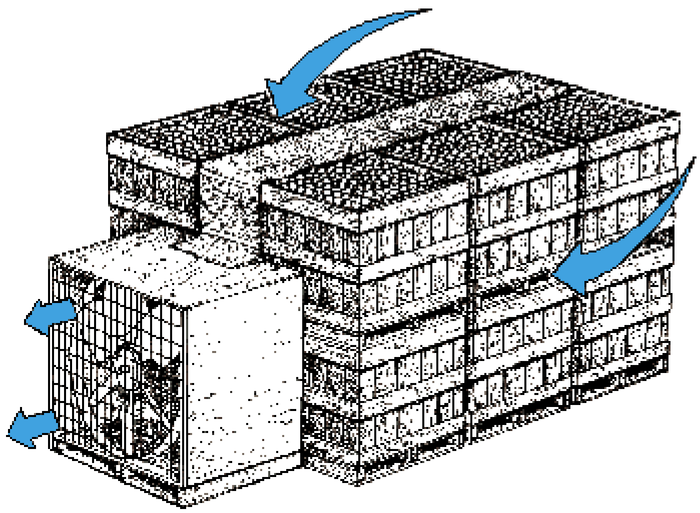
In general most major apple producing countries do not precool their fruit before placing into coolstore; the exception might be for some very early maturing varieties that are harvested when temperatures are high.

However it is possible to make up a small portable unit that can be used for precooling small volumes of product in existing stores. This may be useful for the earliest harvested fruit and for early maturing fruit (Fig. 8).

ACTIONS

- 1. Coolstore operators could build their own portable precooling unit using a frame, an electric motor and a large fan for sucking the air through the packages (bins, crate or boxes) that could be used in different coolstores, as indicated in Fig. 3.
- 2. When planning for building new coolstores, and wishes to precool the product, then he must specify the conditions required to the engineering company, who can design in the extra refrigeration capacity that would be required for dedicated precooling rooms.

FIGURE 9: PORTABLE FORCED AIR PRECOOLING UNIT FOR USE IN EXISTING STORES FOR RELATIVELY SMALL VOLUMES OF PRODUCT IN EACH RUN.



REVIEW PROPOSED SYSTEM FOR PACKING AND STORING THE PRODUCE.

All packing that I saw being undertaken was done manually was very labor intensive, inefficient, time consuming and because of the many transfers involved the risks of fruit sustaining physical damage during the process were high. There were no mechanical graders seen or used as far as I am aware. Until such machines are used then the accuracy and consistency of fruit sizing will be very low.

All coolstore operators recognized the importance of being able to use machines specially designed to allow sorting and segregation into quality and size grades. At least two were already planning to purchase machines when cash flow had increased and funds became available. Highly sophisticated fruit sorting machines are now available; these can be provided as a single lane up 80 or more lanes, each lane being able to be assessed for size (diameter and by calculation weight), shape, density, color, defects and internal sugars (reflected as taste) – see Fig. 9 and 10.

FIGURE 10: A COMPACSORT LTD APPLE GRADER. LEFT: FRUIT CAN BE SORTED ELECTRONICALLY FOR SIZE, WEIGHT, COLOUR, DEFECTS (BOTH SURFACE AND INTERNAL, DENSITY, AND INTERNAL SUGARS AT A RATE OF 12-13 FRUIT PER SECOND. RIGHT: A TWO LANE GRADING MACHINE; MACHINES CAN HAVE UP TO EIGHT LANES OPERATING AT 12-13 FRUIT/SECOND FOR QUALITY LINES OF FRUIT.

A number of commercial electronic sorting systems are available, and operators would need to obtain as much information about the capabilities before they decided to purchase. They would require a dedicated packing shed, and none of them have this at present. Until fruit is sorted in a more objective way to specific grade standards that are dictated by the market , then it is unlikely that the bulk of the fruit reaching the market will improve in quality overall.

Having said that, there are some growers who are making every effort to grow a crop with relatively uniform size (by tree pruning and thinning management) and by spending time sorting into different size grades prior to storage (even for warehouses that have no temperature or humidity control. Some of that fruit was quite uniform in size and color, and was much more appealing to the eye compared with some of the less stringent size and color sorting done by other growers.

FIGURE 11: SINGLE LANE FRUIT SORTING MACHINE FROM COMPACSORT LTD.

Fruit is brought to the accumulation centres in crates or boxes that were filled by hand from containers or heaps of apples (clamps) in the orchard. There is a chronic shortage of such containers in Albania. In modern markets the buyers require fruit of consistent uniform size, and although most of the coolstore operators were sorting into 2 or 3 sizes (small, medium and large). Different operators used different systems, each based on their own facilities and satisfying their market requirements. At the same time fruit was sorted for quality, by removing fruit that had visual physical or pathological defects; such fruit was segregated into separate containers.

Different containers were used for storing the fruit, from bins, to wooden crates, plastic crates and in some cases second hand cardboard cartons that had been used for import of other fruit such as bananas. A mixture of different containers was used in some coolrooms; this is not advisable in general. It is preferable to have the same standardized containers in a room, so that the positioning of the stacks allows optimum airflow over and around the fruit; if mixed containers are used this will disrupt air flow patterns, reduce the efficiency of cooling and thus influence negatively the uniformity of temperature throughout the room.

FIGURE 12: PLASTIC CRATES FROM GREECE, PLASTIC BINS FROM MACEDONIA AND WOODEN BINS ARE USED FOR BULK APPLE STORAGE IN KORCE.

Bins and crates were made with thin flexible timber provided locally. The gaps between the slats in both types of container should be reduced so as to prevent the opportunity for the fruit to be physically damaged (bruised or cut by the sharp edge of the timber) when pressed against the slats by the pressure of other fruit. It is very important to ensure that all boxes and bins are of a standardized size and dimension so they can be stacked easily and consistently in the coolstore.

ACTION

- To meet the increasing quality standards that will be demanded by the supermarkets in Albania, and for any prospective export markets there will need to be installation of efficient and modern fruit sorting equipment to provide uniform lines of fruit of different sizes, color and quality for the different markets.

- The proposed study visit to Greece and/or Italy must visit sheds using different types of sorting machines so that the participants can appreciate the capacity, accuracy and speed of the machines.
- Continuous efforts must be made by extension activities to educate the growers about the importance of careful, minimal handling, and the need for minimising the number of times that fruit is transferred from one container to another.
- It is recognized that the shortage of packaging is a major constraint and bottleneck for many growers. Growers should be encouraged to join together in groups to jointly organise the supply of consistent package types, whether this be wooden boxes or bins, plastic crates or cardboard boxes. Some growers make their own bins and some crates from wood supplied by a local sawmill. See figure 12: He intends to make 18kg wooden crates next year and will no longer have to store his fruit in loose heaps in the shed. Problems with the bins were that the wooden slats are too far apart, and could cause cuts to fruit. If the growers in this village (voskop) joined with growers in the next village (polene) then maybe they could get discounts on bulk purchases of timber, and this grower could make up the wooden crates for other growers in the group.

FIGURE 13: APPLE GROWER SHOWS OFF STOCK

This grower made all his own bins and some crates from wood supplied by a local sawmill. He intends to make 18kg wooden crates next year and will no longer have to store his fruit in loose heaps in the shed. The wooden slats are too far apart, and could cause cuts to fruit. If they growers in this village (Voskop) joined with growers in the next village (Polene) then maybe they could get discounts on bulk purchases of timber, and maybe this grower could make up the wooden crates for other growers in the group.

REVIEW ATMOSPHERIC PARAMETERS INCLUDING TEMPERATURE, HUMIDITY, AND LIGHT.

Relative humidity (RH) appeared to be the over-riding concern of all coolstore operators visited. Temperature almost appeared to be a secondary consideration and this is a misconception. This is probably because the most noticeable quality deterioration seen in fruit stored outdoors in clamps or indoors in non-controlled warehouses, is shrivel that reflects water loss from the fruit.

Temperature is the most important postharvest technique for reducing respiration rate of the fruit, and hence reducing the rate of deterioration, by whatever quality criteria used.

The next most important postharvest technique to maintain quality for extended periods in atmosphere modification (controlled or modified atmosphere storage – CA and MA respectively). However no CA stores exist in Albania to my knowledge and it would not be wise to install such systems until a good basis of experience has been established in operating normal air stores.

If temperature and atmospheres are controlled, then RH may be an issue, but in modern coolstores the design of the evaporators is such that RH can be maintained at 90%+ by the machinery itself. It is important that people who wish to erect new coolstores in the future, inform the design engineers that they wish to have the system control RH as well as temperature; this may cost a little more than stores without this feature but it is a much better, more efficient and less risky option that having to rely on other methods to enhance the RH of the store.

This is not the case with apples stored in clamps or in warehouses. Other recommendations have been to indicate how RH in such stores may be enhanced a little, although in an uncontrolled manner. Most coolstores that I saw were in operating at 6-8oC. There were various reasons given this, but none were valid. Apples should be cooled to the recommended storage temperature as soon as possible after harvest. The recommended temperature for Starking Red and Golden Delicious is 0oC, RH 90-95%. (See Fact Sheets for Red Delicious and Golden Delicious in the Appendices).

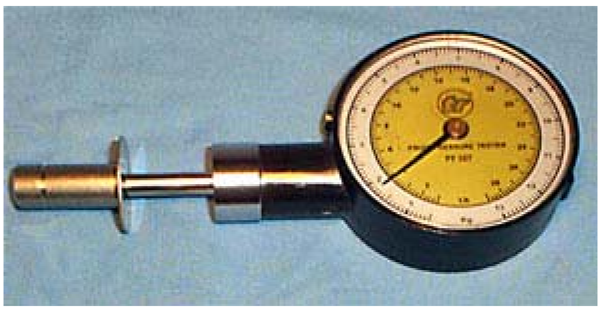
In the Korca region, 2 of the 4 coolstores were new this season, and none of the operators had had experience using such facilities. As such they are not familiar with the idiosyncrasies of their stores (and they do exist). For this reason I suggested that they should store there fruit at 2oC this year and monitor the fruit temperature and condition in different parts of the store, so they gained an appreciation of the variation of temperature that can occur throughout the coolstore. Most of the operators were convinced that the temperature shown electronically on the control panel outside the store reflected the fruit temperature inside. This id s not necessarily so, especially during the temperature 'pull down stage' after loading; normally fruit temperature does not come down to the set air temperature for at least 10-12 days after closing the doors on a full store. Even then fruit temperatures will vary throughout the store depending on patterns of air flow and position in the store. Operators must become familiar with these dynamics in their own stores, in order to manage them efficiently.

Light is not of consequence in coolstores; as long as there is enough light to work in the stores safely, that is all that matters. If the coolstores have a plenum outside in which the fruit is being sorted, as was seen in at least two examples, then light is important in order to be able to see the fruit and make appropriate decision about quality segregation. Natural light is the best light, but a mixture of fluorescent and incandescent lighting is desirable if natural light intensity is low.

Coolstore operators appeared to be concerned about lowering the fruit temperature too quickly and possibly causing injury; this should not be a problem as long as fruit is being placed into the store at regular intervals.

All coolstore operators must have an essential set of tools to assist in the monitoring of coolstore conditions and fruit quality prior to and during storage. Such a tool kit should include: material and containers to undertake the starch iodine test to measure physiological maturity; a penetrometer (0-200 N or 0-20 kg/force- Effigi is a very reliable brand but there others); a refractometers to measure sugar content (Atago is a good brand but there are others); a portable thermometer with a probe on the end of a cable to measure fruit temperature in different parts of the coolstore).

FIGURE 14: TOOLS FOR COOLSTORE OPERATORS SHOULD INCLUDE: PENETROMETER (LEFT) AND REFRACTOMETER (RIGHT).



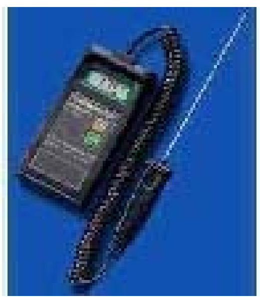
Electricity outages are a common occurrence in some parts of Albania on occasions. This poses potential problems in coolstores as the refrigeration systems will stop. This may not be a problem if the outages are of short duration; the recommendation is keep the doors closed, and because the fruit should be at the recommended temperatures they should be able to maintain that temperature for a few hours. However it is wise business practice to invest a backup, petrol/diesel powered generator that can switch on automatically if the power outage occurs. This will ensure that the coolstore temperatures are maintained.

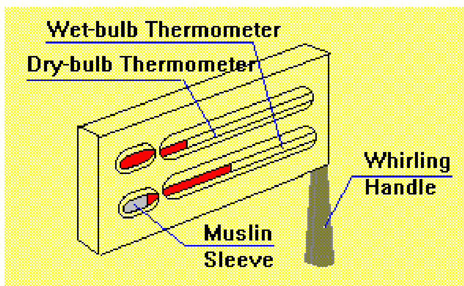
ACTIONS

- Always keep fruit in the shade from harvest to placing into coolstore to avoid excessive heating.
- Ensure that coolstores are turned on at least 2 weeks before the season to make sure that all systems are operating effectively. Calibrate the sensing thermometers by inserting probes into an ice/water slurry for at least one minute; that mixture will be at 0oC.
- Expedite procedure so that fruit can be placed into coolstores that should be turned on and running at 2-4oC before loading commences.
- Precooling should not be necessary for most varieties unless there are special orders, and special requests from the buyer for very high quality early varieties. If this is the case then the portable forced air cooler described in Appendix 4 could be used to cool the fruit within 10-12 hours.
- Heavy plastic strips should be inserted into the door space of the coolstore; these will reduce the cold air loss from the store while the door is open during loading

- Always have at least one check thermometer (alcohol or non-electronic) inside each room as a backup check of room temperature. If possible purchase a temperature probe that can be used to measure actual fruit temperature; use the same fruit (by labeling sites) for all measurements, as this is destructive and the fruit will have small holes it and will not be saleable on removal.
- Monitor and log temperatures at least daily; if possible install a computer controlled monitoring control/alarm unit. Monitor RH with a hand held sling hygrometer at regular intervals and log the information.
- Install petrol/diesel powered generators as a power source should electricity outages occur.

FIGURE 15: LEFT: A DIGITAL THERMOMETER FOR MEASURING TEMPERATURE OF FRUIT. RIGHT: A SLING HYGROMETER FOR MEASURING RELATIVE HUMIDITY.





TASK 2

PREPARE AND PRESENT WORKSHOPS FOR BOTH GROWERS AND COLD STORAGE OPERATORS INCLUDING SOLUTIONS TO THE KEY ISSUES THAT MUST BE ADDRESSED TO ENSURE SUCCESS.

ACTION

PowerPoint presentation prepared “Coolstorage of Apples in Korca” and presented on Friday 24 October in Korca to which all the coolstore operators and a grower had been invited. The structure of the presentation was as follows:

Preharvest factors that affect postharvest quality

- nutrition of trees –stressed importance of balanced fertilizer program to suit local soil and growing conditions; avoid excess nitrogen (N) application that will compromise postharvest quality
- introduced the concept of calcium spray applications 4-6 times during fruit growth to minimise postharvest bitter pit development.
- crop load – the importance of winter and summer pruning to optimise crop load, fruit size and quality
- thinning to eliminate biennial bearing (seasonal periodicity of yield), including the concept of chemical thinning.
- avoidance of stresses during growth such as water stress – many growers have introduced trickle irrigation, and some use fertigation; they must ensure that the fertilizer program is balanced with no N excess.

Harvest Maturity

- Described the development of maturity in apples and the role of starch to sugar conversion at the commencement of the ripening process
- Indicated the recommended patterns of starch that should be used for determining harvest times for fruit destined for different storage times. For example apples for long term coolstorage > 4 months should be harvest at an index of 2-4 with an average of 3; fruit for short term Coolstorage, up to 2 months should have a starch index of 4-6 with an average of 5; apples with a starch index of 6-8 are ready to east with maximum sugar content and will have a short shelf in coolstorage.
- Instructions for using this cheap, reliable and convenient technique to measure the physiological state of the fruit have been provided for the project team in Korca and Tirana. When used with other indicators such as days from blossom, seed color, and fruit firmness, this is the most suitable method for determining when to harvest for fruit destined to be stored for different marketing times.

Temperature management

- fruit are still living and breathing after they are harvested; they use oxygen and produce carbon dioxide in a process of respiration. The rate of respiration is temperature dependent; the higher the respiration rate the faster the rate of deterioration. This reducing temperature will reduce respiration rate and the rate of deterioration.
- place fruit in the shade of the orchard and out of the sun to minimise heat buildup immediately after harvest
- keep fruit out of the sun; use light colored covers if possible to reflect heat; do not use dark colored covers as this will absorb heat.
- place fruit into cool store as soon as possible after harvest
- if these steps are taken there will probably be no need for pre-cooling. Precooling requires additional energy requirements for removing heat from the fruit quickly and none of the stores seen were designed to do this.
- ideally the main apple varieties grown in Korca (Golden Delicious and Starking Red delicious) should be stored at 0oC ; however because this is the first year for 3 of the 4 operators using these new coolstores it was recommended that they have their refrigeration set points set at 2oC minimum and 5oC maximum to avoid any risk of freezing injury. (Most of the coolstore operators had their stores running at 6-8oC, which is too high. I emphasised that the rate of fruit softening is a function of fruit temperature – the softening rate doubles between 0 and 5oC, and doubles again between 5 and 10oC.

Relative humidity

- relative humidity (RH) should be between 90-95% in the coolstore to minimise water loss from the fruit and eventual shrivel. Apples shrivel when about 5% of weight loss has occurred.
- type of evaporators installed in new coolstores should be designed to create this degree of RH. With one exception 3 coolstore operators relied on additional equipment to add water/water vapor into the room, and this equipment had not yet arrived or been installed. Any new coolstores should specify that a RH of 90-95% is required and the system must be designed to those specifications.
- the only suggestion made for the latter operators is to try to keep the floor of the coolstore wet, but without wetting the fruit.

Monitoring

- it was recommended that all new coolstores should include a temperature and RH monitoring system that is logged automatically on a computer that also has an alarm function
- fruit temperatures should be monitored regularly throughout the store to ensure the operator begins to understand the dynamics of airflow and temperature variation in the store
- RH can be monitored using a hand held swing hygrometer
- there should be at least one alcohol (or similar) thermometer in the store that should be checked regularly; it is dangerous to rely on one digital readout from one electronic sensor located in only place in the store.

- it was stressed that fruit temperature in the store would vary according to its location and the degree of airflow across the fruit. Therefore it is very important not to impede air flow through containers in any manner.
- fruit quality should be monitored regularly throughout coolstorage especially firmness as measured with a penetrometer.

Tool kit

- a list of essential tools that should be owned and used by all coolstore operators was described; this list has been left at the Korca and Tirana office, and is based on the list prepared by Professor Thomai from the Agricultural University of Tirana. This will include: a digital thermometer for measuring fruit temperatures; a sling hygrometer to measure %RH; a refractometer to measure Brix (sugar content); a penetrometer to measure fruit firmness; size rings to measure fruit diameter; a starch/iodine kit and chart to measure starch patterns and hence maturity index..

TASK 3

PREPARE QUALITY ASSURANCE “FACT-SHEET” GUIDELINES FOR GROWERS AND COLD STORAGE OPERATORS.

ACTION

- A range of information material has been left at the Korca and Tirana office concerning, covering tree management, pruning, thinning, Ca applications that can be made available to growers and coolstore operators after translation into Albanian.
- A number of storage fact sheets have been left with both the Korca and Tirana offices for translation in Albanian.
- These include design and operation of coolstores, design of portable precooling unit, temperature recommendations and storage protocols for all major apples varieties grown in Korca.
- At all locations I encouraged growers and coolstore operators to form groups rather than acting independently all the time. These need not be formal groups, but simply likeminded individuals who can work together to share technical information, share experiences and agree on quality standards, packaging for fruit from their orchards or coolstores.
- Growers and coolstore operators must be aware of, and follow EU grade standards for the production and postharvest of apples (and all other horticultural products) as Albania intends to become a member and such standards will probably become mandatory on joining. In addition it will be necessary to adopt production and postharvest practices in order to be registered for GlobalGap.

TASK 4

PROVIDE TECHNICAL ASSISTANCE AND GUIDANCE ON INTERNATIONAL APPLE MARKET TRENDS.

ASSESSMENT

- At each coolstore visited I discussed market options with the owners as the management of the fruit flow in the coolstore would be determined by the ultimate market.
- Everyone was focused on the supplying the domestic market in the foreseeable future, using their traditional system of storing their own fruit, or buying fruit from other growers. Fruit would be sold later in the season, either at the local wholesale market or sold to another trader for sale in the Tirana market, the time of sale depending on the price.
- . Only one operator in Korca (Arben Licollari) and one in Berat (Pellumb Berzeshta) appeared to be thinking into the future and considering export to neighboring countries such as Montenegro, Kosova, Croatia and Macedonia. Both recognized the importance of fruit quality and providing product that the market wants the right quantities of the right quality at the right time in the right packaging, but both wish to gain more experience in handling, storage, packaging and marketing before they embark on this journey.
- I encouraged all coolstore operators to make contact and build relationships with buyers from the emerging supermarket chains in Albania, but there was little interest in this concept. There is no doubt in my mind that as the middle class in Albania develops the trend will be for shoppers to purchase more and more of their food and household requirements at these supermarkets in the future, and these pioneer coolstore operators should be developing close business contacts with them as soon as possible and develop along with the supermarkets. There are at least 8 supermarkets in and around Tirana, and this number will increase rapidly in the future.
- International markets, such as those in the EU, the Americas, Japan and Korea all have a high demand for quality fruit. (I saw very little fruit that would meet such standards during my visit; it did not appear that the majority of growers and maybe coolstore operators were aware of the high quality standards that can be achieved and the necessity to grade strictly to standards and to remove fruit that do not comply with the standards of the importing country.
- I stressed the need to develop production and postharvest standards that meet GlobalGap requirements; some growers and coolstore operators appeared to know very little about them, and those that did were not confident that those standards could be met. However there were exceptions; discussions with the CEO from AgriNet indicated that there program seemed to promise that growers could achieve such standards with appropriate education, training and ongoing technical advice.
- In order to meet high export standards the industry in general needs to understand the market requirements and dynamics that exist and there past experience does not allow this occur easily.

- New varieties should be introduced and evaluated for commercial performance in Korca. While I recognize that the domestic market prefers the traditional varieties, I was informed that one grower received his highest prices for Granny Smith, and another was confident that Jonagold had a good future. It is important to attempt the new varieties as the market (consumers) will not be able to evaluate them until there are some for sale – either from local sources or from imported supplies.

FIGURE 16: SOME NEW CULTIVARS OF APPLE APPEARING ON INTERNATIONAL MARKETS. FROM LEFT: JAZZ™, PINK LADY, SELECTION FROM APPLE BREEDING PROGRAM; SONYA™

ACTION

- I recommend that the project implement a series of two visits to other more advance apple producing countries in close proximity to Albania for a carefully selected group from the apple industry to inspect production, storage and market systems with their own ideas. The individuals chosen should be selected with a view to them becoming leading figures in the industry of the future, and should represent all sectors of the chain.
- The first visit should be to Greece within the next 8 months (so that information gained can be built into the 2009 plans for all members of the delegation)where the technologies are more advanced than in Albania, and the people have similar backgrounds and ethnicities in many cases. Also it is adjacent to Albania and thus cheaper than further afield.
- A second visit should be made to Italy where the production and postharvest technologies are more advanced than Greece and the fruit quality is probably better. In addition Italy has an international reputation for manufacturing high quality fruit handling, storage and packaging equipment - all of the refrigeration equipment seen in Albania came from Italy. Such a visit will expand the minds and the visions for the participants, and provide examples towards which they can strive on their return to Albania.

ENCOURAGE LEADING PROGRESSIVE GROWERS TO INTRODUCE AND PLANT A RANGE OF NEW VARIETIES FOR COMMERCIAL EVALUATION. THE LONG TERM FUTURE OF THE INDUSTRY MIGHT WELL DEPEND UPON IT.

OUTLINE COMMERCIAL STRATEGIES AND LONGER-TERM PRODUCT POSITIONING PLANS FOR DIFFERENTIATED APPLE PRODUCT.

The greatest value of apples to the grower and the coolstore operator comes from the fresh, rather than the processed product. The best prices will be received for 1st grade fruit, of consistent size, color, shape and ultimately with fruit of good texture, taste and flavor, packaged in an attractive manner according to the requirements of the buyer. Processing apples that do not comply with the top quality grade standards will low returns to the grower, often less than the costs of production (estimated to be about 17-20 lek/kg).

Added value can arise in several ways. It may come from the introduction of new cultivars onto the market ahead of competitors; a plethora of new varieties have emerged in the past decade and only a few will succeed. New varieties can be developed from breeding programs, or they can arise as spontaneous sports (chimeras) in buds on existing trees.

The Red Gala apple (and other red strains) arose from a sport on a mature a Gala tree. The small twig on which this red colored Gala appeared was used as budwood, grafted onto a rootstock, and over several years enough material was obtained to begin marketing this new cultivar commercially. Apple growers in New Zealand are encouraged to look for sports in their orchards, as they might have commercial potential when patented and developed commercially. At Korca I was shown a rusted Golden Delicious fruit that was a sport from a mature tree; if this was thought to have commercial potential it should be preserved and evaluated for several quality attributes and market appeal.

FIGURE 17: THE PROFESSIONAL PACKAGING USED, WITH INDIVIDUAL PLU LABELS THAT INCLUDE THE VARIETY NAME. FRUIT QUALITY IS VERY UNIFORM IN ALL VISUAL RESPECTS.

to be low. The possibility exists for making apple vinegar; vinegars are being resurrected as a health tonic for animals including humans, and they have potential as cleaning agents in the home

ACTIONS

- AAC staff continue to seek facilitate contact between growers/coolstore operators and potential food processing companies who might be interested in developing existing or new products from second grade apples that do not meet market requirements.
- AAC continue to emphasize the importance of growers in specific regions to join together in groups or associations in order to work together on technical, political and marketing issues of common interest.
- Encourage the use of innovative packaging of high quality fruit for specific niche or luxury markets; this would include gift packs containing 2-6 apples of different varieties and colors attractively packaged and labeled that would sell at a high price (Fig. 17). Another option would to put 1-2 kg of uniformly sized small apples into a brightly branded perforated polyethylene bag and labeled as “Kids apples”; these would be ideal size for a child to take one apple a day to school for a healthy morning snack.
- AAC attempt to find alternate outlets for reject apples, probably through a food processing outlet. This may also involve exploring the options for making vinegar from surplus apples that could be used as a health tonic for humans and animals.
- The apple industry must adopt the EU grade standards and implement systems to move towards accepted GlobalGap standards that will be required for export to EU countries in the future.

FIGURE 19: EXAMPLES OF APPLE GIFT PACKS FOR SALE IN THE USA.

PROVIDE RECOMMENDATIONS FOR ACTORS IN THE APPLE VALUE CHAIN IN THE NEEDED PUBLIC POLICY MEASURES TO FOSTER MARKET FOR IMPROVED ALBANIAN APPLES.

ACTIONS

- Improve quality of roads in rural areas and on main trunk routes.
- Encourage banks to use micro-credits for small loans to farmers to improve the transport systems to accumulation centres, vans instead of donkeys and trailers.
- Extend the period of tariff protection for the import of apples from December to March; this will provide a 6 month window for Albanian producers to supply greater quantities to the domestic market and thus enhance incomes of rural farmers and communities.
- Develop protocols for development of local quality standards for apples that comply with those of the EU.
- Develop policies that will encourage apple producers to work together in groups, so they can gain technical and marketing strength in addition to being able to gain unity and strength in negotiating with trades. More than one trader strongly supported the concept of farmer groups, as they currently have to negotiate with every single farmer independently of each other and this is a time wasting expensive exercise.
- Enhance expenditure on horticultural research and development and extension activities that will provide the technical and marketing support for the apple industry when the current project is completed in 4 years.
- Provide tax incentives for entrepreneurs who invest in postharvest infrastructure and marketing activities that have the potential to earn external Euros/dollars through enhanced exports of quality apple products.

Expected Outputs and Outcomes

- An overall description the harvest and storage elements of the value chain including constraints and solutions. DONE
- Workshop materials developed and presented on key issues in preharvest, harvest, postharvest and storage. DONE
- Individual audits and list of recommendations for selected AAC client operating cold storage units. Suggestions for next steps made. DONE
- Orchards operators will have a practical guideline fact sheet to guide them in pre-harvest, harvest, and post harvest activities. They will receive practical hands-on training in all three phases that occur in their orchard. DONE
- Cold Storage operators will have practical guideline fact sheet to guide them in orchard practices, post harvest handling, transport, pre cooling, and proper storage methods. They will receive practical training and a customized audit report from the consultant. DONE
- The STTA team will debrief the Mission with their findings and recommendations. DONE

- STTA Hewett will complete a final report including protocols for proper post-harvest handling and storage within two weeks after departing Albania. DONE

RECOMMENDATIONS: HUMAN CAPACITY BUILDING

ACTIONS

That the AAC project teams in the different regions develop strong links with local Albanian personnel, in particular any with postharvest knowledge and experience - Professor Tokli (Tomas) Thomai from the Agricultural University of Tirana who was educated to the PhD level in postharvest physiology and technology under the leadership of Professor Evangelos Sfakiotakis, a world famous postharvest scientist) for example; the professors at the local university in Korca, the Ministry of Agriculture Extension Service, who will have a responsibility to continue to provide scientific, technical and outreach advice to the apple industry when the current AAC project is completed in July 2012.

- While the primary clients for this AAC project are the coolstore operators and the growers, it is imperative that there is a cadre of technically skilled and knowledgeable individuals in both the regions (Korca and Lushnja) who will be able to provide technical and scientific advice when the project is completed.
- Therefore it is essential that the project team and technical experts involved in the project develop a close professional relationship with appropriate individuals in Albania who have the appropriate background and ability to provide ongoing advice and information from the international literature and knowledge base.
- Such individuals may exist with the University at Tirana, Korca, or Lushnja, within the Ministry of Agriculture research or extension services, private institute or laboratories or any other relevant organization. The main purpose is to ensure continuity availability of technical personnel who know the apple industry and can provide ongoing technical support.
- To this end such personnel need to be identified quickly and brought into the activities of the AAC team. They could be involved in assisting with monitoring small but important experiments where some of the recommendations need to be evaluated under local conditions and small but critical experiments in the field or in the coolstores to determine the most appropriate operating parameters for local varieties and growing conditions.

That the AAC project organise two study tours during the next 4 years of the project to enable a selected group of industry personnel with potential to change the business of apple production, postharvest, marketing and education and training to visit Greece within 8 months, and Italy in 2 years time to study the more advanced apple industries in those countries.

That the AAC project convene a meeting of apple coolstore operators for a debrief after the current season has ended and all the fruit has been sold. This might occur in late April and would probably take place in both Korca and in Lushnja. If possible this should include the international postharvest expert (who will be in Europe on other business at that time) and the local postharvest expert Professor Thomai, who should have a major responsibility for postharvest research and education in Albania on completion of the project.

That the staff at the Korca office, undertake a small project with selected growers and coolstore operators to formulate their own starch pattern charts for their own fruit grown in their own region. This may have to be created over 2-3 years to ensure that it a consistent pattern is obtained.

That the AAC purchase a few basic but important books on apple production and postharvest science that will serve as ongoing reference material during and after the project.

- I have provided as an Appendix 1 to this report a separate list of some key reference texts that outline protocols and information on apple production and postharvest systems.

That the AAC purchase a set of tools that can used to evaluate apple quality and also tools for monitoring coolstore conditions.

- Professor Thomai has already discussed such a list of equipment with the project team, and I concur with his recommendations.

APPENDIX 1: RESOURCES

List of some relevant text books that AAC should consider purchasing and internet sites that contain relevant and valuable postharvest information

Bartz, J.A. and Brecht, J.K. (Editors). 2003. *Postharvest physiology and pathology of vegetables.* (2nd edition). Marcel Dekker: New York, NY, USA. http://postharvest.ucdavis.edu/

FAO 1989. *Prevention of post-harvest food losses fruits, vegetables and root crops: A training manual on Postharvest*. http://www.fao.org/docrep/T0073E/T0073E00.htm

Feree, D.C. and Warrington, I.J. 2003. *Apples: botany, production and uses.* CABI. http://www.cabi.org/bk_BookDisplay.asp?SubjectArea=&Subject=&PID=1618

Kader, A.A. (editor). 2002. *Postharvest Physiology of Horticultural Crops.* 3rd edition. Publication 3311, University of California, Division of Agriculture and Natural Resources, Oakland, CA, USA.

Kitinoja, L. and Kader, A.A. 1995. *Small-scale postharvest handling practices - A manual for horticultural crops* - 3rd edition. http://www.fao.org/Wairdocs/X5403E/X5403E00.htm

Wills, R.B.H, McGlasson, W.B., Graham, D. and Joyce, D.C. 2007. *Postharvest: An introduction to the physiology and handling of fruit, vegetables and ornamentals.* 5th edition. University of New South Wales Press. www.unswpress.com.au Available from CABI www.cabi.org

Some important internet links on production and postharvest of apples and other fruits and vegetables.

http://usna.usda.gov/hb66 Gross, K.C. and Wallace, H.A. The commercial storage of fruits, vegetables and florist and nursery stock. -an excellent modern summary of basic coolstore principles, and information sheets for all the major horticultural crops.

http://postharvest.ucdavis.edu Postharvest Technology Research and Information Centre, University of California, Davis, CA, USA. A wide range of fact sheets for all major fruits and vegetables in easily accessible format. A number of books are listed for sale on coolstores design and operation as well as Fresh Cut manual.

www.postharvest.com.au Sydney Postharvest Laboratory. - Another good site with postharvest fact sheets and links to other postharvest, fruit and vegetable web sites.

http://hort.cornell.edu/mcp.ethylene.pdf -The most comprehensive list of published papers on the use of 1-methylcyclopropene (1-MCP or Smart Fresh - an inhibitor of ethylene action)

http://www.bae.ncsu.edu/programs/extension/publicat/postharv/index.html North Carolina Postharvest Commodity Notes and Fact Sheets on cooling and handling of a range of important horticultural crops as well as design considerations for a portable forced air cooler and for building new coolstores.

http://www.compacsort.com Compac Sorting Systems Ltd. – a New Zealand company that pioneered electronic fruit sorting including defect sorting and Near Infra red system for determining internal sugars. A single lane sorter will sort 1-5 tonnes of fruit per hour, at up to 13 fruit per second on a good quality line of fruit.

APPENDIX 2: EVALUATING MATURITY OF EMPIRE, IDARED AND SPARTAN APPLES

FACTSHEET

ISSN 1198-712X

Agdex#:	211/50
Publication Date:	March, 2000
Order#:	00-027
Last Reviewed:	March, 2000
History:	Replaces Factsheet "Starch Iodine Test for Determining Maturity and Harvest Dates of Empire, Idared and Spartan Apples", Order No. 88-090
Written by:	C. L. George Chu - University of Guelph; Ken Wilson - Apple Specialist/OMAF

INTRODUCTION

The starch-iodine test is one of several methods used to determine apple fruit maturity. The procedure for this test can be simply performed in the field.

PREPARING THE TEST SOLUTION

Always use a freshly prepared solution at the beginning of every season. This solution is sensitive to light and should be stored in a dark container. A dark-colored bottle or a glass jar wrapped in aluminum foil will serve the purpose. Chemicals needed for this test are potassium iodide and iodine crystals. A pharmacist or a chemist can use the following recipe to make up the iodine solution.

WARNING

Iodine is a very poisonous chemical. The iodine solution should be properly labeled and kept away from children and pets. Do not feed apples used in the test to any animals or used in composting. Do not allow pets to lick the fruit after testing. In case of ingestion of either iodine, or iodine treated apples, induce vomiting and consult a physician immediately.

RECIPE

- Dissolve 8.8 grams of potassium iodide in approximately 30 mL of warm water. Gently stir the solution until potassium iodide is properly dissolved.
- Add 2.2 grams of iodine crystals. Shake the mixture until the crystals are thoroughly dissolved.

- Dilute this mixture with water to make 1.0 L of test solution. Mix them well.

SELECTING APPLES FOR TESTING

It is very important to select representative samples for testing. Sample at least 3 trees of each cultivar in each orchard in order to give reliable results. Sample 10-20 apples from various parts of each apple tree.

PERFORMING STARCH IODINE TEST

In order to perform the test properly, the following requirements must be met:

1. The iodine solution must be fresh and at a temperature higher than 10°C
2. The 10-20 randomly collected apples should be tested immediately
3. The fruit for testing should be at a temperature higher than 10°C. Either procedure A or B can be used depending on individual preference.

PROCEDURE A

1. Use a shallow glass pan. Pour some iodine solution into this pan to a depth of 5-8 mm.
2. Cut each apple in half across the core. Soak the cut surface of the stem half in the iodine solution for one minute. The stem can serve as a convenient handle.
3. Remove the stem halves from the test solution and place them cut surface up to drain.
4. Score each fruit by comparison with the appropriate reference chart and calculate the average score for each lot of apples.

PROCEDURE B

1. Pour the iodine solution in a spray bottle equipped with a hand pump.
2. Cut each apple in half across the core. Place them cut surface upward.
3. Spray the iodine solution onto the cut surface. Wait for about 1 minute.
4. Score each fruit according to procedure A-4.

EVALUATING TEST RESULTS

Apples will show the starch-iodine test scores starting from 1 and ending at 9 over several weeks during the fall season. How to decide "What score indicates the proper harvest date for each grower's orchard?" depends mainly on when the apples will be marketed and what type of storage is used. Apples destined for long-term controlled atmosphere (CA) storage have to be picked early and therefore require a lower starch-iodine test score. Apples destined for immediate fresh market and processing plant can be picked later and therefore require a higher starch-iodine test score. The selection of the proper score largely depends on each individual operation. No single fixed score can be recommended to guide the whole industry.

In general, apples with starch-iodine test scores of 1, 2, and 3 are considered immature. Apples with scores of 4, 5, and 6 are considered mature. Apples with scores of 7, 8, and 9 are considered overmature. Normally, apples with a starch-iodine test score of 3 or 4 are good for long-term CA storage.

EVALUATING TEST RESULTS: PICTURES

FIGURE 2-1. RATING CHART FOR EMPIRE

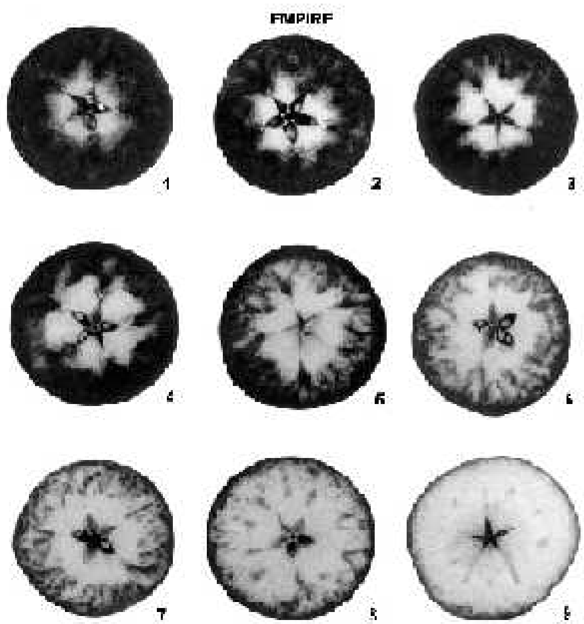


FIGURE 2-2. RATING CHART FOR IDARED

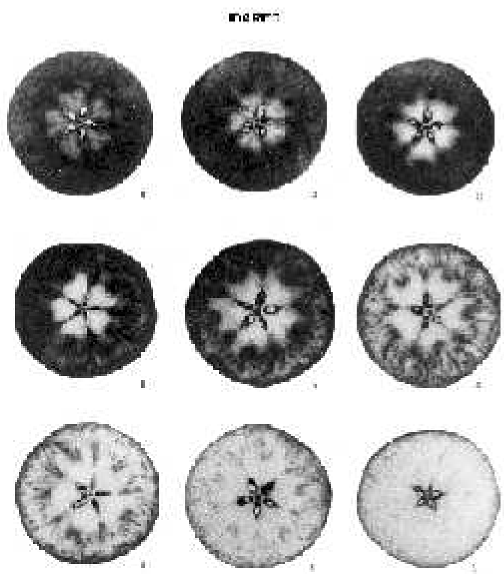
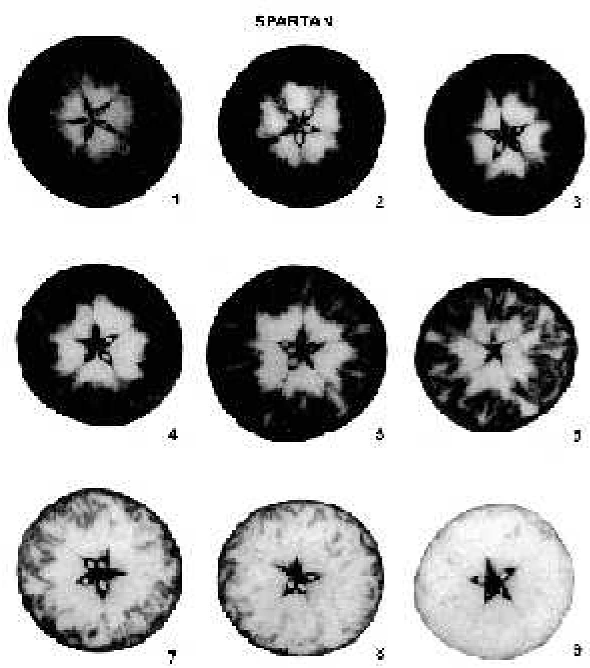


FIGURE 2-3. RATING CHART FOR SPARTAN



For more information:
Toll Free: 1-877-424-1300
Local: (519) 826-4047
E-mail: ag.info.omafra@ontario.ca

FIGURE 2-4. STARCH IODINE PATTERNS IN RED DELICIOUS APPLES OF DIFFERENT MATURITY

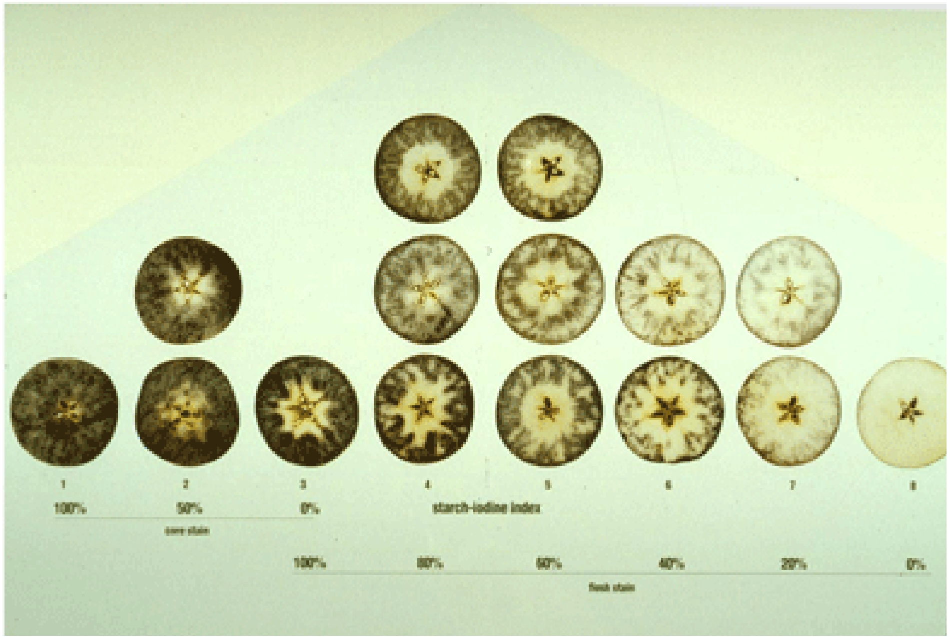
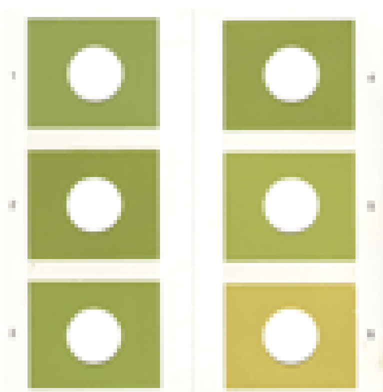


FIGURE 2-5. COLOUR CHARTS USED FOR ASSISTING IN DETERMINING HARVEST MATURITY IN GOLDEN DELICIOUS APPLES.



APPENDIX 3: FACT SHEET FOR GOLDEN DELICIOUS

APPLE: 'GOLDEN DELICIOUS'
RECOMMENDATIONS FOR MAINTAINING POSTHARVEST QUALITY

Elizabeth J. Mitcham, Carlos H. Crisosto and Adel A. Kader
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MATURITY INDICES

Color change from dark green to light green or yellowish-green. Firmness of 17 pounds-force, 20 to 40% of cortex clear of starch. Generally about 135 to 150 days from full bloom.

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, scald, internal browning, or shrivel.

OPTIMUM TEMPERATURE

0°C ± 1°C (32°F ± 2°F); Freezing temperature: -1.7°C (29°F)

OPTIMUM RELATIVE HUMIDITY

90-95% RH

RATES OF RESPIRATION[1]

ml CO2/ kg·hr	3-6	4-8	7-12	15-30

To calculate heat production multiply ml CO2 /kg·hr by 440 to get Btu/ton/day or by 122 to get kcal/metric ton/day.
[1] Higher rates for riper apples.

RATES OF ETHYLENE PRODUCTION[2]

µl/ kg·hr	1-10	2-25	5-60	20-150

[2] Higher rates for riper apples.

RESPONSES TO ETHYLENE

Ethylene stimulates ripening. Mixed results on the benefits of scrubbing ethylene from storage rooms, depending on harvest maturity, and duration and type of storage (air or CA).

RESPONSES TO CONTROLLED ATMOSPHERES (CA)

Fruit to be stored longer than one month benefit from CA storage in terms of retention of flesh firmness, acidity, and skin color. CA storage potential is up to 10 months (vs. 6 months in air).

Recommended atmospheres: 1 to 3% O_2 + 1.5 to 3% CO_2

PHYSIOLOGICAL DISORDERS

Shrivel. Golden Delicious apples are particularly susceptible to water loss. Weight loss can be as high as 3 to 6%. Rapid cooling, storage of fruit with plastic bin liners, and well-designed refrigeration equipment will reduce water loss.

Bruising. Can be excessive, especially for Golden Delicious where bruises are more visible. Gentle handling is important.

Bitter Pit. Sunken brown spots on the skin, especially at the calyx end, related to low calcium concentrations in the apple. Best controlled by calcium sprays prior to harvest and calcium dips prior to cold storage. Apply field sprays under rapid drying conditions to avoid russeting. Reduced incidence with controlled atmosphere storage.

Superficial Scald. Browning of the skin that develops in cold storage. Susceptibility of Golden Delicious is low. Controlled atmosphere storage delays onset. Diphenylamine used infrequently; follow label rates.

Controlled Atmosphere Damage. Oxygen levels below 1% and CO_2 above 15% may induce off-flavors due to fermentative metabolism. Other symptoms of CO_2 injury include partially sunken brown lesions on skin or internal browning and cavities.

PATHOLOGICAL DISORDERS

Moldy Core. Caused by several fungi including Alternaria sp., Fusarium sp., Aspergillus and Penicillium. Golden Delicious apples are particularly susceptible because of the open or deep sinus cavity. Drenching can increase the incidence of moldy core.

Blue Mold and Grey Mold. The two most important postharvest diseases of Golden Delicious apples are caused by Penicillium expansum and Botrytis cinerea. Both fungi are wound pathogens. Sanitation is critical to control of these diseases. Drenching can spread spores of Penicillium and Botrytis to wounds from harvest operations. Use of fungicides during drenching may reduce decay.

APPENDIX 4: FACT SHEET FOR RED DELICIOUS APPLES

APPLE: 'RED DELICIOUS'
RECOMMENDATIONS FOR MAINTAINING POSTHARVEST QUALITY

Elizabeth J. Mitcham, Carlos H. Crisosto and Adel A. Kader
Department of Plant Sciences, University of California, Davis, CA 95616

MATURITY INDICES

Firmness of 18 pounds-force, core clear of starch. Firmness (lbs-f) x soluble solids (%) x starch score (1 to 6 scale) should equal 250 at initiation of harvest.

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, scald, internal browning, shrivel or watercore.

Red skin color intensity and uniformity.

OPTIMUM TEMPERATURE

0°C ± 1°C (32°F ± 2°F); Freezing temperature: -1.7°C (29°F)

OPTIMUM RELATIVE HUMIDITY

90-95% RH

RATES OF RESPIRATION[1]

ml CO_2/ kg·hr	2-5	3-7	5-10	12-25

To calculate heat production multiply ml CO_2 /kg·hr by 440 to get Btu/ton/day or by 122 to get kcal/metric ton/day.
[1] Higher rates for riper apples.

RATES OF ETHYLENE PRODUCTION[2]

µl/ kg·hr	1-10	2-20	5-40	20-125

[2] Ethylene stimulates ripening. Mixed results on the benefits of scrubbing ethylene from storage rooms, depending on harvest maturity and type of storage (air or CA).

RESPONSES TO CONTROLLED ATMOSPHERES (CA)

Fruit to be stored longer than 1 month benefit from CA storage in terms of retention of acidity and firmness and reduction of scald incidence and severity. CA storage potential is up to 10 months (vs. 6 months in air).

Recommended atmosphere: 1 to 2% O_2 + 2 to 4% CO_2

PHYSIOLOGICAL DISORDERS

Bruising. Can be excessive. Gentle handling is important.

Watercore.

Bitter Pit. Sunken brown spots on the skin, especially at the calyx end, related to low calcium concentration in the apple. Best controlled by calcium sprays prior to harvest and calcium dips prior to cold storage. Reduced incidence with controlled atmosphere storage.

Superficial Scald. Browning of the skin which develops in cold storage. High susceptibility. Use diphenylamine at label rates. Controlled atmosphere storage delays onset. Ultra-low oxygen CA storage has been effective in some growing areas.

Controlled Atmosphere Damage. Oxygen concentrations below 1% and/or CO_2 levels above 10% may induce off-flavor associated with fermentative metabolites. Elevated CO_2 injury symptoms include partially sunken brown lesions on skin and/or internal browning and cavities. Low O_2 injury can result in a purple cast to the skin of Red Delicious apples.

PATHOLOGICAL DISORDERS

Moldy Core. Caused by several fungi including Alternaria sp., Fusarium sp., Aspergillus and Penicillium. Red Delicious apples are particularly susceptible because of the open or deep sinus cavity. Drenching can increase the incidence of moldy core.

Blue Mold and Grey Mold. The two most important postharvest diseases of Red Delicious apples are caused by Penicillium expansum and Botrytis cinerea. Both fungi are wound pathogens. Sanitation is critical to control of these diseases. Drenching can spread spores of Penicillium and Botrytis to wounds from harvest operations. Use of fungicides during drenching may reduce decay.

APPENDIX 5: FACT SHEET FOR GRANNY SMITH APPLES

APPLE: 'GRANNY SMITH'
RECOMMENDATIONS FOR MAINTAINING POSTHARVEST QUALITY

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Department of Plant Sciences, University of California, Davis, CA 95616

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.

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 (33 ± 1°F); highest freezing point is -1.5 °C (29.3°F)

Some reports indicate that 0°C (32°F) 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 (33°F) To calculate heat production multiply ml CO_2/kg·hr by 440 to get Btu/ton/ day or by 122 to get kcal/metric ton/day.

RATES OF ETHYLENE PRODUCTION

1 to 6 µl/kg·hr at 0.5°C (33°F)

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 (DPA) 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 (32° F).

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.

* Available from: Fruit and Vegetable Quality Control Calif. Dept. of Food and Agriculture 1220 N Street, Rm. A-265 Sacramento, CA 95814 (916)654-0919 FAX (916)654-0666

APPENDIX 6: FORCED-AIR COOLING FOR HORTICULTURAL CROPS

For many years, produce has been cooled by simply storing it in a refrigerated room, a process known as room cooling. This method is generally sufficient for keeping produce at a low temperature once it has been cooled, but it often does not remove field heat rapidly enough to maintain the quality of highly perishable crops. Room cooling is very often inadequate for produce stored in large containers, such as bulk boxes or pallet loads, and for produce that requires immediate cooling.

In the room cooling process, heat is removed slowly from only that produce near the outside of the container. Near the centre of a container, heat is often generated by natural respiration more rapidly than it can be removed, causing the temperature to rise. Some types of produce, such as strawberries, must be cooled as quickly as possible after harvesting to preserve its fresh quality. Even a delay of several hours may be enough to reduce quality considerably. In such cases, room cooling is not fast enough to prevent serious damage.

To preserve quality, fresh produce should be cooled to its lowest safe (optimum) storage temperature as quickly as is practical and economical. Forced-air cooling is much faster than room cooling and is being used increasingly in North Carolina to cool produce quickly. It offers these advantages:

- It decreases the time the produce remains at elevated temperatures, thereby reducing deterioration;
- It results in shorter cooling times and thus more efficient use of the cooling facility;
- It can cool produce effectively in a variety of unopened containers without wetting it or subjecting it to excessive handling;
- It is often more energy efficient than room cooling when large volumes of produce must be cooled;
- An available room-cooling facility with adequate cooling capacity can be converted to forced-air cooling with only a relatively small investment in fans

ENERGY-EFFICIENT COOLING PRACTICES

The energy cost for forced-air cooling can be greater or less than that for simple room cooling, depending on how carefully the system is used. The faster cooling possible with the forced-air method allows for greater use of the cooling facilities, reducing overall operating costs. In addition, since the amount of time required to cool a load of produce is much shorter, less energy is needed to remove heat produced by respiration and to overcome heat gain through the walls, ceiling, and floor of the building.

On the other hand, forced-air cooling is likely to increase the overall energy cost slightly by increasing electrical demand, a measure of the rate at which electricity is consumed. Demand cost contributes significantly to the electrical power bill for most cooling facilities. To reduce demand cost, produce should not be cooled any faster than necessary. Forced-air cooling can also increase cooling cost by increasing the cooling load per unit of time. Quicker cooling requires larger refrigeration units, the cost of which must be amortized over the life of the facility. The benefits of forced-air cooling, however, far outweigh the costs.

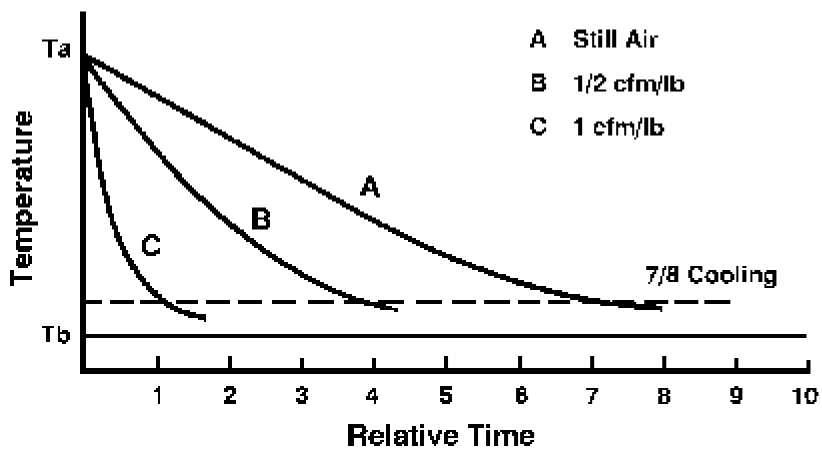
Forced-air cooling is a useful tool for preserving the quality of fresh produce. It is most effective when the produce demands quick cooling or when the amount of produce to be cooled per day or week is large enough to justify the increased equipment and electrical demand costs.

COOLING RATE

Forced-air cooling is accomplished by exposing packages of produce in a cooling room to higher air pressure on one side than on the other. This pressure difference forces the cool air through the packages and past the produce, where it picks up heat, greatly increasing the rate of heat transfer. Depending on the temperature, airflow rate, and type of produce being cooled, forced-air cooling can be from 4 to 10 times faster than room cooling.

The graph of time and temperature in Figure 1 illustrates the response of a typical commodity to airflow rates. The beginning temperature of the produce (pulp temperature) is represented by Ta. This temperature varies with ambient conditions and the amount of field heat in the produce; it normally ranges from 60 to 90 F.

FIGURE 6-1. COOLING TIME FOR VARIOUS AIRFLOW RATES.



The desirable air temperature inside the cooling room, Tb, depends primarily on the type of commodity. Few types of produce will tolerate temperatures below freezing, although some, such as strawberries and apples, require near-freezing storage temperatures. Many others, such as squash and cucumbers, will sustain chill injury if exposed to temperatures lower than 45 F.

The interior air temperature, Tb, is best measured by a thermometer positioned away from the exterior walls, ceiling, and produce containers. In practice, this temperature is regulated by the thermostat setting of the refrigeration system. Correct storage temperatures for most types of produce grown in North Carolina are given in Extension Publication AG-414-1, *Maintaining the Quality of North Carolina Fresh Produce: Introduction to Proper Postharvest Cooling and Handling Methods.*

Curve A in Figure 1 represents the comparatively slow rate of cooling that can be expected without forced air movement (room cooling). Curves B and C demonstrate the increase in cooling rate possible with airflow rates of 1/2 and 1 cubic foot per minute per pound of produce, respectively.

The rate of cooling represented by the slope of the curve, decreases as the produce temperature approaches the temperature of the room air. Reducing the temperature the last few degrees may take from several days to several weeks and is of little practical importance. In comparing cooling times for various methods, the time required to lower the pulp temperature to 7/8 of the difference between Ta and Tb is the value often used. On the graph, the 7/8 cooling time in still air is more than 7, compared to just over 1 for produce cooled with an airflow of 1 cubic foot per minute per pound of produce.

Since the cooling rate for a forced-air system is much greater than for room cooling, a refrigeration system of larger capacity may be required. Whether an existing system sized for room cooling will be sufficient for conversion to forced-air applications depends on a number of factors. These include the size of the original system, the anticipated future cooling loads, and the use factor of the facility. A qualified refrigeration contractor or a refrigeration specialist with the Agricultural Extension Service can help in determining whether additional refrigeration capacity will be needed.

AIR MANAGEMENT

Fans supplied with the refrigeration equipment are used to cool the air by forcing it past the evaporator coils. These fans are not large enough, nor are they properly located in most cases, to force air directly past the produce. Furthermore, the chilled air leaving the evaporator coils is generally much too cold for most types of produce. It must be mixed with the warmer air inside the room to prevent chill injury. Therefore, additional fans are required to move the air past the produce. To achieve good air distribution, these fans should pull, never blow, the cooled air through the produce as fast as practical.

Several different fan positions and produce stacking arrangements have proven successful for forced-air cooling. The shell arrangement shown in Figure 2 uses a portable pallet-mounted fan and is preferred by many because of its versatility. Two parallel rows of produce, positioned approximately 2 to 3 feet apart and covered by a cloth or plastic strip, form the shell. Cold air pulled through the produce flows through the space between the rows and out through the fan. In another arrangement known as the "cooling wall" (Figure 3), the fans are located permanently along one wall. This design might be more convenient for producers and shippers who handle large volumes of produce, especially if they always handle the same commodity or compatible ones. Both types of systems are widely used in North Carolina.

FIGURE 6-2. SHELL ARRANGEMENT WITH PORTABLE PALLET-MOUNTED FAN.

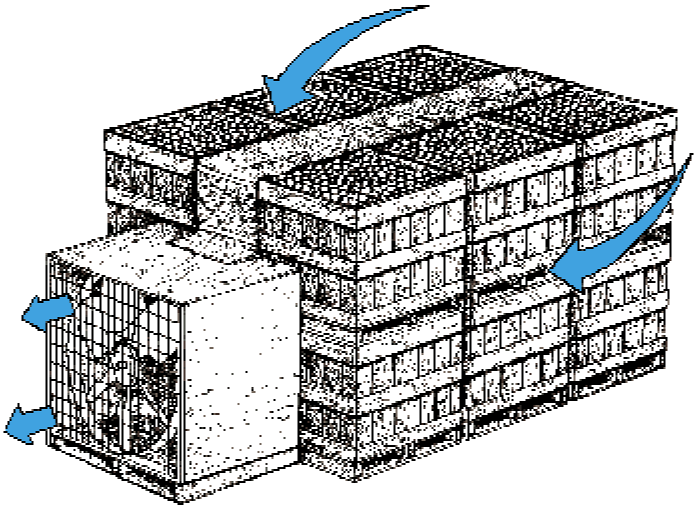
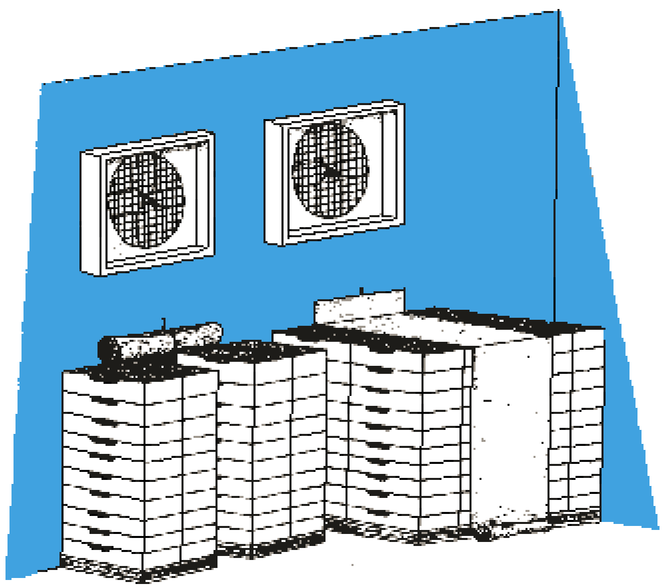


FIGURE 6-3. COOLING WALL ARRANGEMENT WITH PERMANENTLY MOUNTED FANS.



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

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

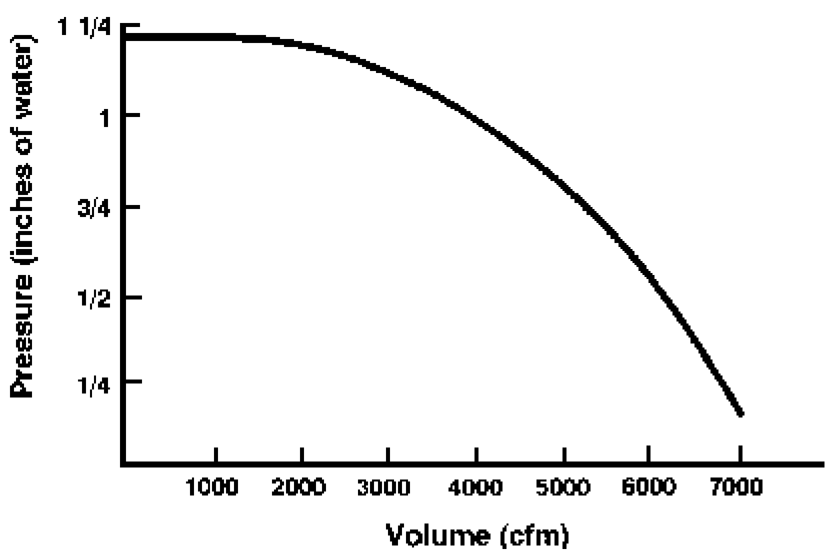
If the condensation from the evaporator coils is drained to the outside, the humidity in refrigerated rooms may become quite low. The amount of condensation that collects on these coils may be decreased substantially by limiting the temperature drop through them to 5 F. This can be accomplished by increasing the size or number of the coils. In practice, relative humidity levels above 80 or 85 percent cannot easily be achieved without some type of humidification system or very careful management.

Low humidity may be corrected by various types of commercial humidification systems. Many operators simply hose down the floors from time to time, but this approach may not be consistent with good sanitation nor particularly effective in many situations. On the other hand, excessively high humidity for long periods can also be detrimental because it encourages the growth of molds and fungi. Although a high-quality humidistat can be used to control the humidifier, the most consistently accurate method to measure relative humidity is with a wet-bulb thermometer. Construction details and directions for the proper operation of a wet-bulb thermometer may be obtained from your county Agricultural Extension Service agent.

FANS

Not all fans are designed to move air at the volume and static pressure required for forced-air cooling. (Static pressure in this case is the resistance to air movement presented by the packages of produce.) Although either centrifugal ("squirrel cage") or propeller fans may be used, their specifications should be carefully evaluated to ensure that they will deliver an adequate quantity of cooling air at higher pressures. Fan curves giving pressure and volume data, such as the one shown in Figure 4, are available for most commercial or industrial fans. Notice that there is an inverse relationship between pressure and airflow rate. In the figure, for example, the flow rate at 1 inch of water pressure is 4,000 cubic feet per minute (cfm), whereas at a pressure of 1/2 inch the flow rate increases to over 6,000 cfm.

FIGURE 6-4. TYPICAL FAN CURVE.



In addition to airflow rate and temperatures, several other variables influence the time required to cool produce with forced air, including the size and shape of the produce and the configuration and venting of the containers. In practice, however, an airflow rate of approximately 1 to 3 cubic feet per minute at 1/2 inch static pressure should be sufficient for most applications. Accurate cooling data for a specific set of conditions can be acquired only by conducting field tests.

The airflow rate through a fan system in a cooling setup may be measured with sufficient accuracy using an inexpensive U-tube manometer mounted to the fan (Figures 5 and 6). U-tube manometers are designed to measure differences in air pressure. One side of the manometer is connected on the upstream side of the fan as far as possible from the blades and the other end is open to the room air. By knowing the static air pressure through the fan and consulting the performance chart usually supplied with new fans, the airflow rate may be accurately determined.

FIGURE 6-5. U-TUBE MANOMETER.

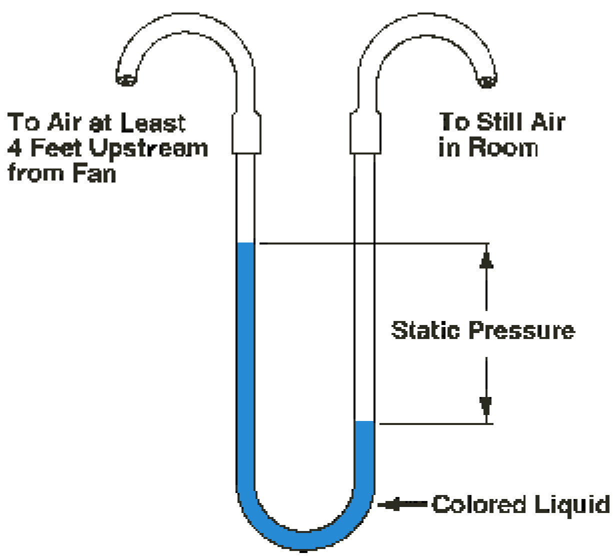
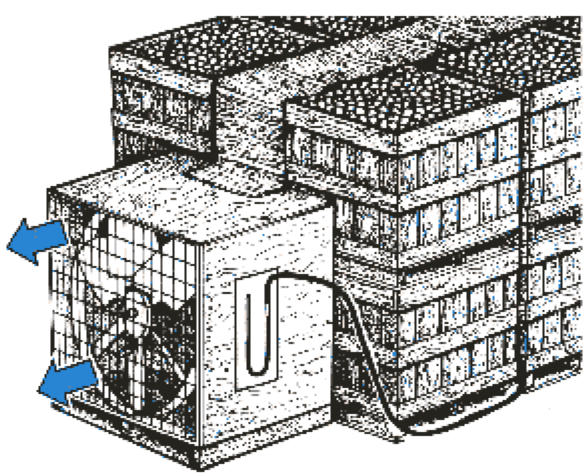


FIGURE 6-6. PALLET-MOUNTED FORCED-AIR COOLING FAN.



In addition, it is also useful to mount a thermometer on the downstream (exhaust) side of the fan. By comparing the temperature of the air as it exits the fan with the temperature of the room air, it is possible to determine the cooling rate. The following example will illustrate the procedure.

A manometer attached to a fan pulling air through 8,000 pounds of peppers shows a static pressure difference of 1/2 inch of water. The performance chart for this fan shows an airflow rate of 14,000 cubic feet per minute at this static pressure. The room air temperature is measured at 45 F and the temperature of the air exiting the fan is 52 F. Since raising the temperature of 54 cubic feet of air 1 F requires one Btu of heat energy:

```
 (14,000)(52-45)
Heat Loss = --------------- = 1,815 Btu/minute
 54
```

It takes approximately 1 Btu to lower the temperature of 1 pound of peppers 1 F. Therefore, at a heat loss rate of 1,815 Btu per minute, the temperature of the 8,000 pounds of peppers is being reduced approximately 1 F every 4.4 minutes.

```
8,000
----- = 4.4
1,815
```

The rate of heat loss changes continuously during the cooling period. As shown in Figure 1, it is greatest at the beginning of the cooling cycle (when the difference between product temperature and air temperature is greatest) and ultimately tapers off to zero.

The interior of a cooling room is often damp or even wet. Fan motors should therefore be of the totally enclosed, fan-cooled type (TEFC) and fully grounded according to local electrical codes to prevent shock.

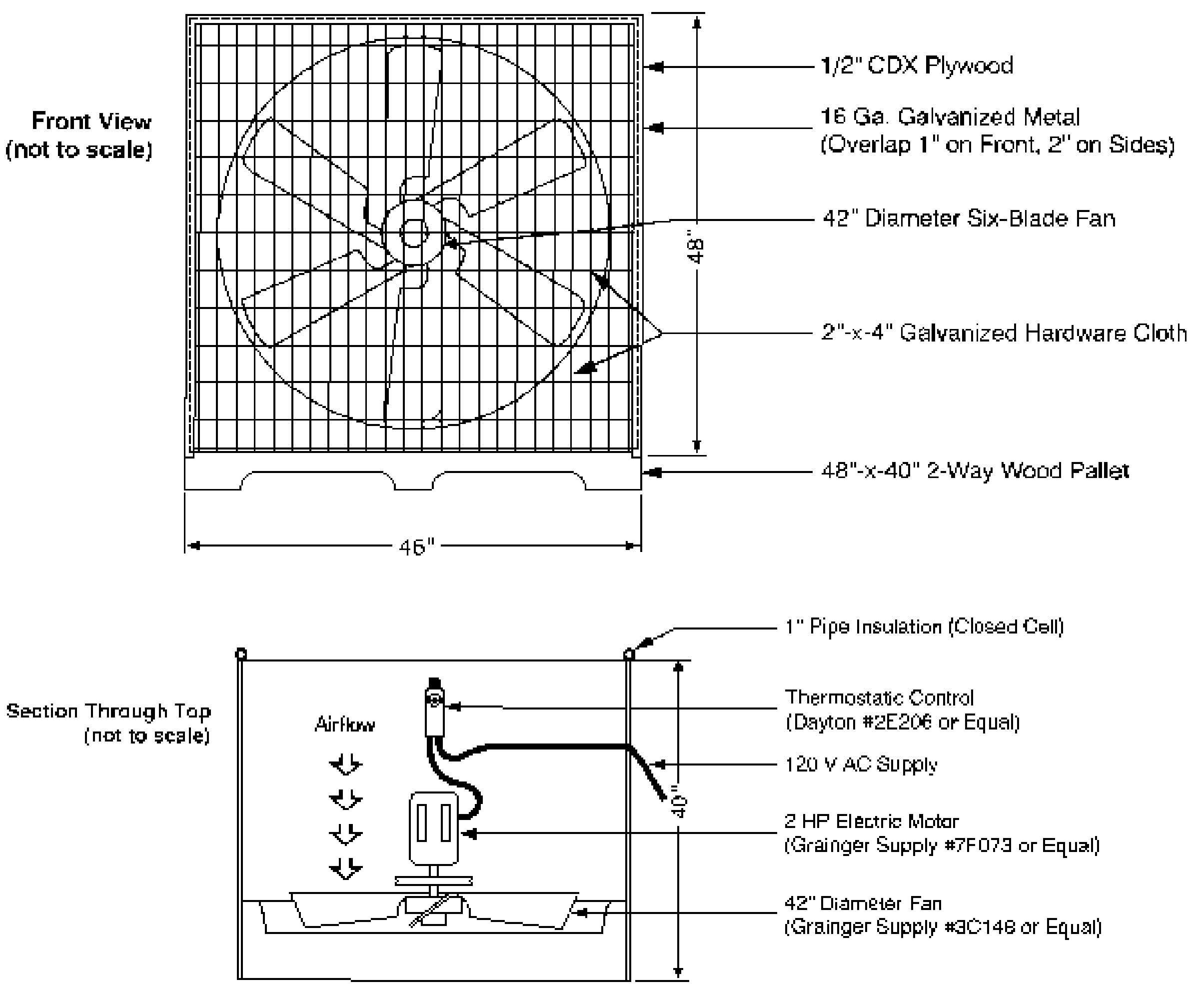
It is also a good idea to control the fan with a line-voltage thermostat mounted in the airstream. The thermostat will stop the fan when the produce has cooled to a predetermined point, thus saving energy. It will also reduce the drying effects of the cooling air because it will not allow the fan keep running for an extended period after the produce has cooled. The thermostat should be set at 5 to 8 F above the temperature of the room air.

Plans and directions for building a portable pallet-mounted fan similar to the one shown in Figure 6 are found at the end of this publication. This fan is capable of moving more than 11,000 cubic feet of air per minute against a static pressure of 3/8 inch of water. It is suitable for use in a variety of forced-air cooling applications.

CONTAINERS

A variety of produce packages have been used with forced-air cooling. They include fiberboard boxes, wooden wirebound crates and hampers, and bulk boxes. The only requirement is that sufficient open space be provided in the sides and bottom to ensure adequate air movement through the containers. Most commercial containers are designed with adequate open space. If not, openings should be added or enlarged so that 5 to 8 percent of the lateral surface and 3 to 5 percent of the bottom is open. Slots at least 1/2 inch wide are better than circular openings that may be blocked by produce. These openings should be well distributed over the surface of the container to ensure good air distribution.

FIGURE 6-7. FORCED-AIR COOLING FAN



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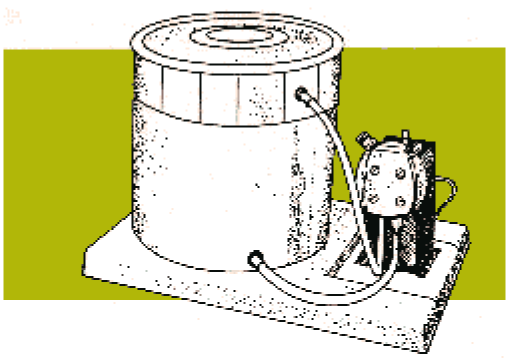
APPENDIX 7: CHLORINATION AND POSTHARVEST DISEASE CONTROL

FIGURE 7-1. EXAMPLE OF A WATER DUMP TANK



In a hungry and increasingly competitive world, reducing postharvest food losses is a major agricultural goal. For highly perishable commodities, such as tomatoes, squash, and peaches, as much as 30 percent of the harvested crop may be lost to postharvest diseases before it reaches the consumer. Investments made to save food after harvests are usually less costly for the grower and the consumer and less harmful to the environment than efforts to increase production. Even a partial reduction in postharvest losses can significantly reduce the overall cost of production and lessen our dependence on marginal land and other scarce resources.

Many factors contribute to postharvest losses in fresh fruits and vegetables. These include environmental conditions such as heat or drought, mechanical damage during harvesting and handling, improper postharvest sanitation, and poor cooling and environmental control. Efforts to control these factors are often very successful in reducing the incidence of disease. For example, reducing mechanical damage during grading and packing greatly decreases the likelihood of postharvest disease because many disease-causing organisms (pathogens) must enter through wounds.

Chemicals have been widely used to reduce the incidence of postharvest disease. Although effective, many of these materials have been removed from the market in recent years because of economic, environmental, or health concerns.

Increased interest in the proper postharvest handling of fresh fruits and vegetables in North Carolina has prompted the widespread use of flumes, water dump tanks, spray washers, and hydrocoolers. To conserve water and energy, most postharvest processes that wet the produce recirculate the water after it has passed over the produce. This recirculated water picks up dirt, trash, and disease-causing organisms. If steps are not taken to prevent their spread, these organisms can infect all the produce that is subsequently processed. In the past, various fungicides and bactericides have been used (alone or in combination with chlorination) to prevent the transmission of diseases. These materials have often been favored over chlorination because they provide some residual protection after treatment.

At present, chlorination is one of the few chemical options available to help manage postharvest diseases. When used in connection with other proper postharvest handling practices, chlorination is effective and relatively inexpensive. It poses little threat to health or the environment. This publication has been prepared to acquaint growers, packers, and shippers with the proper use of chlorination.

POSTHARVEST DISEASES

Many types of postharvest disorders and infectious diseases affect fresh fruits and vegetables (Table 1). *Disorders* are the results of stresses related to excessive heat, cold, or improper mixtures of environmental gases such as oxygen, carbon dioxide, and ethylene. Some disorders may be caused by mechanical damage, but all are abiotic in origin (not caused by disease organisms) and cannot be controlled by chlorination or most other postharvest chemicals. However, abiotic disorders often weaken the natural defenses of fresh produce, making it more susceptible to biotic diseases those that are caused by disease organisms. Further, in many cases injuries caused by chilling, bruising, sunburn, senescence, poor nutrition, and other factors can mimic biotic diseases.

TABLE 7-1. COMMON POSTHARVEST DISEASES OF NORTH CAROLINA FRUITS AND VEGETABLES

Blue mold	*Penicillium expansum* (f)
Gray mold	*Botrytis cinerea* (f)
Black rot	*Physalospora obtusa* (f)
Bitter rot	*Glomerella cingulata* (f)
Blue mold	*Penicillium* sp. (f)
Gray mold	*Botrytis cinerea* (f)
Rhizopus rot	*Rhizopus stolonifer* (f)
Fusarium tuber rot	*Fusarium* spp. (f)
Wet rot	*Pythium* sp. (f)
Bacterial soft rot	*Erwinia* spp. (b)
Slimy soft rot	*Clostridium* spp. (b)
Brown rot	*Monilinia fructicola* (f)
Rhizopus rot	*Rhizopus stolonifer* (f)
Gray mold	*Botrytis cinerea* (f)
Blue mold	*Penicillium* sp. (f)
Alternaria rot	*Alternaria* sp. (f)
Gilbertella rot	*Gilbertella persicaria* (f)
Bacterial soft rot	*Erwinia chrysanthemi* (b)
Black rot	*Ceratocystis fimbriata* (f)
Ring rot	*Pythium* spp. (f)
Java black rot	*Diplodia gossypina* (f)

Fusarium surface rot	*Fusarium oxysporum* (f)
Fusarium root and stem rot	*Fusarium solani* (f)
Rhizopus soft rot	*Rhizopus nigricans* (f)
Charcoal rot	*Marcrophomina* sp. (f)
Alternaria rot	*Alternaria alternata* (f)
Buckeye rot	*Phytophthora* sp. (f)
Gray mold	*Botrytis cinerea* (f)
Soft rot	*Rhizopus stolonifer* (f)
Sour rot	*Geotrichum candidum* (f)
Bacterial soft rot	*Erwinia* spp. (b) or *Pseudomonas* spp. (b)
Ripe rot	*Colletotrichum* sp. (b)
Watery soft rot	*Sclerotinia* sp. (f)
Cottony leak	*Pythium butleri* (f)
Fusarium rot	*Fusarium* sp. (f)
Bacterial soft rot	*Erwinia* sp. (b) or *Pseudomonas* spp. (b)

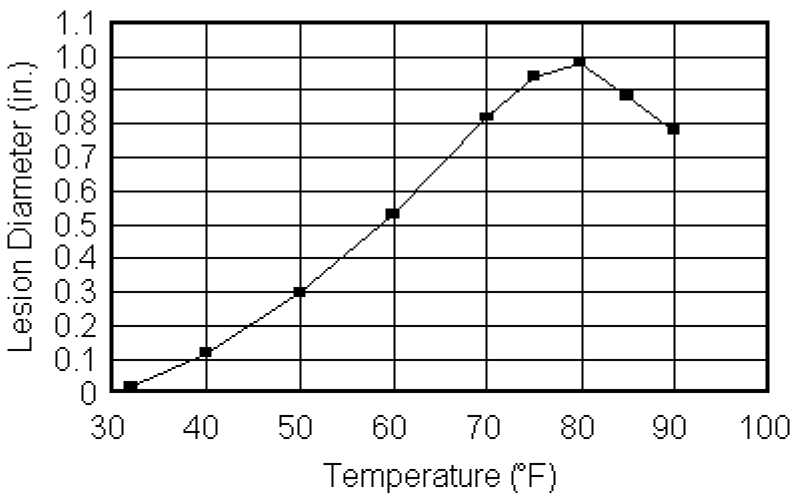
* f = fungus, b = bacterium

The control of biotic postharvest diseases depends on understanding the nature of disease organisms, the conditions that promote their occurrence, and the factors that affect their capacity to cause losses. Postharvest diseases may be caused by either fungi or bacteria, although fungi are more common than bacteria in both fruits and vegetables. Postharvest diseases caused by bacteria are rare in fruits and berries but somewhat more common in vegetables. Viruses seldom cause postharvest diseases, although they, like postharvest disorders, may weaken the produce.

Most postharvest fungal diseases (rots) are caused by the dispersion of tiny dust like spores formed by the actively growing pathogen. Spores have adaptations that allow them to survive in hot, cold, or very dry conditions. They may be carried great distances by wind or water and can cover most exposed surfaces in great numbers.

Spores may remain dormant for long periods until the correct conditions for their germination and growth occur. These conditions include the presence of water (in liquid form or as high relative humidity), warm temperatures, low light levels, adequate levels of oxygen and carbon dioxide, and the presence of nutrients in the form of sugars, starches, or other organic compounds. Many immature fruits and vegetables contain compounds that inhibit the growth of some disease organisms. These compounds and the resistance they provide are often lost during ripening. Therefore, a fresh wound on the surface of a warm, wet, ripened fruit or vegetable enclosed within a shipping container provides an ideal site for postharvest pathogens to colonize and develop. Gentle handling to prevent wounding and thorough cooling immediately after harvest can significantly reduce the incidence of postharvest disease. Figure 2 illustrates the effects of temperature on the development of brown rot (*Monilinia fructicola*) in peaches.

FIGURE 7-2. THE EFFECTS OF TEMPERATURE ON THE GROWTH OF *MONOLINIA FRUCTICOLA* (CAUSAL AGENT OF BROWN ROT) IN RIPE PEACHES. (REDRAWN FROM *JOURNAL OF AGRICULTURAL RESEARCH 37*:507-43.)



Spores of postharvest fungal pathogens are most susceptible to chemical control while they are germinating to produce actively growing mycelium. Under the right circumstances, germination can be rapid, often taking only a few hours. Once active growth is under way and the organism moves below the surface of the fruit or vegetable, chemical control becomes very difficult.

The potential for inoculation and infection by postharvest pathogens is always present when handling fresh produce. Understanding the several different ways by which these organisms can come into contact with the produce can be helpful in formulating control measures.

SOIL AND FIELD CONDITIONS

Soil and decaying plant material in the field can contain postharvest pathogens in great abundance. Hard rains and wind can splash and distribute these materials onto unharvested produce. In addition, warm rainy conditions greatly favor the development of diseases in the field.

CONTAMINATED WATER

Water from ponds and streams should not be used for postharvest cooling, fluming, and washing. Water from these sources is often contaminated by runoff from fields and packing houses and may therefore contain large concentrations of postharvest pathogens. Using pond or stream water for irrigation can also contaminate produce in the field. Muddy water or water taken from the bottom of the pond is especially likely to be contaminated. Always use potable water from a well or other reliable supply.

POOR PACKING HOUSE SANITATION

Pathogens brought into the packing house along with the produce will quickly contaminate all working surfaces. Disease-causing organisms will remain viable for months on surfaces such as tank walls, grading belts, and brushes. Wash all produce-handling equipment daily to remove dirt and decayed produce, and disinfect it with a strong chlorine solution on a regular schedule. Keep the packing house and the immediate vicinity clear of any overripe or rotting produce. Remove culls from the packing house and its vicinity immediately.

AIR

Even the most meticulous attention to sanitation may not completely prevent contamination of fresh produce by disease organisms. Pathogens are present in the air and will infect produce under suitable circumstances. The best defense against airborne pathogens is sanitation, consistent chlorination, proper handling of the commodity, and quick and thorough cooling.

Although the skin of fruits and vegetables offers considerable protection against infection, pathogens can enter produce through a variety of openings when the produce is wetted. Various wounds, such as punctures, cuts, and abrasions, as well as stems and stem scars provide potential points of entry. The probability of a pathogen entering the produce increases with the size of the opening, the depth of submergence, the length of time the produce is in the water, and the water temperature. Even tiny natural openings (such as stomata and lenticels) can serve as pathways for disease organisms. A small amount of detergent added to the solution lowers the surface tension, increasing the ability of the chlorine to move into the small openings and destroy the pathogens.

A chlorine concentration of about 55 to 70 ppm at a pH of 7.0 is recommended for sanitizing most fruits and vegetables. A higher concentration may be needed if the pH is higher or if the temperature of the solution is more than 80 F. In actual practice, concentrations of up to 150 ppm of free chlorine have been recommended.

THE CHEMISTRY OF CHLORINATION

Chlorine is a very irritating, heavy, greenish yellow gas with a strong, pungent odor. Free chlorine is very reactive, combining with any chemical that will react with oxygen, and is never found uncombined in nature. Chlorine in the gaseous form is a very potent disinfectant, although it is seldom used in that form. It is much safer and easier to use when dissolved in water. Disinfection of produce using chlorine or some other chemical is nearly always done during hydrocooling or during the process of washing the produce to remove soil. Chlorine for disinfection may be obtained from one of three sources: pressurized chlorine gas, calcium hypochlorite (a soluble solid), or a solution of sodium hypochlorite.

CHLORINE GAS

Chlorine gas is produced by the electrolysis of salt solutions (principally NaCl) and is furnished commercially in pressurized metal cylinders. Chlorination is accomplished by bubbling a metered amount of the gas into the supply water. Because of dangers involved with the use of chlorine gas and the expense of the metering equipment, the use of the gaseous form for chlorination is usually limited to large applications. Most municipal water supplies are disinfected with chlorine gas. The limited amount of chlorination required by most postharvest fruit and vegetable operations makes the use of chlorine gas impractical.

CALCIUM HYPOCHLORITE

The most common source of chlorine used in postharvest chlorination is calcium hypochlorite. It is available commercially in the form of either a granulated powder or large tablets. Most commercial formulations are 65 percent calcium hypochlorite, with the balance consisting of stabilizers and inert materials. Calcium hypochlorite is relatively stable as long as it is kept dry, and it may be stored for extended periods. The property that makes it stable also makes it difficult to dissolve completely in water. Adding granulated calcium hypochlorite directly to the water often results in undissolved particles that adhere to the produce, causing undesirable bleaching and chlorine burns. This problem is particularly common in hydrocoolers because calcium hypochlorite is very slow to dissolve in cold water. Therefore, always dissolve granulated calcium hypochlorite in a small quantity of tepid water before adding it to the wash tank or hydrocooler. Calcium hypochlorite may be obtained in tablets that are added directly to the hydrocooler or wash tank to eliminate the problem of chlorine burns. Properly used, the tablets will dissolve slowly to yield a continuous supply of chlorine to the water. However, the tablets must be positioned carefully to ensure proper mixing of the chemical with the water.

SODIUM HYPOCHLORITE

The active ingredient of most liquid household bleaches, sodium hypochlorite is commonly used when the scale of postharvest chlorination is limited. Sodium hypochlorite is not generally available in solid form because it is difficult to store. It absorbs moisture readily from the atmosphere, causing it to release chlorine gas.

Household bleach is usually marketed as a solution of water and 5.25 percent sodium hypochlorite. Larger containers of 12.75 percent or 15 percent sodium hypochlorite solutions are also available through some laundry and swimming pool chemical suppliers. For the same amount of chlorination, a sodium hypochlorite solution is generally more expensive than granular calcium hypochlorite because of the additional shipping and handling costs associated with the water it contains.

Chlorination chemicals can be added to the water manually, or concentrated solutions of sodium or calcium hypochlorite can be injected into the wash tank or hydrocooler at a continuous and measured rate. Commercial chlorine injector systems are particularly useful in operations where a continuous supply of clean, chlorinated water is required. Injector systems, such as the one shown in Figure 2, consist of a feed tank and an electrically operated pump with a variable output. Chlorine injectors should always be isolated from water supply lines with an approved check valve to prevent backflow into the fresh water system.

CHLORINATION EFFECTIVENESS

Chlorination is a dynamic chemical process. Its effectiveness is influenced by a number of factors. Proper chlorination requires frequent monitoring of the solution and a thorough understanding of the factors involved. These factors include the pH of the solution, chlorine concentration, water temperature, amount of organic matter present, exposure time, and the growth stage of the pathogens present.

SOLUTION PH

The pH of a solution is a measure of its acidity or alkalinity. A solution that is neutral (neither acid nor alkaline) has a pH of 7.0. Solutions with pH numbers less than 7.0 are acid; the lower the number, the greater the acidity. On the other hand, the greater the number above 7.0, the more alkaline the solution. A change of one pH unit indicates a ten-fold change in acidity or alkalinity.

The pH of the solution has a significant effect on the level of chlorination activity. When chlorine gas or one of the hypochlorite salts is added to water, each will generate chlorine gas (Cl2), hypochlorous acid (HOCl), or hypochlorite ions (OCl) in various proportions, depending on the pH of the solution. The form desired for chlorination is hypochlorous acid (HOCl). Hypochlorite ions are relatively inactive, and chlorine gas quickly bubbles out of the solution, causing worker discomfort and serving no useful purpose.

At a pH slightly above neutral, half of the chlorine will be in the form of hypochlorous acid and the other half in the form of hypochlorite ions. Very little will be in the gaseous form. Solutions that are more acid have a higher percentage of hypochlorous acid but are very unstable, allowing more of the chlorine to escape from the solution as a gas. To maximize the proportion of hypochlorous acid and hence the effectiveness of the solution, the pH should be kept in the practical range between 6.5 and 7.5.

Because well water in North Carolina varies from moderately acid to moderately alkaline, the pH should be checked with a pH meter or test papers before and after the chemicals are added and frequently during operation. Furthermore, even if the water initially has a near-neutral pH, the addition of hypochlorites will change the pH.

Different sources of chlorine have different effects on pH:

- Chlorine gas decreases pH
- Sodium hypochlorite increases pH
- Calcium hypochlorite increases pH slightly.

It may be necessary to add a common acid (like vinegar) to lower the pH. Small amounts of sodium hydroxide (lye) may be used to raise the pH. Inexpensive test papers for checking both the chlorine level and pH may be obtained from most swimming pool and chemical supply houses.

CHLORINE CONCENTRATION

The concentration of a small amount of chemical in a solution is measured in units of parts per million (ppm). In the case of chlorination, this unit of measure indicates the number of parts of available chlorine, by weight, that there are in a million parts of solution. The quantity of calcium or sodium hypochlorite that must be added to a certain quantity of water to obtain a given concentration depends on

- the available chlorine content of the compound
- the concentration of the compound

Table 7-2 shows the minimum chlorine concentrations needed to kill all pathogens within one minute at two different temperatures, assuming a neutral pH. Table 3 gives the amount of 5.25 percent solution hypochlorite solution that must be added to 100 gallons of water to obtain various chlorine concentrations from 25 to 150 ppm. Table 4 gives the same information for 65 percent calcium hypochlorite granules.

TABLE 7-2. MINIMUM CHLORINE CONCENTRATION NECESSARY TO KILL ALL PATHOGENS WITHIN 1 MINUTE AT TWO TEMPERATURES AT NEUTRAL PH

Fungi	30-40	10
Bacteria	20	10

TABLE 7-3. AMOUNTS OF 5.25 PERCENT SODIUM HYPOCHLORITE (NAOCL) SOLUTION REQUIRED TO OBTAIN A SPECIFIED CONCENTRATION OF CHLORINE IN 100 GALLONS OF WATER AT NEUTRAL PH

0.4	25
0.8	50
1.2	75
1.6	100
2.0	125
2.4	150

TABLE 7-4. AMOUNT OF 65 PERCENT CALCIUM HYPOCHLORITE (CA(OCL)2) GRANULES REQUIRED TO OBTAIN A SPECIFIED CONCENTRATION OF CHLORINE IN 100 GALLONS OF WATER AT NEUTRAL PH

0.5	25
1.0	50
1.5	75
2.0	100
2.5	125
3.0	150

TEMPERATURE

The activity of chlorine increases with the temperature of the solution. Unnecessarily warm solutions should be avoided, however, because the chlorine escapes into the air more rapidly as the temperature increases. On the other hand, in hydrocooling the combined effects of low temperature and high pH values reduce chlorination efficiency.

ORGANIC MATTER

Chlorine has a particular affinity for soil particles and organic matter. Chlorinating dirty produce therefore depletes the chlorine supply much faster than relatively clean produce. The amount of chlorine constantly decreases with chlorination reactions. The more organic matter (such as fruit, leaves, or soil) in the tank, the more chlorine will be lost. As a result, the chlorine level should be checked and adjusted hourly, especially when large loads of produce are being processed. Extremely dirty produce (such as sweet potatoes) is commonly washed with clean water before it is placed into the chlorination tank.

EXPOSURE TIME

The effectiveness of chlorination depends greatly on the length of time the produce is exposed to the chlorine solution. Quick dips are much less effective than longer exposures. However, most of the sanitizing action of the chlorine is accomplished within the first several minutes of exposure. Prolonged exposure to strong chlorine solutions has been known to cause surface bleaching. Experience is the best guide to the correct combination of treatment time and chlorine concentration for the crop being processed.

GROWTH STAGE OF THE PATHOGEN

Disease organisms may be either in the active vegetative form or in the form of spores. Chlorine will readily kill the vegetative form, but fungal spores are 10 to 1,000 times more difficult to kill. Therefore, chlorine treatment rarely eliminates all pathogens and sterilizes the surface of the produce. Many spores may remain on the surface to develop later should the opportunity arise. Further, chlorine kills only on contact, not systemically, and is effective only on exposed pathogens such as those suspended in water or those on the surface of produce; chlorine does not kill pathogens below the skin because it cannot contact them. Chlorination leaves no residual effect. Therefore, produce exposed to pathogens after treatment is susceptible to re-infection.

WASTEWATER DISPOSAL

Chlorinated wastewater is customarily drained at the end of each work day or more often if circumstances dictate. This wastewater often contains sediment, pesticides, and other suspended matter. If it is discharged to a municipal wastewater treatment plant or to surface waters (canals, creeks, or ponds), regulatory agencies may consider it to be industrial wastewater. Land application of this material is normally permitted, but a no discharge permit may be required. Operators may be required to obtain wastewater discharge permits.

If you plan to use chlorination, check with the local office of the North Carolina Department of Environment, Health, and Natural Resources to determine whether a permit is required. **Illegal disposal of hydro-cooler wastewater may result in a substantial penalty.**

The Environmental Protection Agency (EPA) regulation of May 8, 1991, (40 CFR part 180) exempts calcium hypochlorite and chlorine gas from residue tolerance requirements when it is used before or after harvest on any raw agricultural commodity. Any amount can legally be used; however, excessive chlorination can damage equipment, injure the surface of fruits and vegetables, and waste money. In addition, the use of excessive amounts of chlorine may pose a worker health and safety hazard that is regulated by the North Carolina Department of Labor.

PRACTICAL RULES FOR SUCCESSFUL CHLORINATION

- **If water is not necessary in the packing process, do not use it.** Wetting the produce greatly increases the likelihood of damage by postharvest diseases. If the produce must be washed to remove soil, there is no alternative to wetting. Hydrocooling also necessitates wetting the produce, although other methods, such as forced-air cooling, may be a viable option in some cases. When water is necessary in packing lines (for example, in dumping tanks, flumes, or a hydrocooler), always treat it to reduce the risk of disease.

- **Monitor the chlorine concentration and the condition of the water.** Check the chlorine concentration and pH frequently using test papers or electronic equipment. Automatic chlorination equipment is available that will continually monitor the condition of the solution, add chlorine, and correct the pH. Also, monitor the water temperature.
- **Avoid overexposure.** Do not allow the produce to remain in contact with the solution longer than necessary. Check circulation patterns in chlorination tanks to eliminate dead spots.
- **Change the water frequently.** Chlorination efficiency is poor in dirty water. If necessary, wash very dirty produce with clean water before it comes into contact with the chlorinated water.
- **Dispose of wastewater properly.** Before installing chlorination equipment, plan how you will dispose of the wastewater. Land application of wastewater is normally allowed, but check to see if a permit is needed. Illegal disposal of chlorinated water could result in a substantial fine.
- **Practice good sanitation.** Hose off the packing equipment and floors daily; remove any dirt and trash that has settled in the chlorination tank. Sanitize the equipment with a spray solution composed of four pints of 5.25 percent sodium hypochlorite solution in 10 gallons of water. As an alternative, steam clean the equipment with an approved detergent. Do not allow culls or decayed produce to remain in or around the packing house.
- **Protect workers.** For their safety and comfort, workers must be protected from the chlorine fumes associated with excessively high levels of chlorine. If the amount of chlorine gas in the work area is great enough to cause worker discomfort, the amount of chlorine being used is well above that required for proper postharvest sanitation. If air monitoring equipment is not available, chlorine concentrations can be checked by asking a person who has not been desensitized by the odor to enter the work area. If he or she can smell the chlorine, the level is probably adequate. The concentration is too high if workers are continually irritated by the odor.
- **Remember that chlorination will not solve all your problems.** Even the best chlorination program may not be sufficient to prevent all postharvest decay. Prompt handling, proper sanitation, and rapid cooling should all be part of your postharvest disease management program. Produce infected in the field or otherwise damaged cannot be saved by chlorination.

ADDITIONAL INFORMATION

The following publications in this series on the postharvest cooling and handling of fresh produce are available from your county Cooperative Extension Center.

- AG-414-1, Introduction to Proper Postharvest Cooling and Handling
- AG-414-2, Room Cooling
- AG-414-3, Forced-Air Cooling
- AG-414-4, Hydrocooling

- AG-414-5, Top and Liquid Ice Cooling

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APPENDIX 8: LEAF ANALYSIS INTERPRETATION FOR APPLES AND PEARS

Macronutrients (%)			
Nitrogen (N)	Below 1.7	1.7 to 2.7	Above 2.7
Phosphorus (P)	Below 0.13	0.15 to 0.30	
Potassium (K)	Below 1.2	1.3 to 1.9	Above 2.0
Calcium (Ca)	Below 0.6	1.2 to 2.0	
Magnesium (Mg)	Below 0.25	0.3 to 0.6	
Micronutrients (ppm)			
Boron (B)	Below 20	25 to 50	Above 60
Copper (Cu)		10 to 20	
Iron (Fe)		60 to 250	
Manganese (Mn)	Below 25	30 to 100	
Zinc (Zn)	Below 15	20 to 50	

Values for most varieties including "Golden Delicious and MacIntosh-types.

FERTILIZER RECOMMENDATIONS APPLES AND PEARS:

Nitrogen: Increase N rates by 10% for each tenth of a percent the concentration is below the deficiency level (e.g. if McIntosh sample contains 1.5% N or 0.2% below deficient level, increase rate by 20%), or decrease rate by 10% for each 0.1% the levels is above the excessive level. As a guide, non-bearing young trees should produce 12 to 24 inches of shoot growth.

Growth on bearing trees should be 8 to 12 inches.

Phosphorus: Tree fruit seldom respond to P, but ground covers may benefit when levels are low.

Potassium: Apply 100 to 150 lb K2O if deficient.

Calcium: If deficient, check soil pH and apply lime as needed.

Magnesium: If deficient, check soil pH and apply dolomitic lime as needed. Also apply Epsom salts (magnesium sulfate) at 15 to 20 lbs/acre in first two cover sprays.

Boron: If deficient, 0.5 B/acre (2.5 lbs Solubor) in each of two foliar sprays in June/July or apply 1 to 1.5 lb B per acre to the soil. Completely dissolve water-soluble packages prior to adding B to avoid plugging filters and nozzles. Soil treatments can be applied with a weed sprayer or blended into fertilizer.

Manganese: If deficient, apply 4 lb manganese sulfate per acre in first two cover sprays.

Zinc: If deficient, apply Zn chelate in first two cover sprays at label rates.