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POSTHARVEST TECHNOLOGY FOR FRUIT & VEGETABLE PRODUCE MARKETERS:

Economic Opportunities, Quality & Food Safety

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PREFACE

This book is the result of many years of fieldwork as consultants in postharvest horticultural handling and processing technology, and has been written to answer the many questions we have been asked as we visited small-scale growers, produce packers, handlers, shippers and marketers throughout the US and in a wide range of developing countries Between us we have worked in many states of the US and in more than 20 countries in Africa, the Caribbean, Latin America Asia and Europe During our assignments we have assisted produce marketers and processors to identify causes and sources of losses and have developed programs and training materials for teaching local handlers to use practices that will reduce postharvest losses maintain quality and ensure food safety

An earlier manual produced as part of the Postharvest Horticultural Series *Small-scale Postharvest Handling Practices A Manual for Horticultural* Crops (Kitinoja and Kader, 1995) introduces many of the topics that we cover in more detail in this book We have included information gathered from hundreds of published books, university and governmental reports, horticultural magazines, trade publications and unpublished sources Our intention is to provide specific recommendations for harvesting, handling, storing, processing and marketing a wide variety of crops currently being handled under a variety of conditions in small-scale horticultural operations in India, California, other U S states and other countries While the U S is known for its large commercial farms, the 1990 USDA Yearbook of Agriculture reports that nearly 65% of U S farms are classified as "rural residence" or part-time farms, with less than $25 000 in annual sales Another 21% are classed as "small commercial" farms with annual sales of less than $100,000 In India the average size of land holdings place most producers into the small-scale category, as in most developing countries the vast majority of producers are farming a few acres or even less Horticulturalists may grow only one commodity or a mix of complementary crops

Since so many improved postharvest technologies have been developed during the past few decades, we first had to narrow our focus to those practices most likely to result in immediate benefits to small-scale producers and/or marketers Our criteria for benefits included postharvest loss reduction, quality and value maintenance and protection of food safety at reasonable cost Most importantly, the examples we cover in Parts I and II were chosen for their potential to enhance the economic value of horticultural produce and improve economic returns to growers and direct marketers Where necessary due to space limitations, we refer readers to well-known books on individual postharvest handling and processing topics For example, there have been many excellent books published on the complicated process of produce marketing, and we must refer readers to these for complete details on the various traditional wholesale and retail and the alternative marketing options outlined in this book Rather than rehash this published information, our focus in Part III is upon the postharvest technologies that must be understood and utilized for small-scale marketers to acheive success in their endeavors using whatever marketing strategies they determine are most suitable for their crops, location and culture

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CHAPTER 1

INTRODUCTION TO PART I
FRESH HANDLING TECHNOLOGIES

Successfully marketing fresh horticultural produce begins with production of a quality product and requires careful attention to the details involved in postharvest handling which protects quality, nutritional value, economic value and assures food safety As a producer, handler and/or marketer of fruits or vegetables you already have some experience with the many steps of postharvest handling of horticultural crops and the general flow of produce from field to market Small-scale growers and direct marketers worldwide often express concern over produce losses and quality changes during handling that decrease their return on investment, and have to deal with consumers' concerns about loss of nutritional value and perceptions of problems with food safety Choosing the most beneficial postharvest practices can be a complex decision, based upon the needs of the commodity, cost of the technology, available market outlets and the desired level of involvement of the marketer Luckily, there are many simple postharvest handling methods from which to choose which will assist you to protect the value of your produce and immediately improve your return on investment

Whether you sell to wholesalers or market your produce directly to consumers, the choices you make during production, handling and marketing have an important effect on your own profits as well as upon the quality, nutritional value and safety of the fresh fruits and vegetables you grow and sell After spending a great deal of time and money on crop production, it makes sense

to spend a little more money to protect its value after harvest The table below lists some of the types of postharvest losses, quality deterioration and safety problems encountered during fresh produce handling and marketing Losses can be economic (loss of value), physical (weight loss or decay), cosmetic and/or nutritional For example, if you sell your produce by weight, any loss of water will be experienced as a direct loss of income since you will have less produce to sell When produce is graded by quality standards before sale, any mechanical damage, shrivel color changes or pest problems will put your produce in a lower grade, and lower its value compared to the highest quality produce

IMPORTANT TYPES OF POSTHARVEST HORTICULTURAL LOSSES, QUALITY DETERIORATION AND FOOD SAFETY PROBLEMS ENCOUNTERED BY PRODUCE HANDLERS AND MARKETERS

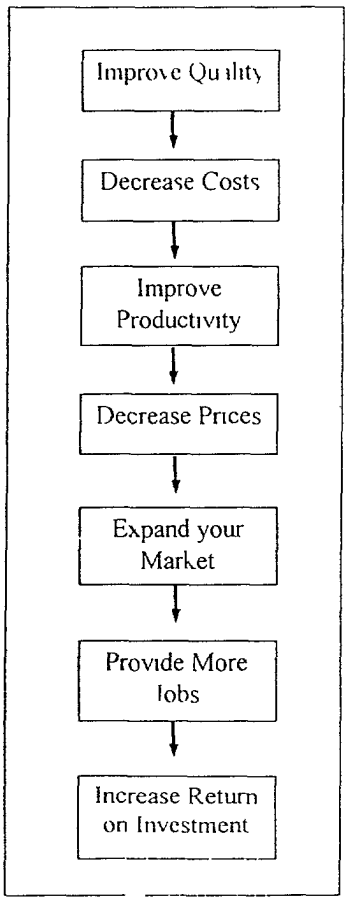
Problems	Examples
Water loss (weight loss)	Shriveling wilting of fruits and vegetables
Water loss (loss of textural quality)	Softening limpness loss of crispiness or juiciness
Mechanical damage	Bruises cuts surface abrasions or crushing
Physical losses due to pests	Fungal and bacterial diseases insect attack
Contamination	Soil pathogenic bacteria (soil-borne disease) Pesticide and chemical residues
Losses from physiological disorders due to temperature	Chilling injury freezing injury heat injury sunburn
Losses from physiological disorders due to nutrient imbalances	Calcium deficiency (bitter pit blossom end rot) Boron toxicity
Losses from physiological disorders due to atmospheric gases	Ethylene damage (russet spotting, ripening) low oxygen or high carbon dioxide (physiological breakdown)
Losses due to continued growth and development after harvest	Rooting sprouting shoot development elongation and curvature of asparagus greening of potatoes fiber development seed germination inside fruits compostitional changes (loss of color flavor softening)
Nutritional losses	Loss of stored carbohydrates vitamin C

The first part of this book will assist you to identify and utilize scale-appropriate, cost-effective postharvest technologies for handling fresh horticultural produce to

- Reduce postharvest losses due to water and weight loss, decay and physical damage
- Maintain produce quality (color, flavor, texture, appearance, nutritional value, etc) and economic value during postharvest handling, storage and transport
- Increase shelf life with proper temperature and relative humidity management
- Assure food safety during fresh handling
- Increase income by adopting those postharvest technologies that are most profitable for your small-scale operation

RETURN ON INVESTMENT

There is a tendency to worry that putting time and money into new postharvest technology will be a waste of resources, since buyers will not appreciate (and be willing to pay for) the investment required to improve quality In fact, any improvement you can make is likely to increase the value of your produce to the point where you will eventually be able to charge *lower prices* and still have more profit than you make now! Dr W E Deming described the theory of total quality management (TQM) many years ago for industrial production, and his ideas, illustrated here, can help horticultural producers and marketers understand how focusing on produce quality can lead to decreased unit costs and ultimately to increased return on investment



Deming s Total Quality Management (TQM) Chain Reaction

The table which follows lists some of the common practices that contribute to postharvest problems from pre-harvest factors and harvesting methods through packing, storage and shipping to fresh marketing In

general rough handling (mechanical damage) and poor temperature management (inadequate cooling) are the cause of the most postharvest problems Direct marketers such as truck farmers, market gardeners and farmer's marketers have the most opportunity to reduce losses and quality problems, since they are responsible for fresh produce thoughout production, during harvest, and are involved in all the steps of packing, storage and transport as well as destination handling during marketing to retailers or consumers

COMMON HANDLING PRACTICES AND CONDITIONS AFFECTING POSTHARVEST LOSSES, QUALITY AND FOOD SAFETY

Pre-Harvest
Inadequate planning regarding planting and harvesting dates or growing cultivars that mature when market prices are lowest
Production of cultivars with high yields but short postharvest life or susceptibility to postharvest pests and diseases
Use of poor quality planting materials
Over-fertilization of vegetables with nitrogen
Lack of use of calcium sprays for pome fruits
Inappropriate irrigation practices (too close to harvest date)
Poor orchard and field sanitation leading to latent infections and insect damage
Lack of pruning and/or thinning fruits leading to small sized fruits with non-uniform maturation
Lack of pest management (lack of spraying for insect or fungal control bagging or using mesh nets to cover produce susceptible to insect or bird damage)

Harvest
Harvesting at improper maturity leading to increased severity of storage disorders lower eating quality (poor flavor and/or texture) failure to ripen or excessive softening
Use of rough and/or unsanitary field containers
Soil contamination of produce
Harvesting during the hot hours of the day
Rough handling dropping or throwing produce fingernail punctures
Leaving long or sharp stems on harvested produce
Over-packing of field containers
Exposure to direct sun after harvesting

Curing
Lack of curing or improper curing of root and tuber crops that are destined for storage
Improper drying of bulb crops before postharvest handling packing and storage

Packinghouse Operations
Lack of proper sorting
Lack of cleaning washing or sanitation
Rough handling
Severe drops and lack of pads on conveyors/ grading equipment
Improper or excessive trimming
Misuse of postharvest treatments (over-waxing inadequate chlorine in wash water misuse of hot water dips for pest management)
Use of inappropriate chemicals or misuse of registered compounds

Long delays without cooling
Lack of accepted and/or implemented and enforced quality grades or standards for commodities

Packing and Packaging Materials
Use of flimsy or rough packing containers
Lack of liners in rough baskets or wooden crates
Containers designed without adequate ventilation
Over-use of packing materials intended to cushion produce (interference with ventilation)
Over-loading containers
Use of containers that are too large to provide adequate product protection
Misuse of films for M A packaging over-reliance on MAP versus appropriate temperature management

Cooling and Humidity Control
In developing countries and farmer's markets general lack of the use of any methods of cooling during packing transport storage or marketing of fruits or vegetables
In developed countries use of inappropriate cooling methods misuse of cooling methods over-cooling (chilling injury freezing)
Lack of efforts to maintain high relative humidity (RH) during cooling and storage
Inadequate monitoring of temperature and chlorine levels in hydrocooler water

Storage
In developing countries general lack of storage facilities on-farm or at wholesale or retail markets lack of ventilation and cooling in existing on-farm facilities
Poor sanitation and inadequate management of temperature and RH in larger scale storages
Over-loading of cold stores (too much produce for cooling system specifications)
Placing warm produce into the cold room
Stacking produce too high (beyond container strength)
Mixing lots of produce with different temperature/RH requirements
Lack of regular inspections for pest problems temperature/RH management

> "India wastes more fruit and vegetables than are consumed in the whole of the U K " Cumulative waste is estimated at about 40% of the total production value Much of the produce becomes inedible within a day or two of harvesting
>
> Source FoodTalk (March 1998)

Transportation
Over-loading vehicles
Stacking heavy produce on top of delicate produce
Loading refrigerated vehicles without pre-cooling (both the vehicle and the produce)
Use of bulk transport or poor quality packages leading to compression damage
Lack of adequate ventilation during transport
Lack of air suspensions on transport vehicles
Rough handling during loading
Lack of cooling and heat gain during delays (turning off the refrigeration unit or leaving produce exposed to the sun)
Ethylene damage and/or chilling injury resulting from transporting mixed loads

Destination Handling
Rough handling during unloading
Lack of sorting poor sanitation improper disposal of culls
Improper de-greening of citrus crops and misuse of ripening practices
Lack of cooling and humidity control during temporary storage
Handling mixed lots of produce leading to ethylene damage and/or chilling injury
Lack of protection from direct sun during direct marketing
In LDCs and farmers markets open markets exposed to sun, wind dust, rain
Over-cooling in supermarket displays of chilling-injury susceptible produce

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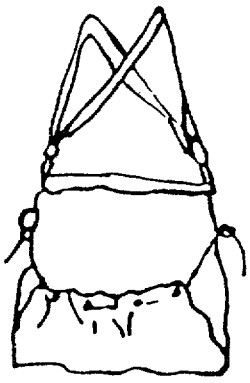
There are many affordable simple to use postharvest technologies available to assist small-scale growers, handlers, shippers and direct marketers to avoid many of the problems and conditions listed above The first part of the book provides detailed explanations of specific technologies for handling fresh produce such as curing, field packing, forced-air cooling, and on-farm storage practices You can try these for yourself on a small scale, work out your actual costs and benefits for the crop(s) you produce and sell, and make the right decisions for your own operation Using the worksheets provided at the end of each part of the book, you can calculate your expected return on investment and adopt only those practices that will increase your profits And if you like to "do-it-yourself" you can construct many of these technologies using simple tools, readily available parts and inexpensive building materials

Chapters 2 through 9 focus upon the specific postharvest technologies useful at each step of the postharvest chain that are recommended for producing, handling and marketing high quality fresh fruits and vegetables Many of these practices are simple to adopt and require little investment


Picking Bag

Each chapter begins with a brief introduction of generally recommended practices and a list of DOs and DON'Ts for achieving high quality The chapters also contain detailed information on more complex technologies that have been shown to be useful in reducing postharvest horticultural losses We recommend that you begin by carefully reviewing your operation using the Commodity Systems Assessment Methodology questions included in Appendix A Answering these questions for a specific commodity and

filling out the CSAM worksheets will help you pinpoint areas where you may be able to improve quality, reduce losses and increase your profits If your loss assessment leads you to one specific area where you have significant problems with physical losses, quality maintenance or food safety, you can refer directly to the chapter that covers that component

Each chapter concludes with a discussion of the expected costs and benefits of the related small-scale postharvest technologies, along with a simplified example of how to calculate return on investment You should use your actual costs and the market prices you expect to receive for your produce to compare your own costs and benefits with the examples given In many cases you may have lower costs due to lower local labor costs or because you can build a piece of postharvest technology, modify an existing building, or buy a used model rather than purchasing new equipment

HACCP

Chapter 10 discusses food safety issues and outlines the recommended steps of a HACCP (Hazard Analysis Critical Control Points) program for preventing food-borne illness when handling fresh produce We have included this topic because we believe that as consumers and governmental agencies become more concerned with outbreaks of food-borne diseases such as those that have been found in fresh produce (*Salmonella* and virulent *E Coli* strains), produce handlers will increasingly be required to show evidence of the actions they have taken to prevent food safety problems

WORKSHEETS

Worksheets that are designed to help you determine whether your adoption of the discussed postharvest technology will be something that result in profits for your operation are included at the end of Part I The specifics will depend upon the crop you grow and sell, the cost of making changes and the expected outcomes (yields, grades and the associated market prices) Profits may be enhanced due to higher produce quality (higher grades, larger sized produce, better flavor, etc),

higher volume of sales (lower losses due to less water loss or reduced decay problems) or higher economic value related to improved food safety higher nutritional value or to marketing an early crop or otherwise extending the season

WORKSHEETS

1 Basic Information

2 Total Costs

3 Expected Benefits

4 Recovery of Invested Capital

Worksheet 1 focuses on collecting basic information needed for producing and marketing crops of any kind (overhead, expected yields, estimated postharvest losses, anticipated market prices) Worksheet 2 requires that you calculate and list the actual direct costs incurred when you grow, handle, store and/or market a horticultural crop Much of this you should know from your day-to-day recordkeeping for running your business Worksheet 3 outlines expected benefits in terms of produce quality grades, sales and profit, and Worksheet 4 helps you to determine the return on investment (leading you through the calculation of how long it will take to recover invested capital) If you are not sure of the market prices you may receive, you can do the calculations for a worst case (lowest price) and best case (highest price) scenario and determine whether your investments will be worthwhile within that range of possible outcomes

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CHAPTER 2

PRE-HARVEST PRACTICES

High quality horticultural produce is appealing in color, flavor, texture, and aroma Consumers expect that the produce they buy is safe to eat and has good nutritional value Certain produce of any type of commodity may be more highly valued due to consumer preferences for size (very small, or extra large), shape (highly uniform or novel in some way), flavor (sweetness or intensity) or availability (earlier or later than during the usual season) In the U S , market prices for organic produce are often much higher than the prices for conventionally grown produce, leading some growers to avoid the use of agricultural chemicals and choose cultural practices that may be more labor intensive Since even the best postharvest handling practices cannot improve produce quality after harvest, it is very important for producers to use pre-harvest practices that will enhance initial quality and assure food safety while ensuring a profit

This chapter presents information on selecting cultivars, using cultural practices during production that promote high postharvest quality (field sanitation, intercropping, trellising, pruning and thinning, certain fertilization and irrigation practices), pre-harvest practices that can extend the harvesting period (choice of commodities for early or late planting protecting plants from excessive cold, heat and pests) and practices that add value (blanching vegetable crops, deflowering herbs, using sprouting inhibitors on bulb crops)

GENERAL DOs AND DON'Ts FOR PRODUCING HIGH QUALITY FRUITS AND VEGETABLES

When choosing cultivars, consider yields but also consider postharvest characteristics and susceptibility to postharvest pests and diseases

Plan planting/harvest dates, select cultivars that mature when market prices are high and demand for the product is high (avoid periods of glut)

For perennial crops such as tree fruits, plant a variety of cultivars to extend the harvest and marketing period

Select cultivars with unusual characteristics (heirloom varieties, different colors or shape variations, produce for ethnic cuisines) to take advantage of market niches

Use clean, healthy, high quality planting materials

Avoid over-fertilization with nitrogen (reduces quality, increases susceptibility to decays, insect damage and storage disorders)

Take care with animal manures and incompletely composted materials used as fertilizers (prevent contact with produce) Make sure a minimum safe interval of time has passed between application and harvest

Test soils for possible contaminants if you suspect that animals have had access to the field, the field has ever been used as a feedlot, land fill or waste site

Avoid wetting the leaves and fruits of plants when irrigating to minimize the spread of disease

Avoid over-irrigation during the weeks before harvest (decreases produce firmness, increases storage problems)

Practice orchard and field sanitation to prevent latent fungal infections and insect damage (Remove mummies from fruit trees, remove diseased produce left in the field or on the orchard floor, do not leave culls in the field, and clean field bins that have been in contact with soil contaminated with innoculum)

Do's and Don'ts continued

Use appropriate pest management practices (spray for insect or fungal control, bag produce susceptible to insect or bird damage, rodent or insect traps, etc)

Use fine-mesh nets (about 10 threads/cm or 20-30 threads per inch nylon mesh) to protect against bird damage

Enhance quality by using appropriate cultural practices (calcium sprays to prevent bitter pit in pome fruits, pruning and/or thinning to increase fruit size for stone fruits, blanching asparagus, celery, cauliflower, leeks and endives, use of ethephon spray to spur uniform ripening in tomatoes)

Extend the season by using appropriate technologies to plant earlier and/or harvest later (hot-caps, row covers or plastic tunnels, shade cloth, mulches, etc)

Consider the pre-harvest application of ethephon {(2-chloroethyl) phosphoric acid} to promote uniform ripening of tomatoes grown for processing

SELECTION OF CULTIVARS

Virtually all postharvest quality characteristics of horticultural crops are genetically programmed and will vary naturally by cultivar As a small-scale grower, you can choose to produce cultivars that have those specific quality attributes that are most highly valued by your customers You can plant a variety of cultivars of the same commodity to extend the harvest period--for example, 'Sierra Crest' peaches begin to mature in California during early May, 'June Lady' and 'Rich Lady' mature in June, while July brings 'Faye Elberta', August 'O'Henry' and 'Ryan Sun' The last peaches to mature in September are 'September Sun', giving you nearly five months of harvest

The following are just a few of the many varieties of horticultural produce available Many seed companies can provide you with full color catalogs and detailed descriptions of their products Check with your local extension agent if you need assistance to ensure you choose cultivars that are well suited to your specific climate, daylength, soils and growing conditions If you save your own seed, always select seed from your highest quality produce to ensure continuing high quality production

Varieties with superior or unusual flavor, color or texture

Apricot/Plum crosses (pluots or black apricots)-- from Russia India North Africa

Berries-- thornless cultivars of blackberries raspberries boysenberries excellent for Pick-Your-Own operations Canby raspberries are thornless extra large heavy bearing and have superior color and flavor

Chard-- cultivars are available with green white pink red orange or yellow stems

Cucumbers-- lemon Armenian, "burpless" varieties

Garlic-- purple bulbs and hot varieties (Korean) elephant garlic

Heirloom varieties-- thousands of rare fruits and vegetable seeds with excellent flavor characteristics are available through the Seed Savers Exchange

Peaches-- 'Peento' varieties from China are flattened white-fleshed self-fertile

Salad greens-- provide a variety of choices to consumers arugula batavia lettuce beet greens chervil chicory corn salad cress dandelion endive escaroles fennel mustard greens New Zealand spinach purslane radicchio red-leafed lettuce romaines sorrel spinach turnip greens

Strawberries-- Locally produced varieties with excellent flavor include 'Earliglow' 'Sparkle' and 'Jewel' (Northeast and Midwest US) 'Cardinal' (Southern US) 'Totem' and 'Redcrest' (Northwest) and Chandler' (Western US) 'Alpine' varieties are white or yellow with a hint of pineapple flavor

Sweet corn-- 'sh2' 'SE/se' varieties are higher in sugar content must be isolated in time or distance from other cultivars during production

Tomatoes-- 'Brandywine' an 1885 Amish heirloom variety has superior flavor and pinkish fruits 'Sungold' is a heavy-bearing orange-fruited cherry tomato

Watermelon— Some Japanese varieties have pineapple-colored flesh

Taking advantage of a marketing niche

Asian vegetables-- "ethnic' produce for specialty markets restaurants and asian cuisine

Basil-- varieties include lemon cinnamon spicy and purple as well as sweet basil

Lettuce-- mini iceberg lettuce cultivars make a salad for one person

Plum/Prunes--provide cultivars with lower water content for processing (drying canning) including 'Italian Prune' 'Valor' and 'Imperial Epinease' (considered the world standard for high quality)

Cultivars recommended by I A R I

Tomatoes
Pusa Early Dwarf
Pusa Ruby
Sioux
Marglobe
Best of All
La Bonita
Pusa 120
Pusa Sheetal
Pusa Gaurav
Italian Red Pear
Roma

Brinjal
Pusa Purpla Long
Pusa Purple Round
Pusa Purple Cluster
Pusa Kranti
Pusa Bhairab
Pusa Anupam

Source Choudhury 1998

Shallots-- gray shallots have a very high value compared to other varieties

Tomatoes-- provide cultivars with meatier flesh lower water content for processing 'Super Italian Paste is very sweet with little juice and few seeds making it excellent for drying or canning

Extending the season with early or late harvests

Blackberries-- 'Black Butte' and 'Siskiyou' ripen weeks before peak berry season

Broccoli-- Saga' is productive in warmer weather than other varieties

Cauliflower— Early Kunwari and Early Patna Late Dania Snowball-16 and Pusa Himjyoti

Chard-- long season swiss chard can become a perennial in warmer climates

Chinese cabbage--joi choi is slower to bolt larger and faster growing than other varieties of pac choi or bok choy

Grapes-- 'Autumn Royal a seedless purple grape can be marketed in the US until mid-January

Green beans--'Venture' and 'Royalty' will produce well in cooler weather

Lettuce-- 'Red Sails' 'Mantilia' resist bolting in warm weather

Onions-- produce a pungent cultivar with multiple uses (harvest young shoots thinnings as green onions small bulbs as cooking onions then allow the remainder to mature cure for storage)

Peas— Early Asauji and Meteor Late N P 29

Peaches-- Spring Baby' and 'Spring Gem' are new early season varieties while 'Autumn Red' ripens later than usual

Potatoes-- harvest young new potatoes of 'Yellow Finn' golden or red-skinned cultivars (gently lift vines after loosening soil remove the small potatoes and replant) then allow the plant to grow to full maturity

Strawberries-- 'Firecracker' and 'Independence' begin ripening in the US around July 4th and bear fruit up to 3 weeks longer than other cultivars

Tomatoes-- 'Oregon Spring Siberian will produce well in cooler weather

POTATOES

very early 'Kufri Alankar'

early 'Kufri Chandramukhi'

late 'Kufri Kisan'

frost resistant
'Kufri Sheetman'

Optimizing shelf life and storage potential

Generally fruits and fruit vegetables that have a shorter production season and mature earlier have a shorter storage life than slower-maturing cultivars
Apples-- cultivars with the storage potential of 5 to 6 months under normal cold storage are Delicious Golden Delicious Granny Smith Rome Beauty Spartan and Winesap

Beets-- Winterkeeper' can be allowed to grow to enormous size without flavor problems

Cabbage-- late cultivars (harvested in the fall) store well for 5 to 6 months at 0 °C compared to 3 to 6 weeks for early spring varieties The longest keeping cultivars belong to the Danish class and include Dutch White' 'Hidena' and Bartolo' which store up to 10 months

Garlic--softneck garlics store better than hardneck (woody stem) cultivars

Lettuce-- Florida Buttercrisp is a hybrid with more durable leaves resulting in less damage during handling

Melons-- St Nick' melon has deep green striped rind and cream-colored flesh stores for 2 months after harvest

Onions--high SSC pungent cultivars store better and longer than sweet cultivars *Kharif* crops do not store well
-- onions grown from seed store better than onions grown from bulbs
--'Sweet Sandwich' requires no chemicals to inhibit sprouting (stores 9 months)

Pears-- 'Anjou' 'El Dorado' and 'Winter Nelis pears can be kept safely for 6 to 8 months in cold storage (-1 °C)

Potatoes-- late fall harvested cultivars are less susceptible to *Fusarium* spp (dry rot) in storage than early cultivars Kufri Chandramukhi is high yielding and keeps well in storage

Radishes-- Winter cultivars can be stored for 2 to 4 months compared to spring cultivars with a storage life of 3 to 4 weeks

Squash--*Curcubita maxima* (Hubbard) stores well up to one year

Tomatoes-- Extended Shelf Life (ESL) cultivars contain a gene that slows ripening and must be harvested at the pink stage or later for optimum quality

Watermelon— Katagola has very good keeping quality

Disease Resistant Crop Varieties (Sources Hart 1995 and Choudhury 1998)

Apples-- Liberty' 'Priscilla Prima

Asparagus-- Jersey Giant Mary Washington

Beans-- 'Derby' 'Greensleeves' Tendercrop and Top Crop' (snap beans) 'Kentucky Wonder' (pole beans) and Eastland' (lima beans)

Broccoli-- Green Comet' 'Emperor' hybrids

Cucumber-- 'Early Pride' 'Salad Bush' and 'Sweet Success Amira' hybrids

Eggplant (Brinjal)-- 'Vittoria' hybrid

Kiwifruit-- 'Issai' a hardy kiwi

Lady s Finger (okra)— Parbani Kvanti is resistant to ym virus Pusa Sawani resists yellow-vein mosaic virus

Melons--'Ambrosia hybrid 'Bush Charleston Gray 'Ediato' 'Dixie Queen' 'Sweet n Early' hybrid 'Sweet Dream' hybrid 'Sweet Favorite

Peas-- 'Green Arrow' Maestro' 'Sugar Bon Sugar Snap

Peppers-- 'Golden Summer' and Gypsy' hybrids 'Bell Boy Lemon Bell

Potatoes-- 'Kennebec' Up-to-Date Kufri Kumar has high resistance to late blight

Pumpkin--'Baby Bear'

Raspberry-- many varieties

Spinach-- 'Melody' hybrids

Strawberry-- 'Allstar' 'Earliglow' 'Guardian' 'Surecrop'

Tomatoes-- 'Roma 'Better Boy' 'Parks Whopper' Better Bush' 'Celebrity' 'Big Pick'

Watermelon-- 'Crimson Sweet'

MAIL ORDER AND INTERNET SOURCES OF SEEDS AND PLANTING MATERIALS

Burgess Plant and Seed Co 905 Four Seasons Road Bloomington Illinois 61701

Burpee Co 300 Park Avenue Warminster Pennsylvania 18974

California Rare Fruit Growers Inc P O Box W El Cajon CA 92022

the Cook's Garden P O Box 65054 Londonderry Vermont 05148 ($1 for catalog)

Garden City Seeds (406) 961-4837

Gurney's Seed and Nursery Co 110 Capital Street Yankton South Dakota 57079

Henry Field's Seed and Nursery Co Shenandoah Iowa 51602

Horticultural Network (HortNet) www hortnet com

le Jardin du Gourmet P O Box 75 St Johnsbury Center Vermont 05863

Johnny s Selected Seeds 299 Foss Hill Road Albion Maine 04910

LeMarche Seeds Int l P O Box 190 Dixon California 95620 ($2 for catalog)

Native Seeds/SEARCH 2509 North Campbell Ave Suite 325 Tucson Arizona 85719

Oregon Exotics Rare Fruit Nursery 1065 Messinger Road Grants Pass OR 97527 ($2)

Owen Nursery 2300 East Lincoln Street Bloomington Illinois 61701

Park Seed Company Inc P O Box 46 Highway 254 North Greenwood SC 29648

Raintree Nursery 391 Butts Road Morton Washington 98356

SeedQuest Online www seedquest com

Seed Savers Exchange RR 3 Box 239 Decorah Iowa 52101 ($1 for brochure)

Shepherd's Garden Seeds 7389 West Zayante Road Felton CA 95018 ($1 for catalog)

Stokes Seed Company P O Box 548 Buffalo New York 14240

Stokes Seeds Ltd P O Box 10 St Catherines Ontario L2R 6R6 Canada

Territorial Seed Company P O Box 157 Cottage Grove Oregon 97424-0061

The Tomato Seed Company Inc P O Box 1400 Tyron NC 28782

COMPARISON OF ESTIMATED COSTS AND EXPECTED BENEFITS RELATED TO DIFFERENCES IN THE PRODUCTION, HANDLING AND MARKETING OF TWO CULTIVARS

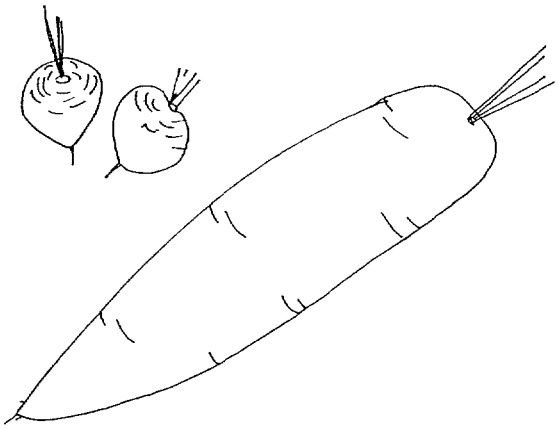
Costs

New planting materials

Land preparation (plowing, planting, etc)

Delay between planting and first crop

Higher cost for improved seeds



Potential Benefits

Lower production costs for new cultivar

Higher market value for new cultivar

Extended season (earlier or later)

Example

Assumptions

1) For the purposes of this example postharvest losses are assumed to be uniform for both varieties of radishes at 10% of expected yields

2) Most expenses for production and postharvest handling for the two cultivars will be similar, with the exception of increased handling/packaging costs for the new cultivar due to increased yields

3) Only average retail prices will be used in the calculations Higher prices obtained for early or late in the season produce will further increase the potential profits

Current cultivar Small round red radishes are direct seeded any time of the year during cool weather at a rate of 2 kg/ 0 1 ha and cost Rs 4400/kg Expected yield in 26 days is 12,000 kg/ha and the average retail selling price is Rs 5/kg

12,000 x 0 1 ha = 1200 kg

1200 kg x Rs 5/kg = Rs 6000

If postharvest losses are assumed to be 10%, expected market value is

Rs 6000- Rs 600 = Rs 5400

Cost of seeds = Rs 8800

Potential profit (for 0 1 ha in about one month) = Rs 5400/month - cost of seeds = Rs (-3400)

Net loss of Rs3400 per month

New cultivar Long white (Daikon) bolt resistant radishes are direct seeded during the late autumn through spring at 1/2 kg/ 0 1 ha and cost Rs 2600/kg Expected yield in 60 days is 30,000 kg/ha and the average retail selling price is Rs 5/kg

30,000 kg/ha x 0 10 ha = 3000 kg

3000 kg x Rs 5/kg = Rs 15,000

If postharvest losses are assumed to be10%, expected income before expenses is

Rs 15,000- Rs 1,500 = Rs 13,500

Cost of seeds = Rs 1300

Potential profit (for 0 1 ha in about 2 months) = Rs 13,500 - cost of seeds = Rs 12,200

Rs 12,200 /mo divided by 2 months = Net profit of Rs 6100 /month

CULTURAL PRACTICES THAT ENHANCE QUALITY, EXTEND THE SEASON AND/OR ADD VALUE

In general the less perennial the horticultural crop, the more influences the environment and the cultural practices you use will have upon produce quality But even with perennial crops, there is plenty you can do to protect your crops in the field or orchard and to ensure the production high quality, high value fruits and vegetables

Field sanitation

Most growers of stone fruits know they must remove mummies from fruit trees to reduce the incidence of brown rot (*Monolinia fructicola)*, and growers of pome fruits try to keep orchards free of fallen fruits to reduce Mucor rot, but there are two other important sources of innoculum for various fungal pathogens and/or hosts for insect pests These are 1) culls left in the field or on the orchard floor, and 2) field bins that have been in contact with soil contaminated with innoculum.

BASIC SANITATION PRACTICES INCLUDE
Remove mummies from trees
Remove mummies and fallen fruit from the orchard floor
Remove culls from field and orchards
Keep field bins clean, smooth and in good repair
Cover areas where bins are kept with sawdust or wood chips or use trailers to hold bins

Extending the season

Quick maturing crops for cool season production include baby carrots beets, chinese cabbage, leaf lettuce and spinach Some quick maturing crops for the warm season are bush beans, summer squash early tomatoes and early sweet corn

Slow maturing extended-harvest crops for the cool season include peas kale onions and brussels sprouts Warm season crops that will continue producing over long periods include lima beans, pole beans, cantaloupes, standard sweet corn, cucumbers, eggplants (brinjal), peppers, winter squash, pumpkins and indeterminate tomatoes

There are a variety of pre-harvest practices that can extend the season by providing a degree of plant protection from excess cold or heat, maximizing sun penetration and ventilation or encouraging early production

Mulching

Mulches can reduce evaporation of water by 10 to 15%, reduce competition from weeds and protect the roots of plants from extremes in soil temperatures Mulching vegetables can increase yields, promote early harvest and reduce produce defects (such as fruit rots, soil contamination) Organic mulches include plant residues, compost, nut hulls, peat moss sawdust, wood bark old newspapers and composted animal manures (with the exception of chicken manure) Other materials used for mulching include aluminum foil and plastic, which can be removed at the end of the growing season and reused for several years Plastic sheets should be perforated to allow air and water to reach the soil

> Splitting or cracking of pomegranates in India can affect up to 50% of the crop Fruits are often harvested prematurely to avoid fruit cracking, but quality is very poor in this case the trouble can be minimized by improving the water retention capacity of the soil by adding organic materials
>
> Source Singh 1998

Loose, dry mulches such as straw or wood chips act as insulation and protect against high temperatures Use a thick layer of straw-- at least 20 cm (8 inches), but first make sure the straw is free of seeds Finer mulches such as sawdust, compost or leaves can be used as a 10 to 15 cm (4 to 6 inch) layer

White paper and reflective foils can keep soil about 3 to 6 °C (5 to 10 °F) cooler than bare soil Potatoes, summer squash and cool season crops such as broccoli and brussels sprouts may benefit from the cooler soil temperatures and have increased yields

Black paper or black and transparent plastic mulches will increase soil temperature by 6 to 8 °C (10 to 15 °F) when compared to bare soil, and will encourage early plant development Melons, cucumbers, peppers, pumpkins, squash and early crops of tomatoes and sweet corn will benefit from soil-warming mulches, and reward you with earlier harvests Sheet mulches need to be well anchored to prevent wind damage A layer of soil around the edges, or a few stakes or heavy rocks will keep the sheets from lifting and flapping in the wind

Protection from cold

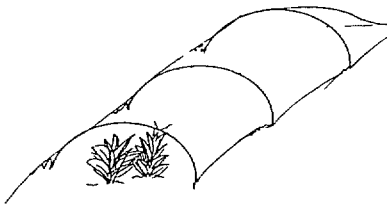
Hots caps plastic tunnels, cloches, row covers and products such as "wall o' water" are clear plastic products that provide protection from frosts and cold nights by keeping plants warmer than the outside air temperatures The clear plastic lets the sun's rays penetrate and warm the plants and surrounding soil, then slows heat loss from the soil during the night (by reflecting infra-red radiation back to the plant) Up to two months can be added to each end of the growing season

Inexpensive hot caps can be constructed for individual plants using empty, clean plastic containers with the bottoms cut out (2 L soda bottles or 1 gallon milk containers) Usually hot caps are placed over plants when a frost is expected, and are then removed during the following day If you plan to leave the caps in place for several days, poke some holes in the sides of the bottles to provide for ventilation, and remove the caps to let heat escape during the afternoon On a 15 °C (60 °F) day, temperatures under hot caps have been measured at 38 °C (100 °F)

Plastic tunnels are row covers that can be constructed from 4 to 6 mil polyethylene sheets held in place over metal, PVC or wooden frames Leaving the ends open will allow for adequate ventilation, but temperatures should be monitored to prevent heat damage Some growers prefer to slit the plastic toward the top of the tunnel to allow for more self-modulation of temperatures, but you still must pay attention to prevent buildup of heat on warm days The plastic should be removed when soil temperature reaches 15 °C (60 °F) The same supporting frames can then be used for shade cloth agricultural fleece or anti-bird netting

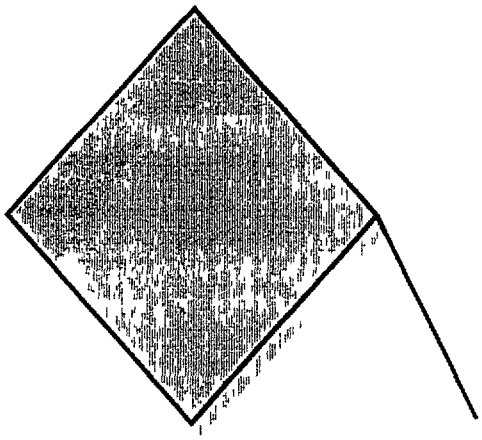
Hot caps

Plastic tunnels



Protection from heat

Shade cloth blocks the sun's rays to keep the plants cooler than outside air temperature and allow you to produce crops that would normally bolt or become infertile during very hot weather You can choose from fabrics that block up to 80% of the sunlight (tight weaves), down to loose weaves that block 30%



SHADE CLOTH cools the soil extends the season for lettuces peas cool season vegetables

Protection from wind

Winds can cause high levels of damage to delicate plants, and can be responsible for heavy losses due to fruit drop The best protection is provided by fully grown trees or a strong 6 foot high porous fence, but few growers have the luxury of waiting years for natural wind-breaks to grow, or have any desire to build long lengths of permanent fencing Agricultural fleece is a very fine polyethylene netting that can be attached to any sort of post or pole to make an instant wind-break If you set up the netting perpendicular to the prevailing winds, it will reduce wind speed by about 60%, and protect an area up to ten times the area of the netting Netting that is 6 feet high and 50 feet in length will protect 2000 to 3000 square feet of the field

Maximizing sun penetration and ventilation

Pruning and thinning

Limiting the vegetative growth of crops such as tomato, pole beans and berries will encourage the remaining produce to mature faster Thinning fruitlets in stone fruit crops, removing side shoots on tomatoes, and removing runners of strawberries results in the production of larger, better quality fruits Severe pruning of blueberries produces less but larger fruit, and encourages more new growth

"GUAVA is rarely pruned in North India, but light annual pruning after harvesting to promote vegetative growth and flowering is desireable "

Source Singh, 1998

For grapes, the general recommendation is to leave 5 or 6 canes on the most vigorous, strong vines, about 4 canes on moderately vigorous vines, and only 2 or 3 canes on weaker vines Studies in California have shown that leaving too many canes on weak vines will reduce produce quality and further weaken the vines over time

The banana rhizome produces many suckers continuously these compete with fruiting and should be removed (Singh, 1998)

When pruning and thinning, there is usually a trade-off to be made between total yield and improved quality, but often the better price received for higher grade produce will suggest that maximizing yield will not maximize profits Thinning stone fruits increases fruit size while somewhat decreasing total yield A cucumber plant is capable of producing many medium-sized or a few large fruits while the total weight of cucumbers produced will be about the same Removing the first and second female flowers from pumpkin vines will increase the weight of the remaining fruit, since all the plant's energy will be directed into this one fruit

RECOMMENDATIONS FOR THINNING FRUITS

Apples	Thin fruit to an average of 6 inches apart after natural fruit drop
Cherries	No thinning required
Grapes	Snip off parts of developing bunches to create the classic cluster shape and to improve size and quality of individual grape berries Gibberellin is a growth regulator used at the 20 to 80% bloom stage by some producers to reduce berry set when grape vines are carrying a larger crop than they can readily support
Peaches & Nectarines	Thin to one fruit per cluster early in the season spaced about 6 inches apart
Pears	Thin pears to two per cluster after natural fruit drop
Plums	Thin large-fruited cultivars to 3 to 4 inches apart thin small-fruited plum cultivars to 2 to 3 inches between fruits

2

Trellising

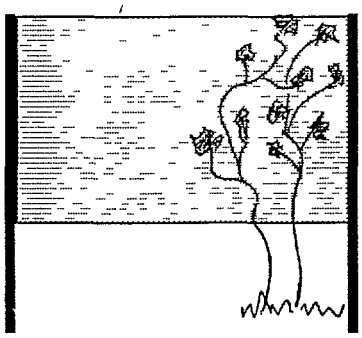
Encouraging plants to grow upward upon trellises will maximize sun penetration into the canopy and provide good ventilation, lowering the relative humidity around the plants and reducing the incidence of disease Improved light penetration is related to increased soluble solids content (SSC) and color development in berry crops Cucumbers will nearly double their yield per plant if trellised during production

Crops that benefit from trellising

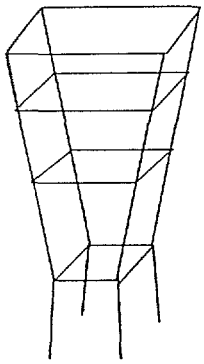
Fruits-- blackberries, raspberries grapes

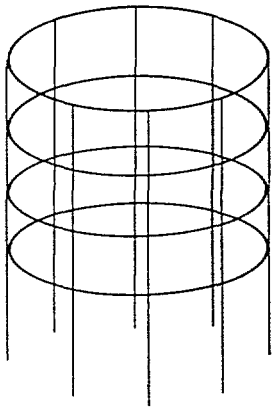
Vegetables-- pole beans, tomatoes, cucumbers squash, sweetpotatoes and melons

TRELLIS for peas green beans cucumbers squash small melons



Trellises can be constructed from poles, twine grids, metal cages, nylon netting, old screens or wire mesh You can be creative and build supports with whatever spare materials you have lying about on the farm. It is important the trellises are strong enough to support the weight of the plants and sturdy so they will not tip over in the wind Heavy crops such as melons will require support as they grow, and should be securely tied to the trellis Some small growers make a sling of cheesecloth for the heavy fruits and tie these to the trellis Trellised plants may require more irrigation to prevent wilting in the heat of the day





TRELLISES
- keep produce clean
- improve quality
- increase yields

Fertilization and Irrigation Practices

Nitrogen

For leafy crops, application of nitrogen is very important for stimulating vegetative growth Too much nitrogen fertilizer can be the source of quality problems in many crops Excess nitrogen increases susceptibility to brown rot (*Monolinia fructicola*) in peaches and nectarines Blossoms of under-fertilized trees are the most resistant to infection Large amounts of nitrogen encourages vegetative production rather than fruit development and results in poor storage quality of vegetables High nitrogen fertilization is related to increased water loss in storage for sweetpotato, decreased flavor in celery, decreased ascorbic acid content in potatoes and cabbage, and the development of hollow stem in broccoli High levels of nitrogen fertilizer contribute to bitter pit in apples, increased leaf production in berry crops (with smaller fruit size and increased incidence of disease) In cranberry, strawberry and kiwifruit excess nitrogen is related to loss of flavor, decreased firmness and the related increased susceptibility to decay

> A top dressing of N fertilizer after each cutting gives quick regrowth of green, succulent leaves
>
> Source Choudhury 1998

In addition to knowing the amount of fertilizer recommended for the soil type in which you are producing the commodity, you must know how much nitrogen is already present in the soil at the start of the planting season It is easy to over-fertilize, since nitrogen may be left over from fertilizers added during the last season, be present in cover crops and other organic matter as they break down in the soil, or added as rainfall and as you irrigate since most water sources contain some nitrogen In general, light colored soils contain little organic matter and will release little nitrogen, while dark colored soils release about one-half pound of nitrogen per 1000 square feet over the course of a growing season

The best approach is to begin by doing soil tests for the nutrients required for high quality production of your commodity, then fertilize to bring the soil up to the recommended rates The cost of a soil test will pay for itself many times if you determine that you have been wasting resources on fertilizers that are not needed

If you are planning to mulch for the first time, you will want to add some extra nitrogen to the soil As soil micro-organisms decompose the mulching materials, they will use some of the nitrogen you intended for crop production The most nitrogen is required for breaking down mulches made from sawdust wood chips leaves and corn cobs

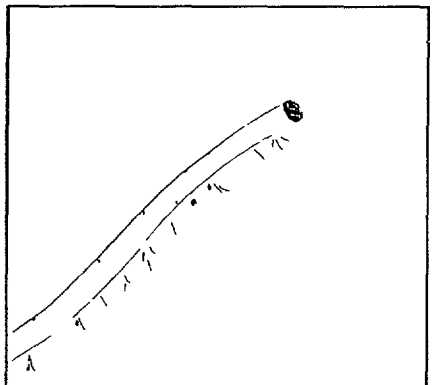
> There are few mango orchards which have received any fertilization, but they would greatly benefit from this practice Yearly requirements are estimated at 1 6 lb N, 0 4 lb P and 1 5 lb K per tree of full bearing age
>
> Source Singh 1998

Calcium

Calcium deficiencies play a part in determining produce quality, and can lead to blossom end rot in tomatoes, blackheart in celery, tipburn in lettuce crops bitter pit and internal breakdown in apples, and to the production of small, hard, sour strawberries Excessively high nitrogen fertilization will prevent apple trees from taking up calcium that is present in the soil Foliar sprays of $CaCl_2$ or $Ca(NO_3)_2$ can improve quality and reduce disease symptoms and decay in storage for these crops, especially if applied after a heavy rain or a period of rapid growth Calcium is also used to enhance firmness in tomato crops that are destined for processing Recommended rates are provided with the product, so be sure to follow the label instructions on the product you purchase

Irrigation and Irrigation Schedules

Using irrigation methods that spray water on the foliage of horticultural produce can increase the incidence of disease and increase the rate of spread of fungal infections Sprinklers also tend to waste water since much of the irrigation water winds up on foliage and bare soil and evaporates directly into the atmosphere before the plant can use it for growth and transpiration Rather than relying on overhead irrigation (sprinklers or sprayers) consider using furrow irrigation methods or installing soaker systems



Soaker Hose

Soaker hoses allow water to reach the plants roots more quickly by delivering water only where you desire These hoses can be purchased at farm supply stores, and are relatively inexpensive

Irrigation of citrus is especially important in summer Frequent light irrigation lowers soil temperature and raises humidity in the orchard

Source Singh 1998

over the long run since they are long lasting and will save you a lot of water Drip irrigation is recommended for some crops but can be overly expensive to install and maintain the drip systems

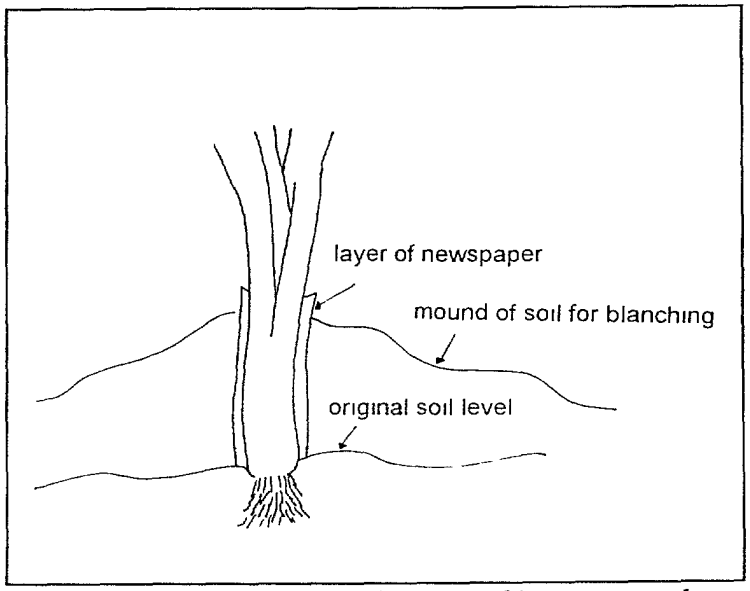
Excess water via rain or irrigation contributes to a loss of flavor in many horticultural crops, increased susceptibility to decay in storage, and early sprouting of root and bulb crops It appears that too little water may often be better than too much, in terms if overall produce quality Under-irrigated stone fruits have thicker cuticles and increased resistance to postharvest disease

The scheduling of the last irrigation has an effect on the quality of onions, garlic and potatoes It is important that irrigation be withheld for a period of 7 to 10 days before harvest, to allow the tops to dry down and the crops to be ready to dig and cure before further handling

Adding Value

Blanching

Pre-harvest blanching of vegetable crops during the last stages of growth makes the produce lighter in color and milder in flavor Blanching requires hand labor but adds market value to crops such as asparagus, cauliflower, celery, endive and leeks According to Singh (1998) using different colors of twine or rubber bands each day makes it easy at the time of harvest to select those plants tied earliest



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BLANCHING

Asparagus Hill soil over beds so shoots grow longer whiten

Cauliflower Grow self-blanching types if possible (the topmost leaves naturally grow upward to cover the head) Cover head with a paper bag or tie outer wrapper leaves around the head

Celery Hill soil around stalks after wrapping stalks in newspaper to keep out soil

Endive Cover head with wrapper leaves 7 to 10 days before harvest

Leeks Cover base of plant with newspaper when it is about half-grown then mound soil about 20-30 cm (8 inches) up the stem

De-flowering herbs

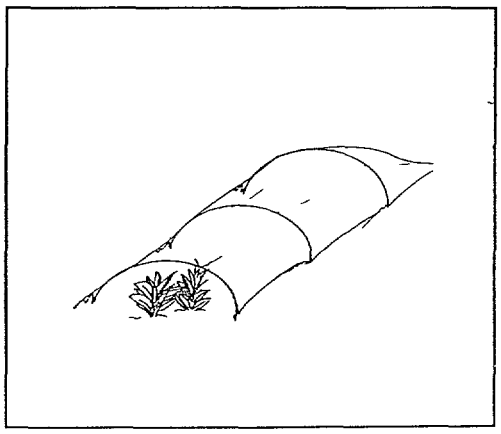
Keep the buds of flowers pinched off herbs such as basil, chives, marjoram, mint, oregano and tarragon to improve quality Just prior to flowering leaves are especially high in the essential oils that give herbs their characteristic flavor and aroma

Sprouting inhibitors

Maleic hydrazide used as a spray a few weeks before harvest adds shelf life to onions Follow the label for instructions on concentrations and proper usage

COSTS AND BENEFITS OF ADOPTING NEW PRE-HARVEST PRACTICES

(example using hot caps, plastic tunnels, pruning, thinning, shading, trellising, mulching, foliar Ca sprays, soaker irrigation systems, blanching)



Costs

Materials

Labor

Potential Benefits

Earlier harvest (higher market value)

Later harvest (higher market value)

Lower physical losses due to pests, disease

Improved quality (higher market value)

Example 1 Using plastic row covers in California to protect a 200 ft long row of hot pepper plants during early planting in cool weather

Costs
Materials $ 15 00 per 100 ft row
Cost for 200 ft row = $30 00
Labor cost for installation of covers 1 hour for 2 rows ($7/hr) = $7 00
Total cost= $37 00

Benefits
Earlier harvest of hot peppers (4 weeks early) gains high market prices of
$1 98-/lb for the first 500 lbs of peppers harvested
Total yield 3000 lbs
Compare to typical mid-season market price of $0 89/lb
$1 98-0 89 = $1 09 per lb higher price x 500 lbs = $545

Profit $545 00 - 37 00 = $508 per year

Example 2 In India, using plastic row covers to protect 65m of cucumber or long melon during early planting in cool weather

Costs
Materials Rs 12 /m
Cost for 65m row = Rs 800
Labor cost for installation of covers 1 hour for 2 rows (Rs 80 /day) = Rs 10
Total cost= Rs 810

Benefits
Earlier harvest of cucumbers (4 weeks early) gains high market prices of
Rs 30/kg for the first 250 of produce harvested
Compare to typical peak mid-season market price of Rs 5/kg
Rs 30- Rs5 = Rs 25 per kg higher price x 250 kg = Rs 6200

Profit Rs 6200 - 810 = Rs 5440 per year

SOURCES OF PRE-HARVEST EQUIPMENT AND SUPPLIES

Bird/pest control reflective tape terror-eyes balloons	 Burpee Johnny's Selected Seeds Peaceful Valley
Cloches, greenhouse film and clips for plastic tunnels	Mellinger's Peaceful Valley Territorial Seed
Floating row covers	Gardener's Supply Johnny's Selected Seeds Mellinger's Peaceful Valley
Irrigation supplies (drip and soaker systems)	A M Leonard Gardener's Supply Mellinger's Natural Gardening Company Territorial Seed
Mulch, paper and plastic	The Cook's Garden Gardener's Supply Johnny's Selected Seeds Pinetree
Pruners, hand tools	A M Leonard
Shade cloth	A M Leonard Peaceful Valley Territorial Seed
Trellises, bean towers	Plants of the Southwest Gardener's Supply Mellinger's
Wall-o-water hot caps	Henry Field's

For addresses of suppliers please refer to Appendix D

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CHAPTER 3

HARVESTING AND PREPARATION FOR MARKET

Now that you have successfully produced a high quality crop, it's time to harvest the fresh produce and prepare it for market The goals of a harvesting system are 1) to gather the commodity from the field at the proper stage of maturity (which will vary depending upon the commodity, the distance from market and its intended use), 2) with a minimum amount of damage and losses, 3) at the rate required for optimum handling (sorting, postharvest treatments, packing, cooling, transport, marketing operations, etc) 4) in a cost-effective way

Small-scale producers can gain an edge over large-scale operations using mechanical harvesting since you, as a small grower, can **harvest earlier**, when vegetables are more delicate **harvest later**, when fruits are at a riper, more flavorful stage, **or harvest more often** (taking advantage of multiple harvests to gather produce at its optimum stage of maturity) All these options can lead to higher profits due to the higher value of the produce you have to offer for sale

One of the most common mistakes growers make is to harvest fruit crops too early, when they are underripe and have not yet developed their full flavor Farm advisors in California warn that many of the organic apples grown for fresh market are harvested immature, when they are of inferior eating quality, and therefore have been poorly accepted by consumers With many horticultural

PROPER MATURITY AT HARVEST IS ONE OF THE KEYS TO HIGH QUALITY!

crops, if you harvest all at once you are sure to have many items that are either undermature or overmature

You can extend the harvesting season by selecting cultivars that are of high quality when picked small and when large, and sell those vegetables and herbs that are removed when thinning during the growing season Perhaps there is a speciality market for highly valued "baby vegetables" such as tiny beets, carrots, collards, turnips, head and leaf lettuces, onion and garlic greens, summer squash, green tomatoes, new potatoes and baby corn Others crops such as leaf lettuce, spinach, collards, chives and swiss chard can be picked and marketed multiple times over the growing season Crops such as Lady's Fingers (okra), green beans, cucumbers and indeterminate tomatoes should be harvested continuously, since if the older fruit is allowed to mature and remain on the plant, yield is dramatically reduced Once harvesting starts, cucumbers in India are generally picked at 2 to 4 day intervals, depending on the weather Lady's fingers (okra) is picked every 2nd or 3rd day, the best time for harvest being 6 to 7 days after the opening of the flowers (Choudhury, 1998) Small scale growers can take advantage of the fact that side shoots of broccoli and cabbages will develop new smaller heads once the central head has been removed, providing another crop about one month later

Mechanical damage during harvest can become a serious problem, as injuries predispose produce to decay, increased water loss and increased respiratory and ethylene production rates which all will lead to quick deterioration Bruising, cuts and other mechanical damage will increase the ripening rate of climacteric fruits such as tomatoes, apples stone fruits and bananas and shorten the marketing period considerably Potatoes and other underground crops can be easily damaged by careless digging and are often pierced or sliced by tools used while turning the soil to expose the produce Training field workers in proper harvesting and handling methods will greatly reduce postharvest problems caused by damage during harvest

Directly following harvest, when produce is prepared for marketing, cooling is essential Harvested produce should always be protected from the sun, and kept in the shade if there is any delay between harvest and preparation for market Avoid exposure to the sun as much as possible

after harvest, as produce left out in the sun will gain heat and may become sun-burned Harvested produce left in direct sun for only one hour will be 13 to 16 ° C (25° to 30° F) hotter than the same produce kept in the shade Field bins should be placed where they will be shaded by trees or temporary shade, or loosely covered (for example with light colored canvas, leafy plant materials, clean straw or an inverted empty container) if delays are expected in removing them from the field Removing field heat (also known as "pre-cooling") directly after harvest, should be done before any further handling Any delays in cooling will shorten postharvest life and reduce quality Produce left at ambient temperatures can lose water at a rate of up to 100 times faster than produce that is cooled immediately to its optimum temperature Even produce undergoing repeated cooling and warming will deteriorate at a slower rate than produce that has not been cooled

This chapter provides information that will assist you to identify the proper maturity stage for harvesting a wide variety of horticultural produce, and explain how to measure a variety of maturity and quality attributes (SSC, TA, firmness, etc) commonly used as maturity indices Next, some of the tools and equipment that can assist in proper harvesting and handling, the equipment recommended for field packing, and several methods for curing root, tuber and bulb crops before removing them from the field are presented and illustrated Examples of costs and benefits encountered when field packing table grapes and when curing sweetpotatoes are included to assist you in completing the Worksheets at the end of Part I

"Very high levels of wastage and value loss in India occur when all produce is harvested simultaneously with no consideration for transport distance "

Source: McKinsey & Co , Inc. 1997

GENERAL DOs AND DON'T's FOR HARVESTING HIGH QUALITY HORTICULTURAL CROPS

Always consider the needs and requirements of the market for your produce (customer preferences for size and/or stage of maturity)

Regardless of commodity or development stage of produce, all horticultural products require extreme care at harvest

Containers used for harvesting should be clean, smooth and free of rough edges, vented, and not too large Steel buckets make good harvesting containers

Use stackable plastic crates as field containers during harvest-- while initially expensive, these are durable, reusable and easily cleaned

Train manual harvesters in the proper way to harvest the crop to minimize damage and waste

Train harvesters to recognize the proper maturity stage for the produce they are handling (such as size, shape, color, sweetness or firmness)

Round the tips of knives to minimize inadvertant gouges and excess damage to perennial plants, sharpen knives and clippers

Wearing cotton gloves trimming fingernails, and removing jewelry such as rings and bracelets can help reduce mechanical damage during harvest

Train pickers to empty their picking bags and/or baskets with care, never dumping or throwing produce into field containers

Keep produce clean and free from soil contamination to reduce food safety hazards

Always provide shade for harvested produce to prevent heat and sun damage

Night or early morning harvest is sometimes an option for harvesting produce when internal temperatures are relatively low, reducing the energy needed for subsequent cooling Let dew dry off first if harvesting crops susceptible to fungal diseases

Cool produce (remove field heat) as soon as possible after harvest

Grade roads between the field and the packinghouse and keep them free from large ruts, bumps and holes

Dos and Don'ts continued

Secure field boxes well during transport and, if stacked, do not overfill

Disinfect all tools and equipment that comes in contact with produce Prohibit the use of field containers for any other purpose (tools, foods, fuel, etc) than carrying produce

Consider field packing to reduce the number of times produce is handled between harvest and marketing

Cure root and tuber crops intended for storage by exposing them to moist, warm conditions that heal wounds and thicken peels

Cure bulb crops such as onions and garlic (by drying neck tissue and outer skins) before packing, storage or marketing

IMPORTANCE OF MATURITY INDICES

- Physiological maturity is the stage when a fruit is capable of further development or ripening when it is harvested
- Horticultural maturity refers to the stage of development when vegetables should be harvested to meet consumer needs

Using Maturity Indices

- Assists you to ensure sensory quality (flavor, color, aroma, texture) and nutritional quality Harvesting horticultural produce too early (when under-developed or immature) will result in poor color, flavor and under-developed nutritional characteristics

- Ensures an adequate postharvest shelf life Harvesting too late will reduce postnarvest life Over-mature produce can be too ripe and soft to withstand postharvest handling, or be too fibrous, tough or woody (have reduced eating quality)

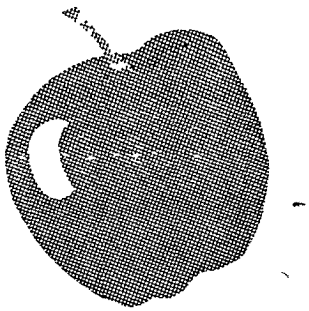
- Facilitates scheduling of harvest and packing operations Maturity indices help to predict beginning dates of harvest and the related equipment, materials facilities and labor needs

- Facilitates marketing over the phone Objective maturity standards can enhance communication about quality between wholesale buyers and sellers This is important when selling to distant buyers, and allows buyers to have a clear idea of the quality they are purchasing without having to do a visual inspection of produce

- Improves productivity on the farm Being able to predict maturity and harvest dates can influence overall productivity You may need to schedule multiple harvest to increase yields of produce at optimal maturity and highest value

Which fruits will continue to ripen after harvest?

Ripening is the process by which fruits attain their desirable flavor color and textural properties **Climacteric fruits can ripen off the plant** once they have reached physiological maturity



Climacteric fruits include apples avocado, banana blueberries, breadfruit, cherimoya, durian, feijoa, fig, guava kiwifruit, mango, muskmelon, papaya, passion fruit, pears, persimmon, plantain, quince, sapodilla, sapote, soursop, stone fruits (apricots, nectarines, peaches, plums) and tomato Some of these these fruits if harvested "mature-green" can be ripened after harvest and short term storage (for more information on postharvest ripening technologies see Chapter 17 on Destination Handling) Pears are unusual in that they develop the best flavor and texture characteristics when harvested mature-green and ripened off the tree

Some climacteric fruits give off high quantities of ethylene during ripening These include apples, apricots, avocadoes, cantaloupe, kiwifruit, nectarines, peaches, pears, plums and passion fruit A small dose of ethylene gas will stimulate other climacteric fruits to begin the ripening process A few climacteric fruits, such as muskmelons, will not increase in sugar content during ripening, but will soften

Non-climacteric fruits must ripen on the plant if you want a fully mature fruit, since once they have been harvested, no further ripening will occur Flavor and texture will be of low quality if fruits are picked before fully ripe

Some **non-climacteric** fruits include berries cherries, citrus fruits (lemons, limes oranges grapefruits mandarins tangerines), cucumber dates, brinjal (eggplant), grapes, lychee lady's fingers (okra) peas, peppers pineapple, pomegranates strawberry summer squash tamarillo and watermelon

Non-climacteric fruits will not respond to attempts to ripen them with ethylene gas A partially red strawberry for example will not develop any more color or sweetness after being picked, and will deteriorate faster if exposed to ethylene Watermelons develop most of their sweetness during the week before they reach full maturity, making early harvest very undesireable

Maturity Indices

Harvesting crops at the proper maturity allows handlers to begin their work with the best possible quality produce Fruits harvested too early may lack flavor and may not ripen properly, while produce harvested too late may be fibrous or overripe Pickers can be trained in methods of identifying produce that is ready to be harvested for your various markets For example, tomatoes for local immediate marketing can be harvested red ripe, while those for distant markets should be harvested earlier (pink stage) so they are red ripe by the time they reach the destination market

Many fruits are harvested when sugar content or sugar/acid ratio indicates ripening has begun, with minimum standards set for each cultivar Vegetables are harvested over a wide range of physiological stages, depending upon which part of the plant is used as food High quality flavor and texture is often correlated with smaller, immature sized vegetables The following table provides recommended maturity indices for harvesting high quality produce for selected commodities (sources US Standards for grades, CA Food and Agricultural Code and UC Postharvest Outreach Program publications)

WHEN TO HARVEST

When to harvest?	Maturity indices or characteristics
Almonds	splitting of hull separation of hull from shell development of abscission zone
Apples	
'Gala'	ground color change from green to light green or white
Fuji	ground color change to light green or white 180-90 days from full bloom
Golden Delicious'	12% SSC 18 lb firmness
Granny Smith	average starch score of at least 2 5 on the 6 point CA apple starch scale
Red Delicious	11% SSC 18 lb firmness
'Rome'	12 5% SSC 21 lb firmness
Artichoke	immature compact closed buds (smaller buds are often more tender)

When to harvest?	Maturity indices or characteristics
Asian pears	skin color change from green to yellowish green 180 days from full bloom
Asparagus	cut when spears are 9' (23 cm) long width is not a maturity indicator
Avocado	will not ripen on the tree minimum dry weight (17 to 20 5 % dry weight standard set for each cultivar)
Banana	disappearance of angularity in a cross section of the finger
Basil	before night temperatures drop to below 50 °F (10 °C)
Beans (green)	pods are filled but not bulging seeds are immature
Beans (haricot vert)	very thin over-mature if they snap when bent
Beets	adequate size highest quality beets are less than 2" (5 cm)
Blueberries	10 to 15% SSC and pH 3 43 to 3 73
Broccoli	adequate diameter, compact all florets should be closed
Brussels sprouts	buds that are 2 5 to 5 cm (1" to 2") in diameter
Cabbage	firm head
Cantaloupe	3/4 to full slip (abscission from vine) under slight pressure
Carrots	immature when roots have reached adequate size, have uniform taper
Cauliflower	mature curds at least 6" in diameter compact
Celery	90 to 120 days after transplanting
Chard (swiss)	adequate size of large outer leaves (cut and come again)
Cherry (sweet)	minimum SSC 14-15% (dep on cv) ssc 16% for highest quality minimum light red color for most cvs red mahogany stage recommended for Brooks' 'Garnet' 'Ruby Tulare' 'King
Corn (sweet)	silks dried kernels immature milky" when squeezed tight green husk
Cucumber/gherkin	immature glossy skin 55 to 60 days from flowering before seeds fully mature
Cucumber (lemon)	color change of fruit to yellow or orange
Endive/escarole	after 2 to 3 weeks of blanching discard outer leaves

When to harvest?	Maturity indices or characteristics
Eggplant (Brinjal)	immature glossy skin 40 days from flowering before seeds fully mature
Garlic	well-filled bulbs tops dry down undercut bulbs and cure
Ginger	8 to 9 months after planting for maximum yield minimum of 4 5 months
Grapes (table)	minimum SSC % of 14 to 17 5 depending on cultivar SSC/TA of 20 or higher
Guava	about 5 months after flowering color changes to yellowing green
Jicama	large roots require up to 8 months can harvest anytime after 3 months
Kiwifruit	minimum 6 5% SSC minimum firmness 14 lbf (8mm tip)
Leeks	diameter from 3/4" to 2 " (5 cm)
Lemon	30 % or more juice by volume
Lettuce (bibb romaine)	adequate size 60 to 70 days
Lettuce (head)	compact head not too firm
Lettuce (leaf)	adequate size leaves 50 to 60 days
Lychee/litchi	total SS total acid ratio of 30-40 bright red in color
Mandarines	minimum 8% SSC about 9 months after flowering
Mango	changes in shape (increased fullness of cheeks or bulge of shoulder) flesh color to yellowish-orange
Melon (honeydew)	ground color change to white with greenish tint slightly waxy peel
Mushrooms (button)	caps well rounded partial veil completely intact
Okra (Lady s fingers)	4 to 7 days after flower has opened (pods 2 to 4 long) not fibrous tips of pods pliable
Olives (green)	pale even green color exudes a white juice when squeezed
Olives (black)	dark color 3 to 4 months after green stage
Onion (green)	minimum 6 tall
Onion (dry bulbs)	when 10-20% of tops fall over (withhold irrigation undercut and cure)

When to harvest?	Maturity indices or characteristics
Oranges	SSC/TA ratio of 8 or higher and orange color (refer to Munsell color chart)
Papaya	skin shows yellowing
Peaches	ground color change from green to yellow (varies by cultivar)
Pears	harvest mature-green less than 60% starch, minimum firmness (standards set by cultivar) 'Bartlett' 20 lbf max min SSC 10% 'Anjou' and 'Bosc' optimum 13 lbf 'Comice' optimum 11 lbf
Peas (edible pod)	5 to 7 days after flowering pods slim, immature and very small
Peas (green)	pods well filled but not faded in color
Peppers	fruit size and color (depends on cultivar and intended market)
Persimmons	'Hachiya' blossom end is orange or reddish color for other cultivars change to a yellowish -green color
Pineapple	minimum 12% SSC max acidity of 1% change of shell color to yellow at base
Pistachios	splitting of hull separation of hull from shell development of abscission zone
Plums	skin color changes (varies minimum color described by CA standards for 56 cultivars)
Pomegranate	minimum 1 85 % TA and red juice color
Potatoes	harvest before vines die completely cure to heal surface wounds
Radish (spring)	20 to 30 days after planting
Radish (winter)	45 to 70 days after planting
Shallots	when tops dry down
Spinach	adequate size (35-45 days after planting) young or mid-maturity or cut outer leaves and come again in 3-4 weeks
Squash (summer)	immature glossy skin 45- 60 days from flowering before seeds mature
Squash (winter)	rind hard before hard frost
Starfruit (carambola)	fully yellow for best quality, 3/4 yellow for long distance marketing

When to harvest?	Maturity indices or characteristics
Strawberries	CA minimum stds 2/3 of berry surface showing pink or red color
Sweetpotatoes	adequate size of roots before first frost
Tomatoes	seeds fully developed gel formation advanced in at least one locule (seeds not cut when fruit is sliced) minimum MG2 maturity stage refer to color/ripeness charts (page 3 12)
Turnips	adequate size before weather warms
Walnuts	ease of removal of hull packing tissue browning
Watermelon	ground spot change from white to creamy yellow arils around seed have been absorbed flesh color is >75% red 10% SSC in flesh near center

MEASURING MATURITY AND QUALITY

Since maturity of horticultural crops is closely correlated with quality, it is important to measure changes associated with maturity to determine when the best time will be to harvest The results of many of the detailed chemical tests described below can instead be obtained very simply by visually inspecting the internal structures and color of the produce, and by tasting the produce for yourself and judging its crispness, firmness, sweetness and/or tartness

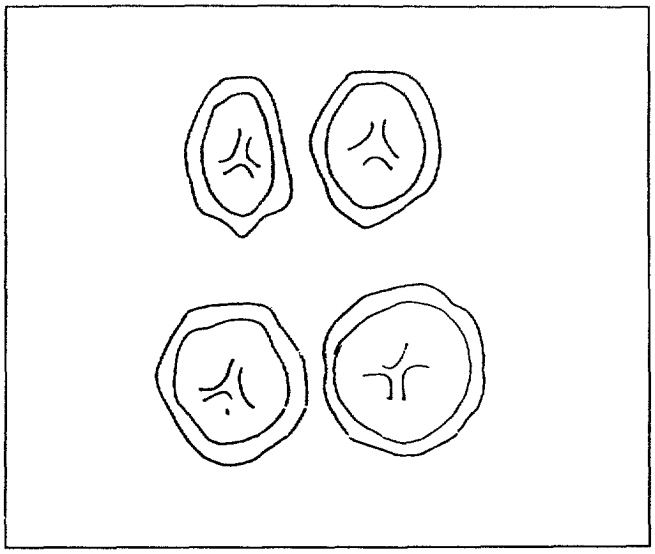
The quality attributes that you measure will be different for different types of crops, and what to look for will depend upon the standardized maturity indices described for each crop on the previous pages Always start with a representative random sample and make measurements on several units to compensate for variability Sources for tools and equipment used for quality/maturity determination are included for your use

Size and shape

Size and shape charts and sizing rings are available for many commodities Size is a useful index for most fruits and vegetables, and shape is useful for determining maturity of bananas (angularity) and mangoes (fullness of cheeks and roundness of shoulder)

If you do not have access to suppliers or do not want to spend the money to buy pre-made charts you can make them by using photos or hand drawings of the commodity These charts can be carried and used by harvesters to visually compare produce still on the plant to a known standard

Size charts, calipers and rings can be easily used to compare produce to pre-determined maturity standards before it is harvested Sizing rings with holes for specific sized produce can be easily fashioned from a thin piece of wood or sturdy plastic



Color

Color charts or guides are available for many commodities Harvesters can compare the produce in the field with a known standard, and select only those units that are ready for harvest Color charts are used for determining the maturity of stone fruits, bananas and tomatoes You can make color charts using photographs or provide each harvester with a sample unit of produce of the proper color to use as a comparison while harvesting

TOMATO MATURITY AND RIPENESS CLASSES (FOR RED VARIETIES)

Mature green 1	Seeds are cut when slicing fruit with a sharp knife no jellylike material in locules
Mature green 2	Seeds not cut when fruit is sliced jelly in at least one locule minimum harvest stage
Mature green 3	Jellylike material well developed but still completely green
Mature green 4	Internal red coloration at blossom end but no external color change
Breaker	First external pink or yellow color at the blossom end
Turning	10 to 30% of surface shows color change from green to yellowish pink or red
Pink	30 to 60% of the surface is colored
Light red	More than 60% is pinkish red but less than 90% of the surface is red
Red	More than 90% of the surface shows red color

"Vine-ripened" tomatoes are usually harvested at the breaker or turning stage, but flavor is enhanced if ripening is allowed to continue on the plant Since most tomatoes for the wholesale market are harvested mature-green and held in storage for a few weeks before they are marketed to consumers, it is understandable why "store-bought" tomatoes have a reputation for less than delightful flavor If you are harvesting for local specialty or direct markets, you may receive a higher price if you are willing to harvest light red or full red fruit, and carefully pack and handle fully ripened tomatoes Tomatoes grown for processing should be harvested when fully red

SSC (soluble solids content)

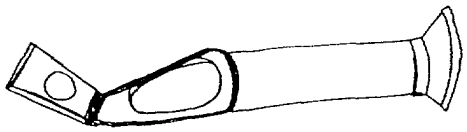
Sugars are the major soluble solid in fruit juices and therefore soluble solids can be used as an estimate of sweetness A hand-held refractometer can be used outdoors to measure % SSC (in equivalent degrees Brix) in a small sample of fruit juice Temperature will affect the reading (increasing about 0 5% SSC for every 5 °C or 10 °F), so you should adjust the measurement for the ambient temperature

A garlic press works well to squeeze the juice from fruit samples For small fruits, use the whole fruit, while for large fruits, take a wedge for the stem end to the blossom end and to the center of the fruit Remove any pulp by filtering the juice through a small piece of cheesecloth You must clean and standardize the refractometer between each reading with distilled water (should read 0% SSC at 20 °C or 68 °F)

On the next page are some examples of minimum % SSC for selected commodities If your reading indicates a higher % SSC, then your produce is better than the minimum standard Strawberries which are of excellent flavor, for instance would measure 10% SSC

Good mango varieties contain over 20% of total soluble solids (sugars)

Source Singh 1998



MINIMUM %SSC for HIGH QUALITY

apricot	10 %
cherry	14-16
grape	14- 17 5
kiwifruit	6 5
muskmelon	10
nectarine	10
peach	10
pear	13
plum	12
pomegranate	17
strawberry	7

Firmness

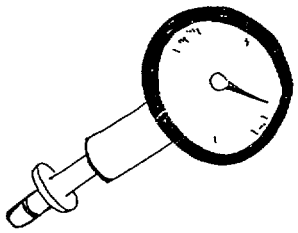
The degree of softness or crispiness can be estimated by squeezing produce, or by taking a bite Objective measurements can be made with inexpensive penetrometers The most common way to measure firmness is resistance to compression or pounds-force (lbf) The Effe-gi fruit penetrometer is a hand-held probe with a gauge for pounds-force

To measure firmness, use fruit that are uniform in temperature, since warm fruit are usually softer than cold fruit Use fruits that are uniform in size, since large fruit are usually softer than smaller fruit Make two puncture tests per fruit on larger fruits once on opposite cheeks, midway between stem and blossom ends Remove a disc of skin (larger than the tip to be used) and choose the appropriate plunger tip (see below) Hold the fruit against a stationary, hard surface, and force the tip into to fruit at a uniform speed (take 2 seconds) to the scribed line on the tip Take the reading to the nearest 0 5 lb-force

Appropriate Effi-gi plunger tip sizes to use when measuring firmness in selected fruits

1 5mm (1/16 inch)	Olive
3 mm (1/8 inch)	Cherry, grape, strawberry
8 mm (5/16 inch)	Apricot, avocado, kiwifruit, mango, nectarine, papaya, peach
11 mm (7/16 inch)	Apple

Calibrate firmness testers by holding the tester vertically and placing the tip on the pan of a scale Press down until the scale registers a given weight then read the firmness tester Repeat 3 to 5 times, if you find the instrument reads the same as the scale it is ready to use You can adjust the penetrometers by inserting washers in the appropriate locations (follow the instructions that come with the instrument)



Titratable acidity (% TA)

The level of acidity in produce affects flavor (tartness or sourness) Most people may vaguely remember learning how to measure acidity in chemistry class, but probably never thought you'd ever have to use it during your daily life Luckily the process is straightforward and the formula is simple Titratable acidity can be determined by titrating a known volume of fruit juice with 0 1 N NaOH (sodium hydroxide) to an end point of pH=8 2

In practice, NaOH solution is added to the fruit juice until the pH changes to 8 2 as indicated by phenolphthalein or by using a pH meter Use 1 to 10 ml of juice, and add about 20 ml bottled water and a few drops of phenolphthalein (The actual amount of juice you use depends on the expected acidity, if the sample is highly acid, use less to reduce the amount of NaOH required to titrate the solution) Stir constantly while very slowly adding the NaOH solution from a calibrated container (such as a buret or small graduated cylinder marked in ml), and stop adding NaOH when the water/juice mixture turns pink and stays pink when you stir vigorously If you are using a pH meter, stop adding NaOH when the meter reaches 8 2

Plug your numbers into the formula below to calculate the % TA of the commodity

$$\% \text{ TA} = \frac{\text{ml NaOH} \times \text{N(NaOH)} \times \text{acid meq factor} \times 100}{\text{ml juice titrated}}$$

For berries, citrus fruits and pineapple, use citric acid (acid meq factor = 0 064)
For apples, pears, peaches and nectarines use malic acid (acid meq factor = 0 067)
For grapes, use tartaric acid (acid meq factor = 0 075)

Example 10 ml of 'Perlette' grape juice in 20 ml water is titrated with 8 ml 0 1N NaOH

$$\% \text{ TA} = \frac{8 \text{ ml NaOH} \times 0\ 1\text{N(NaOH)} \times 0\ 075 \times 100}{10 \text{ ml juice titrated}} = 0\ 6\ \%$$

Sugar/Acid ratio

Knowing the sugar content alone is not enough to measure maturity and quality of citrus fruits and grapes In these cases, the ratio of sugar to acid content is a much better predictor of high quality produce You need to measure both %SSC and % TA, then divide SSC by TA to calculate the ratio of the two

Examples of minimum SSC/TA ratio	
grapefruit	6 0
mandarin	8 0
orange	8 0
grape	20 0

Sources of quality/maturity measurement instruments

McCormick Fruit Tech (sizers sizing rings refractometers penetrometers pH meters)
615-B S 48th Ave
Yakima WA 98908
Phone (509) 966 3999
FAX (509) 966 7635

DeltaTrak (pH meters)
P O Box 398
Pleasanton, CA 94566
Phone (800) 962-6776
FAX (510) 856 1147

Fruit and Vegetable Quality Control CA Department of Agriculture
(color charts sizers, Granny Smith Apple Starch Scale)
1220 N Street, Room A-265
Sacramento CA 95814
Phone (916) 654-0919
FAX (916) 654 0666

International Ripening Corporation (refractometers temperature probes, calipers sizer rings pressure testers pH meters chlorine meters)
1185 Pineridge Road
Norfolk, Va 23502
Phone (800) 472 7205

Radiometer America, Inc (titrators)
811 Sharon Drive
Westlake, Ohio 44145
Phone (800) 0600, Extension 72
FAX (216) 835 8118

VWR (refractometers titrators, penetrometers)
P O Box 7900
San Francisco CA 94120
Phone (415) 330 4017
FAX (415) 330 4122

To request a catalog, contact

Fisher (unbreakable buret, buret stand and clamp glassware and magnetic stir bars and stir plates)
Phone (800) 766 7000 FAX (800) 926 1166

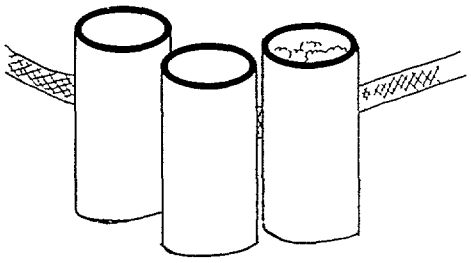
Sigma Chemical Co (0 1 N NaOH in pre-measured vials, phenolphthalein pH indicator)
Phone (800) 325 3010 FAX (800) 325 5052

Harvesting Tools and Containers

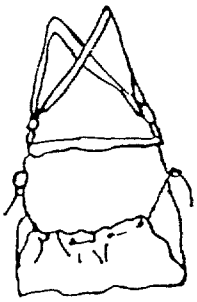
To protect produce quality and safety, keep your harvesting tools and containers clean Use a 1 part chlorine bleach 1 part clean water solution to clean tools and plastic or wooden picking containers before use each day Use containers that are smooth on the inside or provide clean disposable liners made from paper or cardboard

Picking baskets, bags and buckets come in many sizes and shapes You can reduce some of the drudgery of harvesting and minimize damage to produce by providing containers that can be easily carried and filled by workers Portable containers that can be opened on the bottom allow harvesters to gently fill larger field containers without 'dumping' produce With a bit of creativity, you can even construct picking containers that allow workers to sort while picking

Raspberry sorting cups
(worn as a belt around the waist)

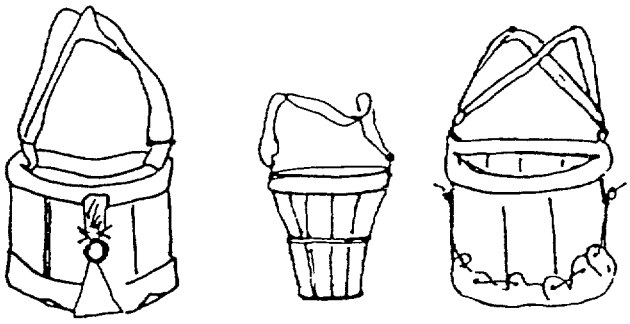


Picking bag fabric bag with openings on both ends
(worn over the shoulders with an adjustable harness)

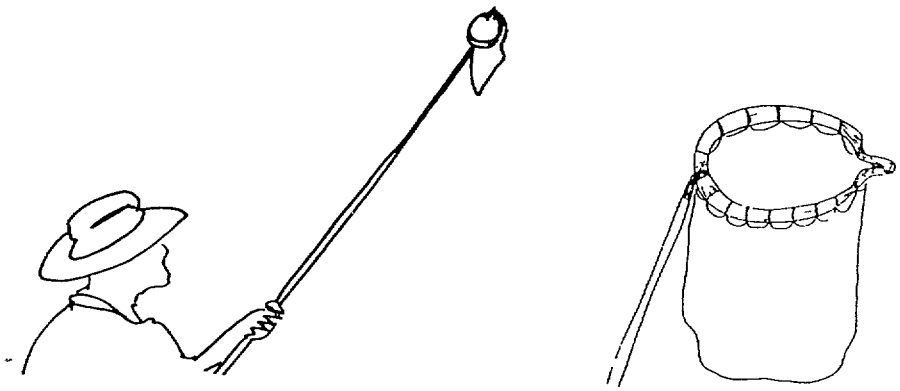


Harvesting containers can be made by fitting fabric over the opened bottom of ready-made baskets, fitting readymade canvas bags with adjustable harnesses or by simply adding some carrying straps to a small basket All of these will reduce mechanical damage to produce if used properly by harvesters and not over-loaded

Picking Bags/Baskets (Source Friend Manufacturing Co 1993)

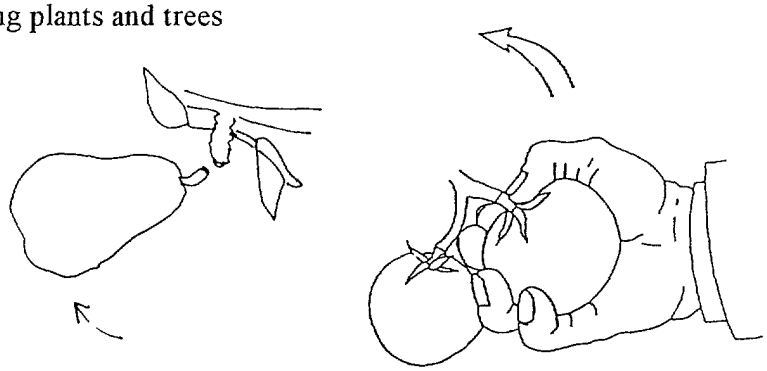


Picking poles and catching sacks can be made by hand or purchased from horticultural supply companies A long pole is attached to a collection bag, allowing the harvester to cut and catch produce growing on a tree without having to climb a ladder The collection bags can be hand woven from strong cord or sewn from canvas The hoop used as the collection bag rim and sharp cutting edges can be fashioned from sheet metal, steel tubing or recycled scrap metal

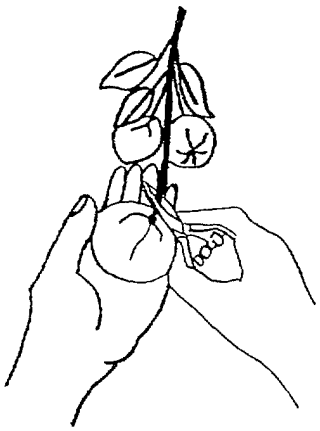


Harvesting practices should cause as little mechanical damage to produce as possible Gentle digging picking and handling will help reduce crop losses For some crops, a natural break point forms at the junction of the stem and the stalk when produce is mature Harvesters should grasp the product firmly but gently and pull upward as illustrated below Wearing cotton gloves trimming fingernails and removing jewelry such as rings and bracelets can help reduce mechanical damage during harvest

Pick carefully to avoid damaging plants and trees



Some fruits such as citrus, avocadoes and mangoes, need to be clipped or cut from the parent plant Clippers or knives should be kept well sharpened and clean Penduncles, woody stems or spurs should be trimmed as close as possible to prevent fruit from damaging neighboring fruits during transport

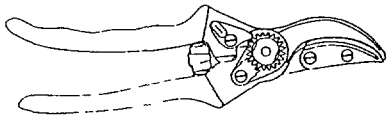


Pruning shears can be used for harvesting fruits and some vegetables A variety of styles are available as hand held or pole models including shears that cut and hold onto the stem of the cut product This feature allows the picker to harvest without a catching bag and without dropping fruits

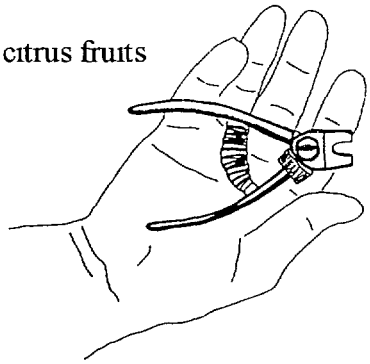
Straight bladed hand shears
for fruits and flowers

Thin curved blade for
grapes and fruits

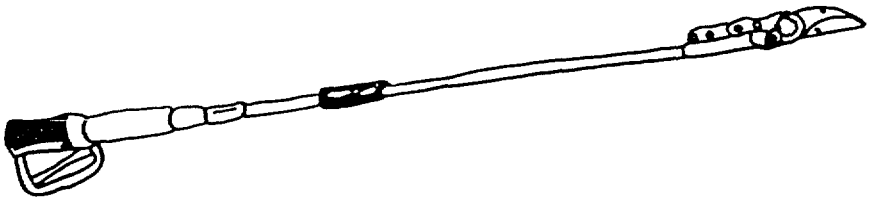
Cut and hold hand shears



Clipper for citrus fruits

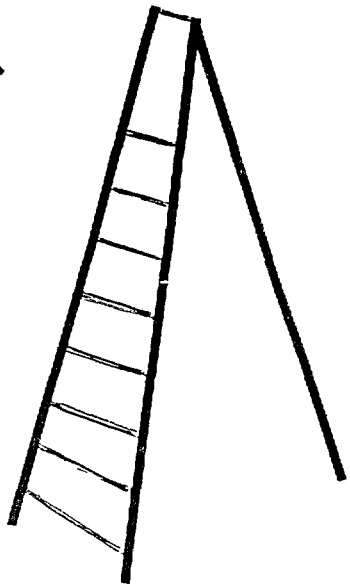


Pole mounted cut and hold picking shears



Tripod ladders

A ladder with three legs is very sturdy and more stable than a standard ladder The single pole of the front leg lets the picker get safely into the canopy of the tree to harvest fruits without damaging branches

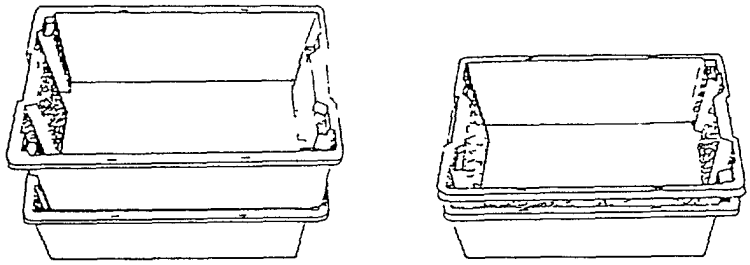


Harvesting Containers

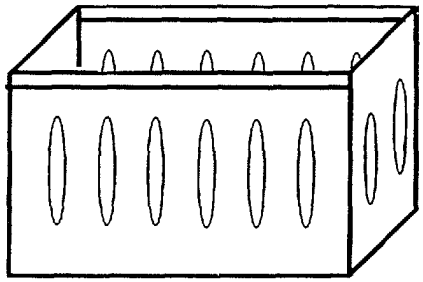
Plastic crates are relatively expensive to purchase but are very durable reusable and easy to clean They have the characteristics you really want-- stacking strength ventilation holes and long life You can use them for harvest, storage, cooling procedures transport and even for display in retail markets

If you decide to buy plastic crates, look for crates that can be nested when empty to save space in storage or transport Various brands and styles are manufactured, but all can be stacked securely if they are not over-filled

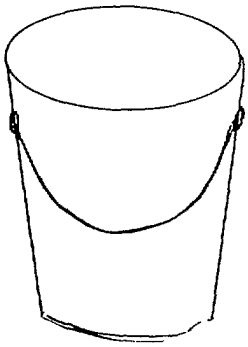
Stackable, reusable plastic crates



Plastic vented crate



Steel buckets are a good investment since they will last for many years and can easily be cleaned The inside surfaces are smooth and will not damage delicate crops if the buckets are not overloaded



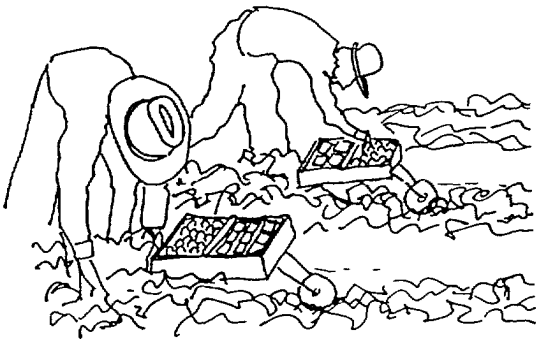
Steel bucket

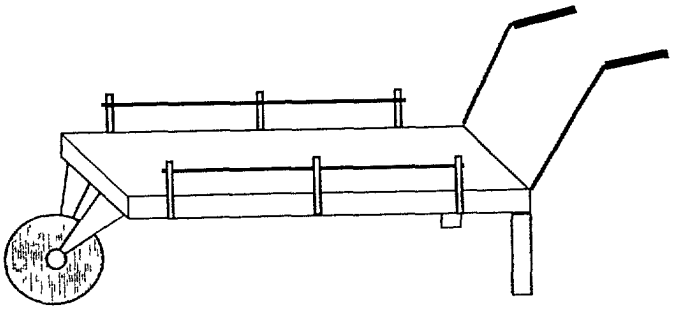
FIELD PACKING

Selection, sorting, trimming and packing the produce in the field at the time of harvest is known as "field packing", and has great potential to reduce mechanical damage by reducing the number of postharvest handling steps between the field and the consumer Any practice that reduces the number of times the produce is handled will help reduce postharvest losses Field packing often also reduces costs since you won't need to build and manage a packinghouse, and can reduce handling problems such as "shaker" problems in melons (where the seed cavity loosens from the pericarp wall), while allowing producers to market produce of the optimum quality and highest value

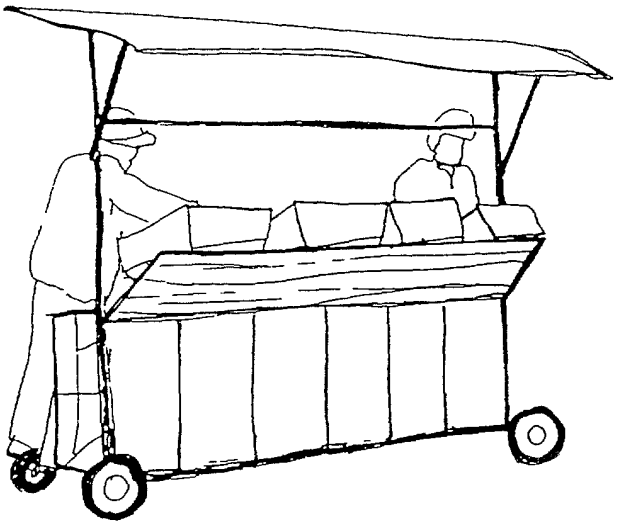
When crops are field packed the picker harvests and then immediately packs the produce after minimal handling Fruits can be harvested at a riper, more flavorful stage, and vegetables can be handled while very young and delicate Strawberries are generally field packed, since even a small amount of handling will damage these soft fruits When lettuce is field packed, several wrapper leaves are left on the head to help cushion the produce during transport

Providing workers with a small cart can help reduce the amount of bending and lifting the picker has to do during harvest The carts shown here have a single wheel in front, and can be pushed along the row ahead of the picker Filled cartons should be immediately moved into the shade and then into the cooler as soon as possible

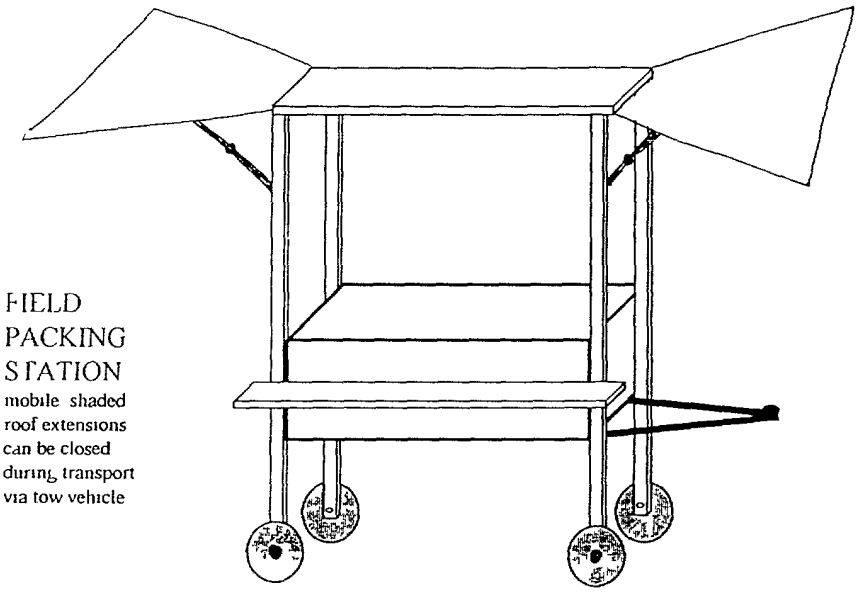




Small mobile field packing stations are designed to be moved along with the packers and to provide shade for packing operations A movable cart should provide a comfortable place for packers to fill boxes and have a wide roof to provide shade The cart illustrated here was designed to be pushed along the outer edge of the small field where a table grape harvest is taking place



Carts for field packing can also be designed to be pulled by a small tractor into the field when the crop is harvested This type of cart can be used for field packing many types of crops The roof folds down for easy transport, and opens up to provide a wide area of shade for the packers and the commodity The cart design can be modified as needed to suit various products and different operations



FIELD PACKING STATION
mobile shaded roof extensions can be closed during transport via tow vehicle

COMPARISON OF ESTIMATED COSTS AND EXPECTED BENEFITS RELATED TO TRADITIONAL PACKHOUSE OPERATIONS OR FIELD PACKING FRESH PRODUCE

Costs
Equipment (carts, mobile packing stations or wagons equipped with shade)
Trained Labor
Packages suited to field packing, cooling

Benefits
No packinghouse to maintain
Less damage to produce (no dumping, resorting)
Quick handling (less water loss)

Example 1
If 1000 lbs of table grapes are harvested and field packed by 4 trained workers (1100 lbs of grapes are picked trimmed, packed 25 lbs per carton, and SO_2 pads inserted) in 2 hours Losses are calculated to be 10% compared to the typical 20% losses associated with grading, trimming, packing and cooling grapes in a local packinghouse Workers are paid $1 00 more per hour than usually paid to field laborers who harvest crops to be transported to the packinghouse

Costs
Additional labor cost $1 00 x 4 workers x 2 hours = $8 00/day
Equipment -- shaded packing station $150 00 (used for several seasons)
Materials -- same grape lugs and pads used in packinghouse = $ 1 50 per set
Cooling -- same cost as for packinghouse

Benefits
Packinghouse power, water and ventilation costs savings = $10 /day
Postharvest losses reduced to 10% (4 additional cartons per day from the vineyard)
100 lbs x 0 50 per lb = $50

Return on investment
(for simplicity, assume 20 days of harvesting are equal to one month of sales)
Difference in costs for field packing = $150 + $8/day for 20 days = $310

Savings compared to current practice = ($10 /day - $6/day for extra packages) x 20 days =$4 x 20 = $80

Change in sales using field packing = $50/day x 20 days = $1000

Calculate ROIC in months to pay for investment
(Difference in costs - savings) / **Change in Sales** per month = Months to pay for investment

($310 - $80) / $ 1000 per month = 0 23 Months or 4 6 days

Example 2
If 1000 lbs of table grapes are harvested and field packed by 4 trained workers in India (500 kg of grapes are picked trimmed, packed into wooden crates) in 2 hours Losses are calculated to be 10% compared to the typical 20% losses associated with transport grading, trimming, packing and cooling grapes in a local packinghouse Workers are paid Rs 20 more per day than usually paid to field laborers who harvest crops to be transported to the packinghouse

Costs
Additional labor cost (4 workers x 2 hours) = Rs 20/day
Equipment -- shaded packing station Rs 2200 (used for several seasons)
Materials -- same grape lugs used in packinghouse (Rs 1/ 1 kg produce packed)
Cooling -- same cost as for packinghouse

Benefits
Packinghouse power, water and ventilation costs savings = Rs 100 /day
Postharvest losses reduced to 10% (4 additional cartons per day from the vineyard)
50 kg x Rs 30/ kg = Rs 1500

Return on investment
(for simplicity, assume 20 days of harvesting are equal to one month of sales)
Difference in costs for field packing = Rs 2200 + Rs 20/day for 20 days = Rs 2600

Savings compared to current practice = Rs 100 /day - Rs 50/day for extra packages) x 20 days =Rs 50 x 20= Rs 1000

Change in sales using field packing = Rs 1500/day x 20 days = Rs 30,000

Calculate ROIC in months to pay for investment
(Difference in costs - savings) / **Change in Sales** per month = Months to pay for investment

(Rs 2600 - Rs 1000) / Rs 30 000 per month = 0 086 Months or 1 7 days

Curing root, tuber and bulb crops

Mechanical damage can be extensive when harvesting root, tuber and bulb crops Bruises and cuts allow the produce to lose water more rapidly, while wound-induced increases in respiration will lead to increased rates of water loss decay and physiological deterioration

Fortunately much of this damage can be corrected if you are willing to take some time and create the proper conditions for these crops to "heal" before they are removed from the field Curing root and tuber crops such as sweetpotatoes, potatoes, cassava and yams is especially important practice if these crops are to be put into storage for a month or more The reduction in water loss and decay rates will more than pay for the cost of curing

> If tubers are placed immediately after harvest into cold storage at 5 C, wound healing (periderm formation) is delayed
>
> Source Choudhury, 1998

Curing practices for root and tuber crops require holding the produce at high temperature and high relative humidity for several days while harvesting wounds heal and a new, protective layer of cells form. The best conditions for curing vary among crops as shown in the following table, but in practice curing is usually done under ambient field conditions At the time indicated as the minimum, begin to check the produce for signs of proper curing (thicker, toughened peel, healed over cut surfaces) until it is ready for removal from the field for postharvest handling, storage and marketing

RECOMMENDED CURING CONDITIONS

Commodity	Temperature °C	°F	Relative Humidity (%)	Days
Potato	15-20	59-68	90-95	5-10
Sweetpotato	30-32	86-90	85-90	4- 7
Yams	32-40	90-104	90-100	1- 4
Cassava	30-40	86-104	90-95	2- 5

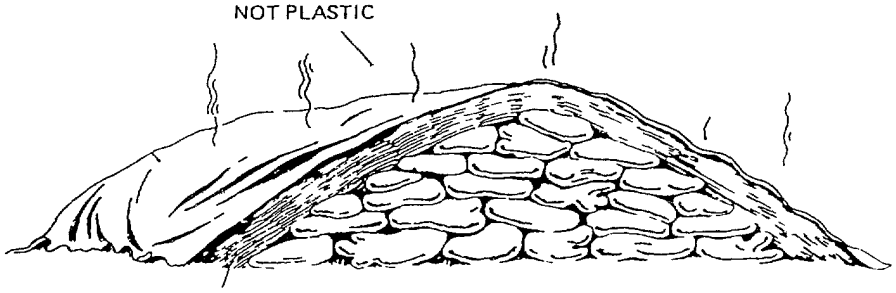
Curing onions and garlic refers to the practice of allowing the external layers of skin and neck tissue to dry out directly following harvest prior to handling and storage If forced heated air is used for curing onions and other bulbs one day or less at 35 °C (95 °F) and 60 to 75% relative

humidity is recommended The dried layers of 'skin' then protect the produce from further water loss during storage

Field Curing

Root and tuber crops

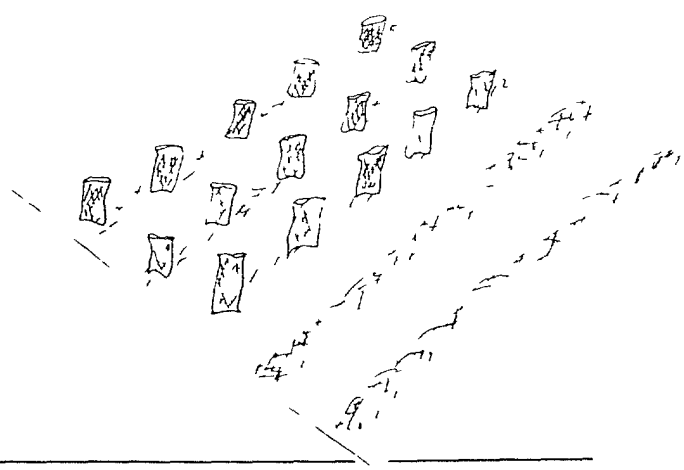
Yams and other tropical root and tuber crops can be cured outdoors if piled in a partially shaded area Cut grasses or straw can be used as insulating materials and the pile should be covered with canvas, burlap or woven grass mats Curing requires high temperature and high relative humidity and this covering will trap self-generated heat and moisture The stack should be left for about four days



At least 6 (15 cm) depth of cut grass placed on top of yams

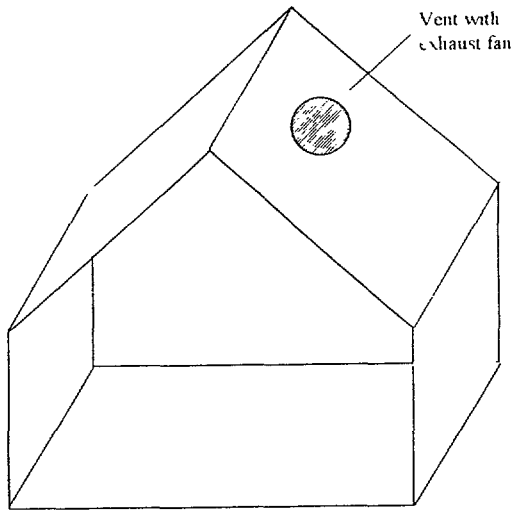
Bulb crops onions and garlic

Onions and garlic can be cured in the field in regions where harvest coincides with the dry season If local weather conditions are dry and warm, these crops can be undercut in the field and left there to dry for five to ten days The crops can be cured either in windrows or after packing into large fiber or net sacks The dried tops of the plants or a light covering of dry straw can be arranged to cover and shade the bulbs during the curing process, protecting the produce from excess heat and sunburn The produce can be left in the field for five days, then checked daily until the outer skin and neck tissues are properly dried Curing may take up to ten days, depending on weather conditions The best scale color is obtained when onions are cured at 25 to 32 °C (77 to 90 °F)



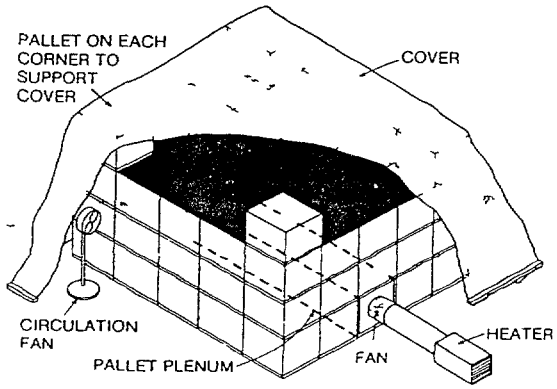
Curing assisted by shade and ventilation

The curing of bulb crops can be assisted by the use of ventilated sheds in regions where solar radiation and/or relative humidity is high or natural air movement is low Produce in sacks should be stacked in the shade on canvas tarpaulins under one or more ceiling fans



Emergency Curing

If conditions such as rain or flooded fields do not permit field curing and curing facilities are not available, a temporary tent can be used for curing onions In the example illustrated below, the tent is constructed from large tarps Heated air is forced into a hollow area (known as a plenum) at the center of the bins of produce Several fans are used to circulate the warm air through the onions while they are curing



COSTS AND BENEFITS OF CURING ROOT TUBER AND BULB CROPS

Example 1 Curing sweetpotatoes in California

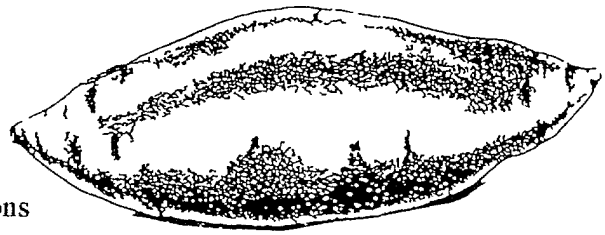
Costs
Heaters-- $175 00 used over many seasons
Fans-- $150 00 used for many seasons
Fuel-- $6 00 per 1000 lb lot
Labor-- 1/2 hour at $7 00/hour to load produce into the curing room, set up and monitor the curing process
Total recurring costs = $6 + $3 50 = $9 50

Benefits
Reduced water loss (about 2% per month compared to uncured loss of 3% per month)
Reduced losses due to decay (20% after 4 months compared to 60% for uncured)
Longer storage life (4 to 6 months)

1000 lbs of sweetpotatoes are cured for 5 days at 85 F and 90% RH at a cost of $9 50 ($0 01 per lb) Market value is $15 00 per 40 lb carton

Produce available for marketing after 4 months in storage 20 cartons = $300
(compared to 9 cartons for uncured = $135)
Profit = ($300-135) -$9 50 = $155 50

Return on investment
Capital costs for the heaters and fans = $325
The first three loads of sweetpotatoes cured will pay for the fans and heaters, and each additional 1000 lb load that is cured before storage will result in an additional profit of $155 50 compared to uncured sweetpotatoes



Example 2 Curing sweetpotatoes in India

Costs
Heaters and fans-- Rs 9000 used over many seasons
Fuel-- Rs 1000 per 1000 kg lot
Labor-- 1/2 hour to load produce into the curing room, set up and monitor the curing process (very low labor costs)
Total recurring costs = Rs 1000

Benefits
Reduced water loss (about 2% per month compared to uncured loss of 3% per month)
Reduced losses due to decay (20% after 4 months compared to 60% for uncured)
Longer storage life (4 to 6 months)

1000 lbs of sweetpotatoes are cured for 5 days at 30 C and 90% RH at a cost of Rs 1000 (Rs 1 per kg) and placed into storage for 4 months

	Cured	Uncured
cost of curing	Rs 1000	
Postharvest losses	20% (200 kg)	60% (600 kg)
produce available for marketing	800 kg	400 kg
market value	Rs 6/kg	Rs 5/kg
potential sales	Rs 4800	Rs 2000

Return on investment
The first three loads of sweetpotatoes cured will pay for the fans and heaters, and each additional 1000 kg load that is cured before storage will result in an additional profit of Rs 2800 compared to uncured sweetpotatoes

SOURCES OF TOOLS, EQUIPMENT AND SUPPLIES FOR HARVESTING AND PREPARATION FOR MARKET

baskets/buckets/crates/barrels	Adelman-Fisher Packaging Bradbury Barrel Company Texas Basket Company
buckets/bucket straps	Duluth Trading Company
bucket liners/ bucket skirts	Rod Smith Canvas Co
fruit pickers (long poles with basket)	Burpee's
gloves	Pacific 4/Ranch Brand Supply Co
harnesses	Orchard Equipment and Supply Co Rod Smith Canvas Co
harvesting aids for field packing	Ramsay Welding and Machine Inc
harvesting equipment/potatoes	Thomas E Moore Inc
harvesting tools	Farber Bag & Supply Co Orchard Equipment and Supply Co
ladders	Orchard Equipment and Supply Co

	Stokes Ladders Inc Pacific 4/Ranch Brand Supply Co
nut harvesters shakers	N H Savage Equipment Inc
picking containers	Buckhorn Friend Manufacturing Corp Glacier Valley Enterprises Hydro-Gardens Inc Orchard Equipment and Supply Co Rod Smith Canvas Co
potato separator/cleaner	Sorting Technology Inc
reusable plastic containers	Buckhorn
safety supplies	Pacific 4/Ranch Brand Supply Co
shade cloth	local hardware and garden supply stores
U-pick containers	Rockford Package Supply Inc

For Addresses/Phones of suppliers please refer to Appendix D

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CHAPTER 4

PACKINGHOUSE OPERATIONS AND PACKING PRACTICES

Packinghouse operations can be as simple as moving produce from a field lug directly into a shipping container, or may include a variety of postharvest handling practices, from cleaning, waxing, sizing, and quality grading to color sorting or hot water dips It is important to minimize mechanical damage by avoiding drops, rough handling and bruising during the steps of packinghouse operations Recent studies have shown that average levels of postharvest cherry damage in California packinghouses is extremely high About 28% of the fruits were bruised between harvesting and arriving at the packinghouse, and another 23% were damaged during mechanical sorting and packing Hand-sorting by trained workers greatly reduces the rate of damage

Make sure your packing operations take place in a shaded area if you don't have a permanent roofed structure Shade can be created using whatever materials are locally available, such as shadecloth woven mats, plastic tarps or a canvas sheet hung from temporary poles Shade alone can reduce air temperatures surrounding the produce by 8 to 17 °C (15 to 30 °F)

This chapter describes the postharvest handling steps that typically take place in a packinghouse, and provides examples of practices and simple equipment that will help you to sort handle and protect produce quality and food safety during market preparation and packing For those who

would like to reduce the amount of handling steps involved in packing, 'ranch packing' methods can be adopted for most produce Completing the worksheets at the end of Part I will assist you in determining whether these practices and postharvest technologies can be economically beneficial for you operation

GENERAL DOs AND DON'Ts FOR PACKING HIGH QUALITY FRESH PRODUCE

Provide shade for harvested produce waiting to be sorted and packed

Grade the roads and entryways between the field and the packing facility

Avoid locating the packhouse directly next to an unpaved, dusty road

Minimize mechanical damage--avoid drops, throwing and rough handling

Use hand-carts to assist workers in the careful movement of produce

Pre-sort to remove damaged, diseased, immature or overmature produce

Keep the packing line as simple as possible and keep it clean

Provide sanitary facilities (bathrooms and hand washing stations) for workers

Hand sorting can reduce damage if workers are well-trained and provided with appropriate tools and equipment

Know the requirements and postharvest handling recommendations for the crops you handle

Consider the use of a water dump system for handling water-tolerant produce

Do NOT wash green beans, cabbage, okra, peas, peppers or summer squash before packing

Do's and Don'ts continued

Monitor chlorine levels in wash water to ensure adequate levels (100 to 150 ppm)

Provide cushioning on all sharp edges and rough surfaces of packing tables or the washing/sorting/grading/packing line Clean the tables regularly

Provide good lighting so that workers can see properly to sort and grade produce

When trimming produce, do NOT remove more than necessary for high quality Dispose of waste materials properly

Use appropriate postharvest treatments (waxing, hot water dips, SO_2, fungicides, etc) to reduce the rate of decay or water loss

Do NOT use any chemical treatments that are not specifically recommended for your commodity

Pack securely to immobilize produce, but do not overfill or underfill packages

Use "ranch packing" practices whenever possible to reduce handling damage

Hand packing allows you to handle delicate vegetables and ready to eat, ripe fruits for specialty markets

Cool the produce as soon as possible after harvesting

The Indian Standards Institution has specified four grades for tomatoes

Super A
Super
Fancy
Commercial

THE PACKINGHOUSE

When deciding upon where to locate a packinghouse consider ease of access to both the field and the market point You will need to provide adequate space for transport vehicles or people carrying produce to enter and leave the packinghouse and consider factors such as the ease of access for laborers and where best to provide parking space for their private vehicles The size of the packinghouse, volume of produce and the number of employees you have will determine the number of docks, packing stations, restrooms, and other facilities you will need

In the simplest packinghouse, produce is delivered in picking containers immediately after harvest, directly to the packers The packers then sort, grade, size and pack the produce directly into appropriate containers In this case, each worker must be knowledgeable regarding produce defects, grade and size requirements, and packing methods If you are packing delicate produce such as tree-ripened fruits and do not want to field pack, this simple 'ranch packing' method is the next best choice, since handling is minimized and high quality, ripe fruits can be packed safely as long as they are handled gently As the size and complexity of the packinghouse increases, more operations and workers trained in specific tasks might be added

Any of the following postharvest handling steps may help you to protect the value the produce you produce and market

PRE-SORTING
WASHING/CLEANING
TRIMMING/TOPPING
WAXING
SIZING/GRADING
BUNCHING/WRAPPING
POSTHARVEST TREATMENTS
PACKING
COOLING

DUMPING

Unless produce is field packed, it must somehow be removed from the field bin or harvesting container and packed into a shipping container The first step of handling is known as "dumping" the produce from the field container Dumping must always be done gently, whether you are using water assisted methods or dry dumping

Wet dumping can decrease bruising and abrasions by using moving, chlorinated (100-150 ppm) water to receive produce You can dump produce into a water-filled basin or immerse the whole container to float produce out of the field bin and carry delicate produce toward the graders and packers Wet dumping can reduce mechanical damage, since water is more gentle on produce than a hard surface of a sorting table or a conveyor belt If the specific density of the produce, such as apples, is lower than that of water, the produce will float naturally For some produce, such as pears, salts (such as sodium lignin sulfonate, sodium silicate or sodium sulfate) must be added to the water to increase its specific density and make the fruits float

When using dry dumping, having padded, sloped ramps or moving conveyor belts will decrease injuries to produce The field container should be emptied slowly and gently onto a tilted ramp with padded edges

PRE-SORTING

Pre-sorting produce is usually done to eliminate injured, decayed, or otherwise defective produce before cooling or additional handling These un-marketable units are sometimes called "culls" Pre-sorting will save energy and money because culls will not be handled, cooled, packed or transported Removing decaying produce items is especially important, since this will limit the spread of infection to other units during handling When packing organically grown produce, pre-sorting is especially critical since pre-harvest chemical controls and postharvest pesticides are not being used during packing and storage

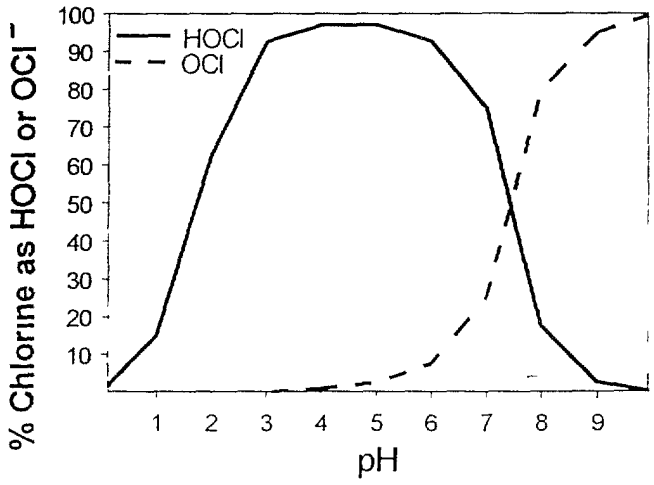
CLEANING/WASHING

For some commodities, such as kiwifruits and avocadoes, dry brushing may be sufficient to clean the produce Other commodities, however, such as bananas and carrots, require washing The choice of brushing and/or washing will depend upon both the type of commodity and the type of

contamination Certain produce should not be washed because washing will remove the natural waxes that protect produce from water loss and disease

Wash before cooling and packing tomatoes cucumbers leafy greens
Wash to remove latex reduce staining mangoes bananas
Wash after storage sweetpotatoes potatoes carrots
Dry brush after curing or storage onions garlic kiwifruit
Do Not Wash green beans melons cabbage okra peas peppers summer squash

Sanitation is essential both to control the spread of disease from one item to another, and to limit spore buildup in wash water or in the packinghouse air Chlorine treatments (100 to 150 ppm available Cl) can be used in wash water to help control innoculum buildup during packing operations There is some variation in the strength of chlorine bleach available commercially in different countries but a rule of thumb is to use 1 to 2 mls of chlorine bleach per liter of clean water (1 to 2 ounces of chlorine bleach per 8 gallons) More chlorine will be required if temperatures are high or water contains a lot of organic matter Maintain the pH of the wash water between 6 5 and 7 5 for best results



You can use a variety of methods for washing produce, but a constant flow of clean water is essential This tank for washing produce is made from galvanized sheet metal A baffle made of perforated sheet metal is positioned near the drain pipe and helps to circulate water through the produce Fresh water is added under pressure through a perforated pipe, which helps move

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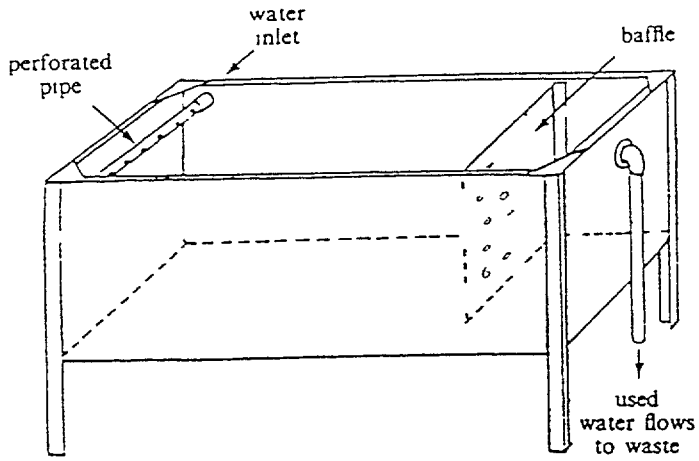
floating produce toward the drain end of the tank for removal after cleaning Improvements to the design might include a removable trash screen in front of the baffle, and/or a recirculating system for the wash water (with the addition of chlorine)

Source FAO (1989)



TRIMMING/TOPPING

Certain crops should be trimmed or topped to remove medible plant material or excess outer leaves before packing This simple practice also helps to reduce the high rate of water loss which occurs through the leaves of root and tuber crops

REMOVE OLDER OUTER LEAVES
cauliflower head lettuce swiss chard and other leafy crops

REMOVE TOPS radishes carrots beets turnips and other root vegetables

TRIM EXCESS TISSUE (mostly for appearance or ease of packaging) long leaves from green onions (although oriental food markets prefer the entire plant) tough stems from asparagus spears

WAXING

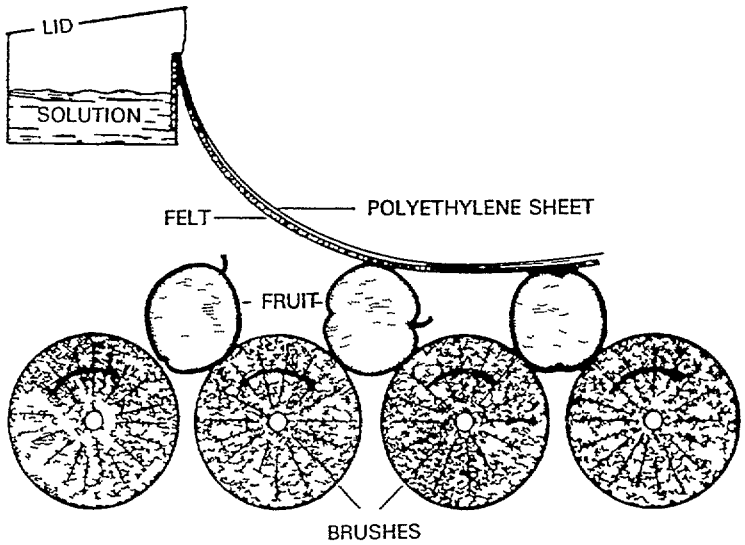
Waxing of immature fruit vegetables such as cucumbers and summer squash mature fruit vegetables such as eggplant, peppers and tomatoes and fruits such as apples and peaches is a common postharvest practice Food grade waxes are used to replace some of the natural waxes removed during harvesting and sorting operations, and can help reduce water loss during handling and marketing If produce is waxed the wax coating must be allowed to dry thoroughly before further handling

WAXING CASSAVA ROOTS
dip roots in 95 °C paraffin wax for 15 seconds, allow wax to cool and dry before further handling

Source Ravi et al (1996)

Waxing cassava roots can greatly extend their usually short postharvest life While cassava has a typical shelf life of 2 weeks at 2 to 4 °C waxing can increase shelf life to 1 to 2 months

The waxing device illustrated here was designed in Tasmania to be used after a series of dry brushes on a small-scale packinghouse conveyor line Industrial wool felt is used to distribute the liquid wax to the fruits or vegetables from a trough made the same width as the conveyor belt Evaporation of wax from the felt is reduced by covering the felt with a layer of heavy polyethylene sheeting



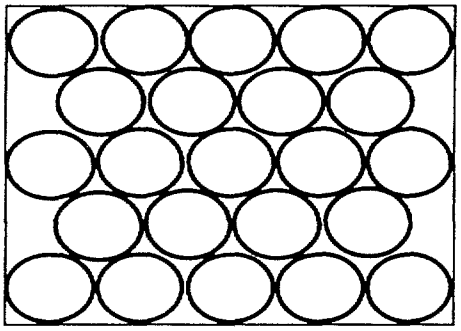
Source Martin &Miezitis (1964)

SIZING/GRADING

Sizing produce is usually a part of grading and you must meet the standards for any produce packed for sale through traditional wholesale markets Sizing produce is optional for direct marketers, but may be worthwhile if certain size grades receive a higher price than others

Another reason to desire uniform sized produce is for place-packing produce by count or for accurately filling trays When using these packing methods, if non-uniform sizes are packed together, some produce is not immobilized within the container while other units may be squashed

Place-pack



Under the AGMARK scheme, Indian Bartlett pears are graded into 4 classes

Extra large (2 3/4" diameter)

Large (2 1/2")

Medium (2 1/4")

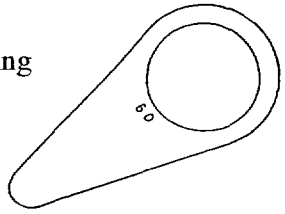
Small (2")

Source Singh, 1998

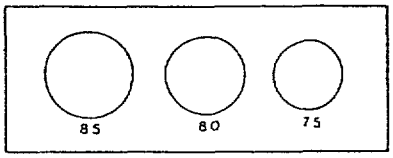
In most low-input packinghouses manual sizing is still commonly practiced Operators should be trained in selecting the size desired and to either directly pack the items into containers or place the selected produce gently into a bin for packing further down the line Sizing can be done subjectively (visually) with the use of standard size gauges Examples of the smallest and largest acceptable sizes for each product can be placed within view of the operator for easy reference Hand held sizers are used for a variety of products

Round produce units can be easily graded by using sizing rings Rings can be fashioned from wood or purchased ready-made in a wide variety of sizes

Single size hand held sizing ring

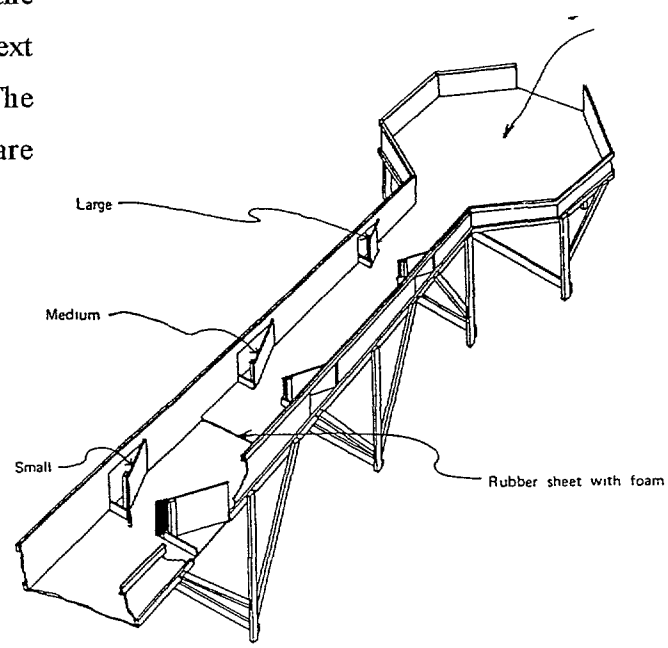


Multiple size rings
Source FAO 1989



Several types of mechanical sizers are available for small scale operations One type is composed of a long slanted tray with a series of openings which converge (largest at the top smallest at the bottom) This type of sizer works best with round commodities

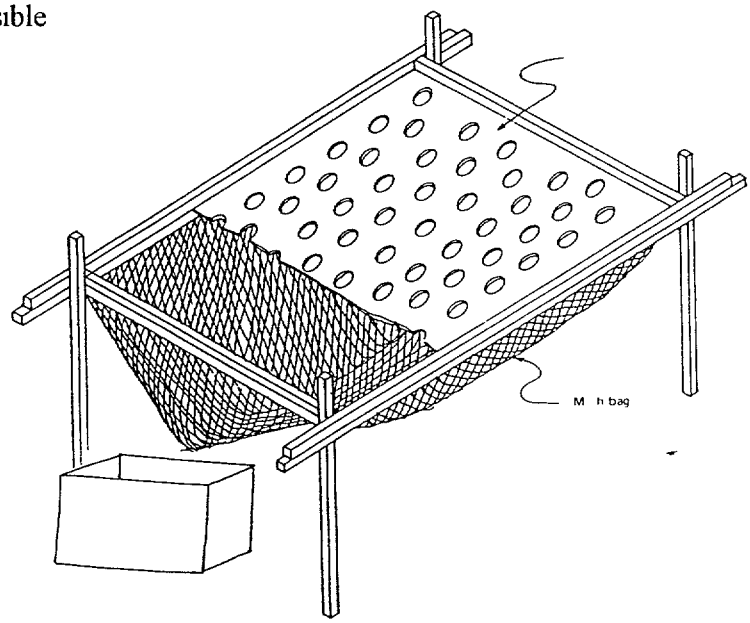
The citrus sizer illustrated here is composed of a rectangular chute made of plywood, padded with foam to prevent bruising The fruit is gently dumped into the octagonal platform at the top of the chute, then allowed to roll, one by one, down toward a series of constrictions Large fruits are caught in the first constriction, medium in the second, and small in the last Undersized fruit passes out the end of the chute directly into a container Workers must manually remove each fruit and place it into the appropriate size container before the next fruit can pass through the chute The sizing is fastest when five workers are stationed at the sizer



Source Reyes M U (Ed) 1988

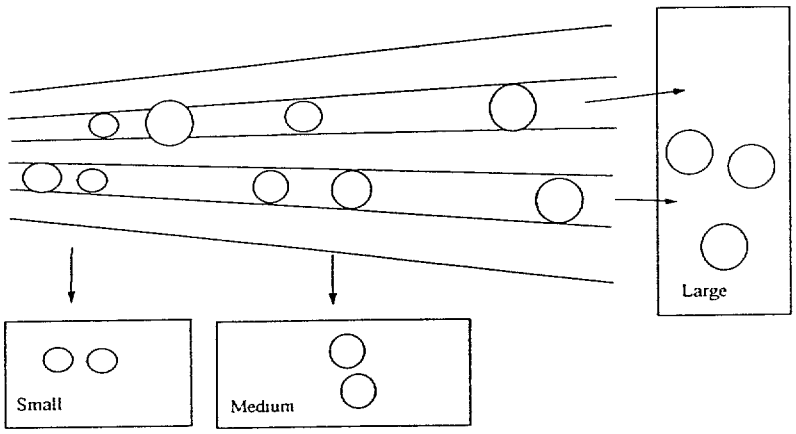
The onion sizing table illustrated on the next page is one of three (or more) tables used in a series Each table is made of plywood and has been perforated with holes of a specific size The first table has the largest size holes, and the last table has the smallest holes A layer of onions is dumped onto the first table and moved by hand toward the holes Those that do not pass through are classified as "extra-large" in size Those that pass through fall into a mesh bag and roll into a large padded container This container of onions is then dumped onto the second sizing table The onions that do not pass through the holes in that table are classified as "large", and so on

Reduce potential damage to the produce by minimizing the height of the drop into the container, using a thick layer of padding in the collection container, and making sure sorters dump the onions onto the table as gently as possible



Source Reyes M U (Ed) 1988

A wide variety of sizers are designed as conveyors fitted with chain or plastic belts with various sized openings, and are useful for sizing most commodities Another simple method for mechanical sizing in a small-scale packinghouse is to use a set of diverging bar rollers where the smallest sized produce falls through the rollers first to a sorting belt or bin, and larger sized produce falls between successively more divergent rollers It is important to minimize the height of drops to prevent bruising produce



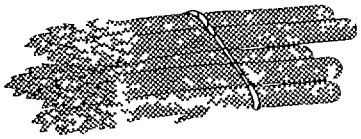
Sorting by maturity can maximize the market value of crops such as stone fruits mangoes and tomatoes Mature green fruits can be stored for a short time (one to two months under proper conditions) then ripened when there is market demand

RIPE TOMATOES CAN BE FURTHER SORTED AS FOLLOWS

Full ripe ready to eat	→	local market immediate sale or processing to paste or dried forms
Partially ripe (pink or turning)	→	transport to regional or distant markets
Breaker stage (10 days from full red at 18 ° C or 64 °F)	→	short term storage or long distance shipping

BUNCHING/WRAPPING

Some commodities are easier to handle and pack if they are bunched and/or wrapped Wrapping cauliflower in vented polyethylene film can reduce damage to the delicate heads by protecting against abrasions during postharvest handling Small items such as radishes can be bagged and packed as a unit of 0 5 lb or 1 lb, while green onions, broccoli and asparagus spears are often bunched with a wide rubber band before packing



POSTHARVEST TREATMENTS

There are some chemicals used in the packinghouse that are generally recognized as safe (GRAS) which can help control physiological disorders and a variety of molds and fungi on fruit crops

Calcium Chloride

A solution of $CaCl_2$ (2 to 3% in clean water) can be prepared as a dip, and acts to control bitter pit in early harvested, lower maturity apples

Chemical fungal control

Sulfur dioxide (SO_2) is used as a fumigant or a water spray (0 5% for 20 minutes for the initial treatment, then 0 2% for 20 minutes at 7 day intervals) on grapes to control *Botrytis*, *Rhizopus* and *Aspergillus* fungi You need to provide a location such as a gas-sealed room or outdoor tent, where fumigation can be done without the gas leaking into work areas

Careful calculation of the amount of sulfur dioxide required to treat grapes can greatly reduce the need to vent or scrub the storage air after fumigation to remove excess SO_2 For information on the "total utilization" fumigation technique that has been developed for treating grapes with sulfur dioxide, see Luvisi (1992)

Sulfur is used on bananas as a paste (0 1 % active ingredient) to control crown rot fungi

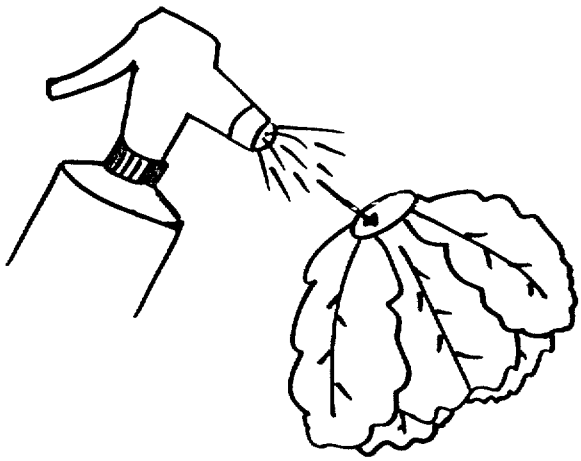
Sodium or potassium bisulfite

Bisulfites are used in a sawdust mixture (usually contained within a pad that can be placed inside a carton) to release SO_2 for control of molds on grapes (5 grams for a 24 to 28 lb box)

Chemical Bacterial control

Bacterial soft rot (*Erwinia*) of cabbage can be controlled by using lime powder or a 15% solution of alum (aluminum potassium sulfate) in water After treatment of the butt-end of the cabbage heads, the produce should be allowed to dry for 20 to 30 minutes before packing Lime powder can be easily applied by pressing the butt-end of the cabbage into a small pile of powder

Applying alum solution
(spray or brush on)



Heat Treatments

Postharvest heating using hot water or hot forced-air to kill or weaken pathogens can be used as a method for decay control in fresh fruits and vegetables Fruit should not be handled immediately after heat treatment Whenever heat is used with fresh produce, cool water showers or forced cold air should be provided to help return the fruits to their optimum temperature as soon as possible after completion of the treatment

HOT WATER TREATMENTS

Commodity	Pathogens	Temperature (°C)	Time (min)	Possible injuries
Apple	*Gloeosporium* sp *Penicillium expansum*	45	10	Reduced storage life
Grapefruit	*Phytophthora citrophthora*	48	3	
Green beans	*Pythium butleri* *Sclerotinia sclerotiorum*	52	0 5	
Lemon	*Penicillium digitatum* *Phytophthora* sp	52	5-10	
Mango	*Collectotrichum gloeosporioides*	52	5	No stem rot control
Melon	Fungi	57-63	0 5	
Orange	*Diplodia* sp *Phomopsis* sp *Phytophthora* sp	53	5	Poor degreening
Papaya	Fungi	48	20	
Peach	*Monolinia fructicola* *Rhizopus stolonifer*	52	2 5	Motile skin
Pepper (bell)	*Erwinia* sp	53	1 5	Slight spotting

Source Barkai-Golan and Phillips (1991)

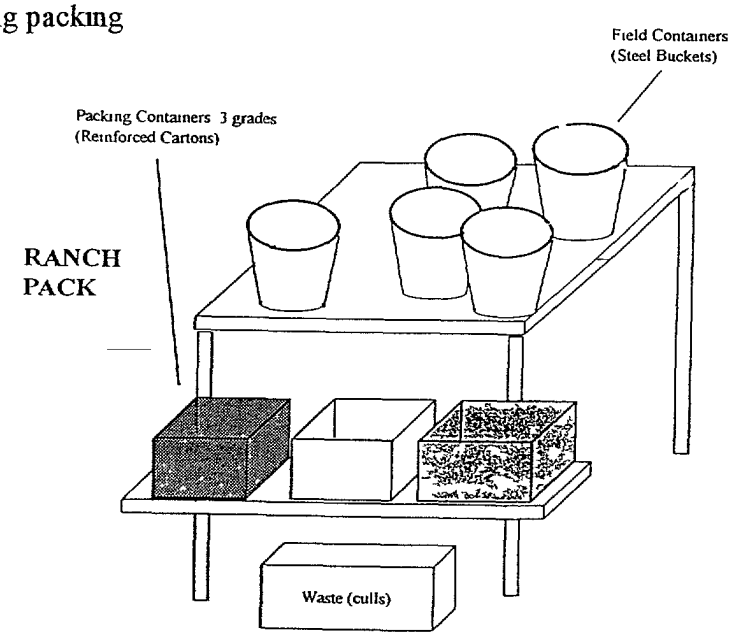
HOT FORCED-AIR TREATMENTS

Commodity	Pathogens	Temperature (°C)	Time (min)	RH (%)	Possible injuries
Apple	*Gloeosporium* sp *Penicillium expansum*	45	15	100	Deterioration
Melon	Fungi	30-60	35	low breakdown	Marked
Peach	*Monolinia fructicola* *Rhizopus stolonifer*	54	15	80	
Strawberry	*Alternaria* sp *Botrytis* sp *Rhizopus* sp *Cladosporium* sp	43	30	98	

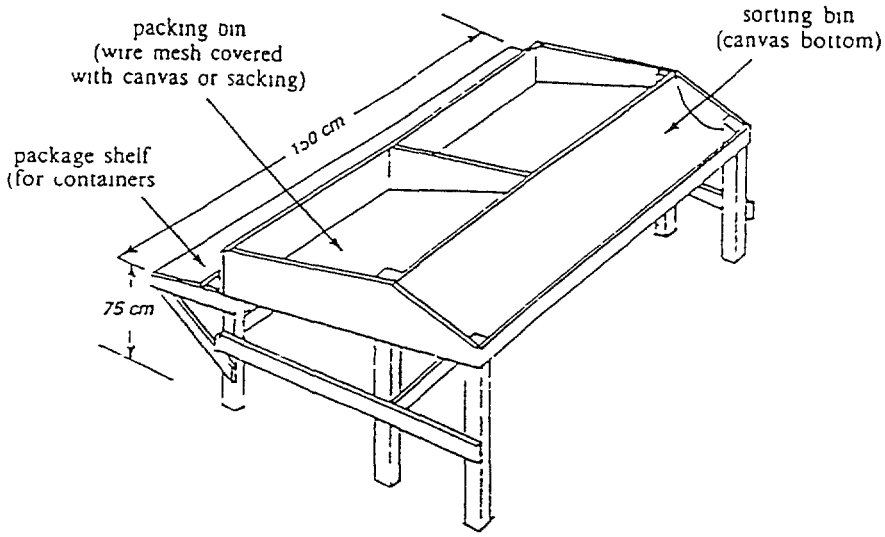
Source Barkai Golan and Phillips (1991)

RANCH PACKING

A single worker can pack produce by removing it directly from the field container, grading by size, color or quality, and hand packing each unit into the appropriate container For example, if there were three quality grades being packed, the worker would have three open cartons within easy reach, and place each unit into the correct package This practice avoids the handling steps of dumping, cleaning and other postharvest treatments and greatly reduces the amount of mechanical damage during packing



The table illustrated here is a combination sorting and packing stand Incoming produce is placed into the canvas sorting bin, sorted by one worker into the packing bins and finally packed into cartons by a second worker If workers must stand to sort produce, a firm rubber pad for the floor can help reduce fatigue



Source FAO (1986)

COMPARISON OF ESTIMATED COSTS AND EXPECTED BENEFITS OF SORTING/SIZING/GRADING/PACKING OPERATIONS

Costs
Equipment
Labor
Packages

Benefits
Reduced losses due to decay, less spread of infection
Improved overall quality, less damaged produce
Higher market price for highest graded produce

Example 1
Unsorted chili peppers packed in 50 lb sacks have a value of $0 20/lb in the wholesale terminal market in the U S At a given time 1000 lbs are packed and marketed to commercial buyers, who must sort the peppers before resale to consumers or for food service use with average postharvest losses due to decay of 15% Sorted produce will have additional marketing options

Costs
Sorting table $50 00, usable over many seasons
Labor $7/hour for sorting and packing 20 lb cartons of 3 quality grades
(3 hours for 1000 lbs) = $21 00
48 Packages cost $1 50 each (= $72 00) vs 20 sacks which cost $0 50 each (= $10 00)
Total costs (unsorted) = $10 vs Total costs (sorted/packed) 50 + 21 + 72 = $123
(Total recurring costs for sorting/packing = $21 + $72 = $93)

Benefits
Unsorted/unpacked market price = $10 /50 lb sack, 20 sacks Total = $200 00
Sorted/packed market prices highest grade = $ 0 45 /lb
medium grade = 0 20 /lb
lowest grade = 0 15 /lb

If 60% of the produce is of the highest grade (30 cartons) = $270
If 25% is medium grade (12 cartons) = $48
If the remainder are the lowest quality (6 cartons) = $12
Culls (not packed) = 4% (equivalent of 2 packages)
Total = $330

Expected profits from sorting/grading/packing This example demonstrates an immediate recovery of invested capital The first 1000 lbs of peppers sorted and packed pays for the capital outlay (the sorting table), after this, each 1000 lbs packed results in a return of an additional $47 ($330 - $93 in costs = $237) in comparison to peppers sold unsorted in sacks ($200- $10 = $190)

Example 2 Unsorted 20 kg sacks of sweet peppers (bell peppers) have a market value of Rs 20/kg in the wholesale mandi in Punjab 1000 kg are harvested, and 15% postharvest losses are due to water loss during transport to market

Costs
Sorting table Rs 3000, usable over many seasons
Labor for sorting and packing 3 quality grades (one day @ Rs 80/day)

100 fiberboard boxes cost Rs 10 each (= Rs 1000) vs 50 sacks which cost Rs 2 each (= Rs 100)
Total costs (unsorted) = Rs 100 vs
Total costs (sorted/packed) Rs 3000 + Rs 80 + Rs 1000 = Rs 4080
(Total recurring costs for sorting/packing = R80 + Rs 1000 = Rs 1080)

Benefits
Unsorted/unpacked market price = 50 sacks of 20 kg @ Rs20 /kg Total = Rs 20,000
Sorted/packed market prices highest grade = Rs 40 /kg
medium grade = Rs 25 /kg
lowest grade = Rs 15 /kg

If 50% of the produce is of the highest grade (500 kg) = Rs 20 000
If 30% is medium grade (300 kg) = Rs 7500
Culls (not packed) = 4% (40 kg)
If the remainder are the lowest quality (160 kg) = Rs 3000

Total = Rs 20,000 + 7500 + 3000 = Rs 30,500

Expected profits from sorting/grading/packing This example demonstrates an immediate recovery of invested capital The first 1000 kg of produce sorted and packed pays for the capital outlay (the sorting table), after this, each 1000 kg packed results in a return of an additional Rs 9520 (Rs 30,500 - Rs 1080 in costs = Rs 29,420) in comparison to peppers sold unsorted in sacks (Rs 20,000- Rs 100 in costs = Rs 19 900)

SOURCES OF PACKINGHOUSE EQUIPMENT AND SUPPLIES

brusher/washer	Northwest Int'l Equipment Co Orchard Equipment and Supply Co
chlorine meters chlorination system	International Ripening Corp American Machinery
cleaners	Brogdex Co Orchard Equipment and Supply Co
conveyors	Agri-Tech, Inc Michigan Orchard Supply Northwest Int'l Equipment Co Sorting Technology, Inc
dumpers bin	Agri-Tech Inc Durand-Wayland, Inc Orchard Equipment and Supply Co Northwest Int'l Equipment Co
field boxes, crates, buckets or baskets	Durand-Wayland Inc
fruit and vegetable waxes	Brogdex Co Michigan Orchard Supply Orchard Equipment and Supply Co
gloves	Pacific 4/ Ranch Brand Supply Co
inspection roller tables	Market Farm Implement Orchard Equipment and Supply Co

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lifting/handling equipment	
folding mini-dolly	Seal-o-Matic
fork lift attachment for tractor	Orchard Equipment and Supply Co
pallet jack	Market Farm Implement
packing lines	Ag-Pak American Machinery TEW Manufacturing Co
pH meters	Fisher International Ripening Corp
rotary tables	Market Farm Implement Michigan Orchard Supply Orchard Equipment and Supply Co
scales	Orchard Equipment and Supply Co
sizers	
chain sizers	Michigan Orchard Supply
expanding rollers	Northwest Int'l Equipment Co
nut sizers	N H Savage Equipment, Inc
onion sizers	Chinook Packing Equipment
sizing rings	Orchard Equipment and Supply Co International Ripening Corp
washers and waxers	Agri-Tech Inc Durand-Wayland, Inc Market Farm Implement Michigan Orchard Supply Orchard Equipment and Supply Co
water dump	Michigan Orchard Supply
water quality analyses equipment	HACH International Ripening Corp

For addresses and phone/FAX numbers refer to Appendix D

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CHAPTER 5

CONTAINERS AND PACKAGING MATERIALS

Produce packed for traditional wholesale terminal markets will require the use of new, standard sized packages and standardized packing counts and/or weights With increasing concerns for environmental health, reusable or recyclable packages and packaging materials are becoming more widely used in the horticultural industry Typical packaging materials include fiberboard (cartons boxes bins flats, dividers and partitions), wood (wirebound or nailed crates, baskets, trays lugs), paper (bags, sleeves, wraps, liners, pads, excelsior), plastic (boxes trays, mesh bags, solid bags, containers, film wraps, dividers) and polystyrene (foam boxes, trays lugs, sleeves, liners, pads and dividers) Direct marketers can use any suitable package, and can sometimes reuse disposable packages many times as long as they are kept clean Depending on the delicacy and handling requirements of various produce, packages can be simple and inexpensive to complex and costly

This chapter describes a variety of packages, packaging materials and package liners and inserts that can be used to protect produce quality during postharvest handling, storage, transport and marketing Included is a brief introduction to the principles and practices of Modified Atmosphere Packaging (MAP) for those of you who want to take a quick look at a modern postharvest technology that can be used along with temperature management to greatly increase shelf life for certain horticultural produce MAP requires the use of flexible packaging films specific to the requirements of each commodity Since MAP is relatively expensive, this technology may be cost effective only for high value produce such as berries and fresh-cut products

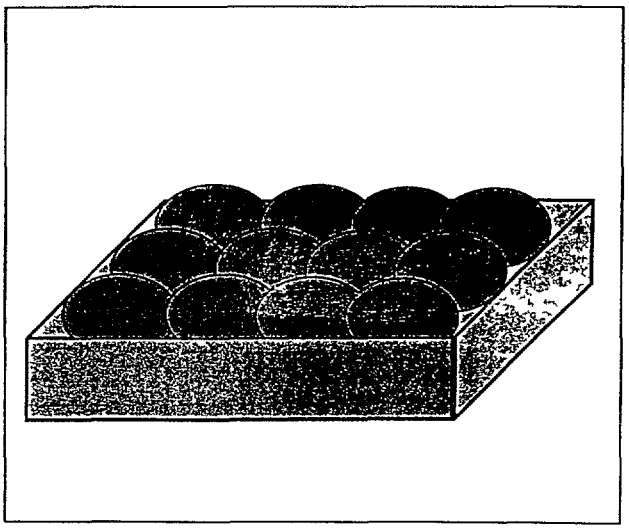
In addition to protection, packaging allows quick handling throughout distribution and marketing and can minimize impacts of rough handling If produce is packed for ease of handling, heavily waxed cartons, wooden crates or rigid plastic containers are preferred over bags or open baskets, since bags and baskets will provide no protection to the produce if they are stacked Sometimes locally constructed containers such as sturdy baskets or palm-rib crates can be lined to provide added protection to produce Waxed cartons, wooden crates and plastic containers, while more expensive, are reusable and can be used for hydro-cooling and package icing Although waxed cartons are not recyclable and some people choose to avoid these packages, they stand up to the high relative humidity found in the storage environment

Containers should not be filled either too loosely or too tightly for best results Loose products may vibrate against others and cause bruising, while overpacking results in compression bruising Shredded newspaper or paper excelsior are inexpensive and lightweight fillers for immobilizing produce in shipping containers

Throughout the entire handling system, packaging can be both an aid and a hindrance to obtaining maximum storage life and quality Packages need to be properly vented to allow proper air circulation yet be sturdy enough to prevent collapse Collapsed packages provide little or no protection, requiring the commodity inside to support all of the weight of the overhead load Packing is meant to protect the commodity by immobilizing and cushioning it, but temperature management can be made more difficult if packing materials block ventilation holes When packing materials act as vapor barriers they can help maintain beneficial higher relative humidities within the package

Simple hand-packing or mechanical packing systems often use the volume-fill method or tight-fill method, in which sorted produce is delivered into boxes then vibration settled Most volume-fillers are designed to use weight as an estimate of volume and final adjustments are done by hand For most small-scale operations, hand packing will be a major part of the postharvest handling system. While hand packing requires a lot of labor, produce can be hand-packed to create a more attractive pack often using a fixed count of uniformly sized units (in molded trays or place packed, sometimes individually wrapped) Hand-packing also allows you to package riper fruits and more delicate herbs and vegetables and provide buyers with great tasting, ready-

to-eat produce If you package ripe produce for specialty shops or create gift-packs or gift-baskets these consumer packs will generally have to be packed into larger containers which will then provide more suitable protective packaging



For small-scale handlers interested in constructing their own cartons from corrugated fiberboard Broustead and New (1986) provide detailed information Many types of agricultural fibers are suitable for paper making (Hunsigi, 1989), and cooperatives of small growers/handlers/shippers may find it economically sensible to include these operations in their postharvest system.

GENERAL DOs AND DON'Ts FOR PACKAGING HIGH QUALITY PRODUCE

Use sturdy packages, capable of standing up to handling, cooling and storage conditions (high humidity environments)

Line rough packages such as baskets and wooden crates with cardboards inserts

Reinforce packages used for heavy produce with corner supports or folded dividers

Don't use very large packages-- the larger the container, the more likely the produce is to suffer damage during handling

Use shallow packages for delicate produce such as berries grapes summer squash and ripe stone fruits (single layer or double layers)

Do NOT overload packages or allow produce to bulge up over the sides

Packages should be vented about 5% of the surface area per side

Don't pack produce either too tightly or too loosely

Do's and Don'ts continued

Consider using packaging materials such as trays cups wraps liners and pads to help immobilize and protect produce, but don't overdo it

Small, rigid plastic containers such as clamshell baskets (consumer sized containers placed into larger boxes) are useful for protecting berries from damage and water loss

Liners made of perforated plastic films will decrease the rate of water loss from produce such as cherries

Make sure the packages you use for garlic and onions have plenty of ventilation (mesh bags will provide the lower humidity environment required for proper handling)

Do NOT block the ventilation holes of packages with fillers or liners

Label containers with your logo or farm name for enhanced marketing (have cartons printed or use inexpensive paper labels or stickers)

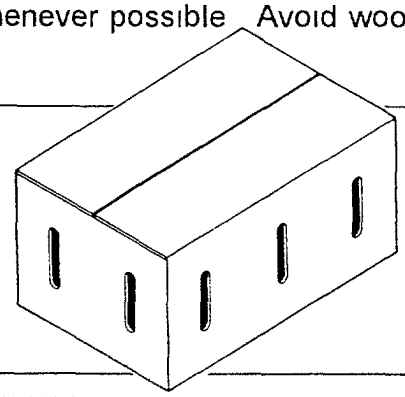
Consider the use of modified atmosphere packaging for your speciality products (read the section of this chapter on MAP if you are considering modified atmosphere packaging)

Consider using packages that can be used as to display produce during marketing (printed sides, display materials on flaps)

Pack 'consumer packages' such as gift packs or display trays into larger more protective outer containers before stacking transport and marketing

Consider the use of packages with "hand-holds"-- these cut-outs can reduce damage since they provide an easy way to pick up and carry produce

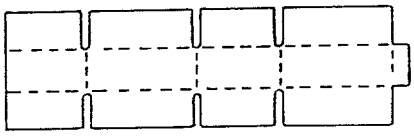
Use virgin/food grade materials whenever possible Avoid wood, nails, staples due to possible food safety problems

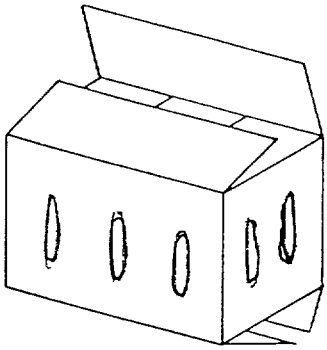


PACKING CONTAINERS

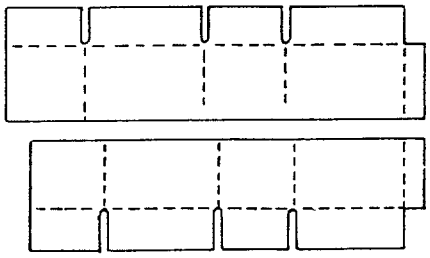
There are many types of packing containers available for horticultural produce, and they come in a huge range of sizes The three containers styles illustrated here are constructed from corrugated fiberboard The regular-slotted container is fully collapsible and the most economical Collapsible containers can be flattened and stacked making transport easy and less expensive and take much less space to store while empty in the packinghouse

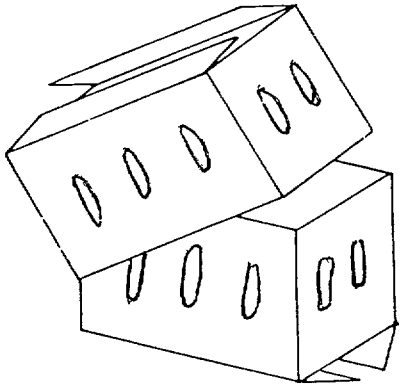
Source Fibre Box Association



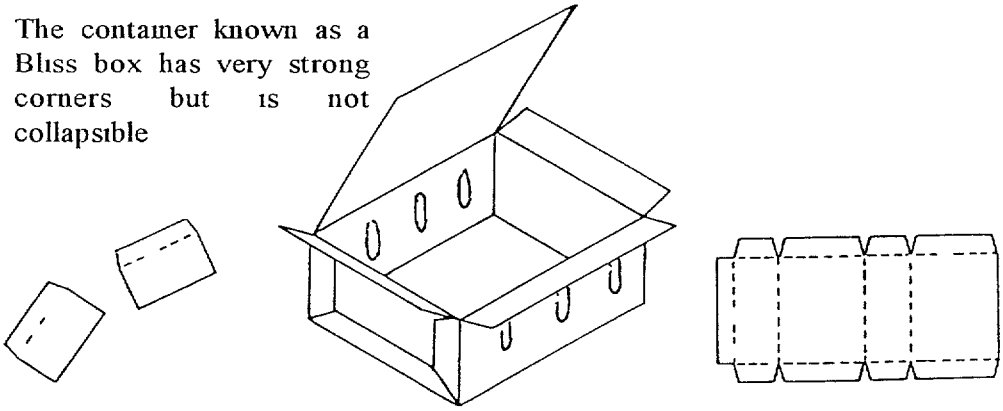


Half or full-telescopic containers have the highest stacking strength and protect against bulging but are more costly Your choice of package style will depend on what commodity you pack and how you intend to use the container throughout the postharvest system (during cooling, for long-term storage, as a display)

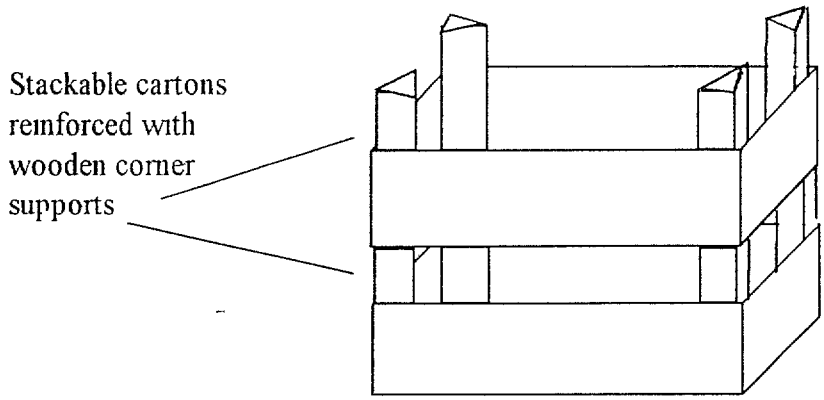




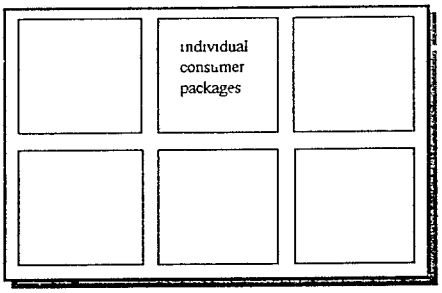
The container known as a Bliss box has very strong corners but is not collapsible



A simple wooden tray with raised corners is stackable and allows plenty of ventilation for fragile crops such as ripe tomatoes



Smaller consumer sized containers can be packed into a larger container

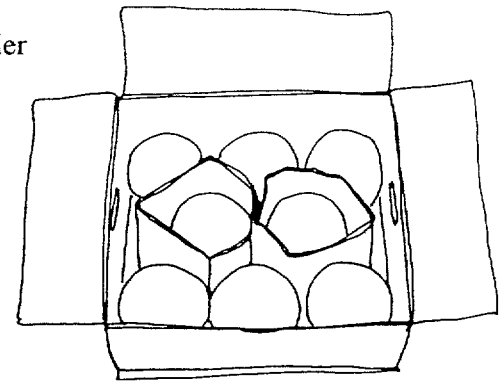


Carton designed to hold six small containers per layer used for berries snow peas, herbs

PACKAGE INSERTS, FILLERS AND LINERS

Adding a fiberboard divider to a carton will increase stacking strength The use of simple dividers is common with heavy crops such as melons and prevent melons from vibrating against one another during handling and transport

Fiberboard divider

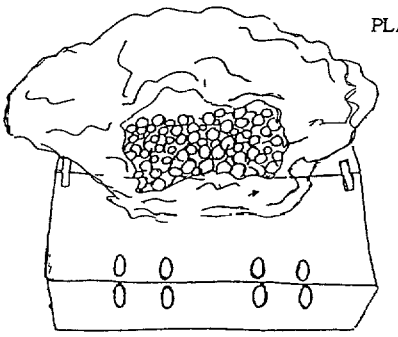


Wooden inserts or fiberboard folded into tight triangles and placed in all four corners can be especially useful when a carton needs strengthening

Triangular support right angled block anchored into corners of simple cartons to reinforce corners provide ventilation and increase stacking strength constructed of wood or heavy-weight folded fibreboard

Using a polyethylene liner in a fiberboard carton can help protect produce and reduce water loss in commodities such as cherries nectarines kiwifruits, bananas and herbs Water vapor given off by the product is contained within the liner increasing the RH around the product and decreasing the rate of water loss The liner can also reduce abrasion damage that results from fruit rubbing against the inside of the box It is important to keep produce cool to prevent causing damage in cartons lined with polyethylene due to gas composition changes related to increased respiration rates

Never use unperforated plastic bags to store onions or garlic--the relative humidity (RH) inside the bag is too high for proper handling and storage Losses due to rooting, sprouting and postharvest decay will increase dramatically

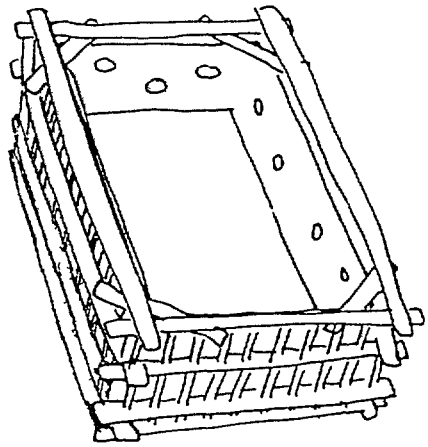


Thompson (1996) reported that perforated film bags used for onion storage resulted in the following rates of rooting

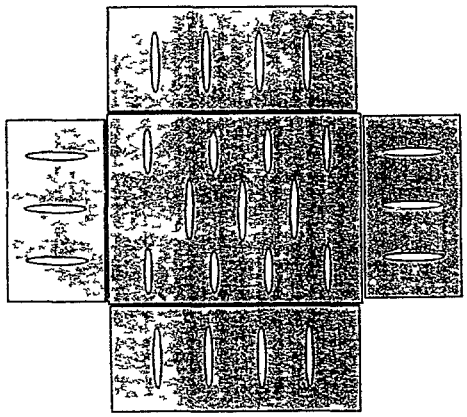
No perforations (98% RH)	71% rooted
36 perforations of 1 6mm (88% RH)	59% rooted
16 perforations of 6 4mm (54% RH)	17% rooted
32 perforations of 6 4mm (51% RH)	4% rooted

When locally made containers have sharp edges or rough inner surfaces, a simple inexpensive liner can be used to protect produce from damage during handling

Cardboard liner for a palm rib crate



Liner for a wooden crate



LABELING

Labeling packages helps handlers to keep track of the produce as it moves through the postharvest system, and assists wholesalers and retailers in using proper practices Cartons can contain information on maximum stacking heights, recommended temperature range and RH conditions The label on a container of lettuce might warn against storage with ethylene producing crops

Labels can be preprinted on fiberboard boxes or glued stamped or stenciled on to containers Brand labeling can aid in advertising for the product's producer packer and/or shippers Some shippers also provide informational brochures detailing storage methods or recipes for consumers Some growers put small stickers (with a colorful representation of the farm name logo or variety name) on individual units of specialty produce both to increase consumer awareness of where the produce they are eating comes from and to enhance its perceived value

Labeling of consumer packages is mandatory under FDA regulations Labels must contain the name of the product net weight, and name and address of the producer, packer or distributor

Shipping labels can contain some or all of the following information

Common name of the product including the variety of the commodity
Net weight count and/or volume
Brand name
Name and address of producer packer and/or shipper
Country or region of origin
Size and grade
Recommended storage temperature
Special handling instructions
Names of approved waxes and/or pesticides used on the product

Economic Considerations

Packages and packaging materials must be evaluated regarding all the costs associated with adapting the package into your marketing system. According to Mitchell (1992) you should consider packaging costs, packing costs, handling costs, marketing costs and product value costs

COSTS ASSOCIATED WITH PRODUCE PACKING AND PACKAGING

1 Packaging costs package components shipping/handling costs associated with purchasing packages labor and materials for package make-up liners pads, trays wraps storage costs for empty packages

2 Packing costs number of packing steps required effect on packing operation labor efficiency

3 Handling costs stacking efficiency costs of pallet strapping glues pallet materials

4 Marketing costs effect on load density special labor or equipment needed for handling adaptibility of package as a display unit

5 Product value costs effect of package in reducing deterioration value of losses due to package failures value of brand reputation related to package performance

MODIFIED ATMOSPHERE PACKAGING

The basic premise of modified atmosphere packaging (MAP) technology is that once produce is placed in a package and sealed, an environment different from ambient conditions will be established as the produce continues to respire The key to successful use of MAP technology is knowing what type of environment will be most beneficial to the produce inside the package and then determining which packaging materials should be used to create such an environment **MAP is ONLY a supplement to proper refrigeration and NOT a replacement for temperature management** MAP without refrigeration is of little benefit in extending the shelf-life of any perishable, and will actually decrease shelf life if produce is handled at temperatures of 20 °C (68 °F) or above

MAP in combination with cold storage may benefit produce in the following ways

- Reduce moisture loss (reduced weight loss)
- Delay ripening (longer marketing time)
- Control decay (reduced postharvest losses)
- Delay undesirable composition changes (delay loss of fruit acids and sugars)

Environmental conditions important to perishables that MAP can effect are atmospheric oxygen (O_2), carbon dioxide (CO_2), ethylene (C_2H_4) and water vapor (relative humidity) concentrations Correct use of MAP technology can significantly extend the shelf-life of produce but if incorrect packaging materials are chosen atmospheric conditions may be generated which will injure produce and this will result in shorter shelf-life or reduced product quality This section will explain how MAP extends produce shelf-life how to chose an appropriate packaging film and what packaging materials are available for fresh produce

In general unless you are marketing highly valuable produce you will probably find that the added cost of MAP is not warranted Good candidates for the use of MAP are berries, fresh-cut produce and for long-term storage of some fruits

GENERAL DOs AND DON'Ts FOR USE OF MODIFIED ATMOSPHERE PACKAGING

Use MAP only in combination with refrigeration

Do NOT package mushrooms in MAP due to the risk of *Clostridium botulinum*

Always precool products before packaging

Use films that will not cause product fermentation (you must know the respiration rate of the produce at the temperature at which it will be handled)

Do NOT use MAP on decayed or injured produce

Do NOT use MAP on overripe or senescent produce

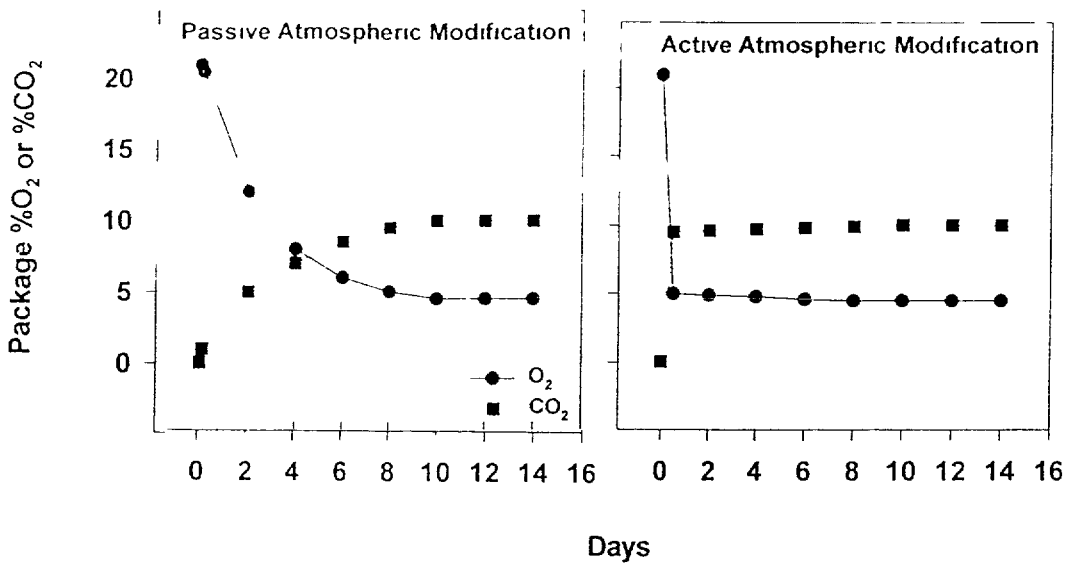
One of the greatest benefits derived from use of MAP is maintenance of high relative humidity around the product Natural barriers to water loss may be removed during harvesting, leaving fresh produce susceptible to dehydration Flexible film pouches significantly reduce the rate of water loss from fresh produce by creating an environment inside the package that is near 100% relative humidity However, water condensation on the interior of the package, usually caused by temperature fluctuations, may promote the growth of spoilage microorganisms and obscure consumers' ability to examine the product prior to purchase Temperature control, appropriate selection of flexible film water vapor transmission rate and incorporation of antifog additives into a flexible film can eliminate these problems

Active versus Passive MAP

Generation of a low O_2 and/or elevated CO_2 environment within a MAP extends produce shelf-life by slowing browning reactions at cut surfaces, reducing the rate of product respiration and reducing ethylene biosynthesis and action When the low $O_2$and/or elevated CO_2 atmosphere within a MAP results from the produce consuming O_2 and releasing CO_2 within a confined space, this is called a passively modified atmosphere Flexible packaging films used for produce allow O_2 to move into the package from the outside air and CO_2 to be released from inside the package The atmospheric composition within a MAP is determined by the O_2 consumption and CO_2 evolution rate of the product, film O_2 and CO_2 permeability, as well as film surface area and product mass

The rapid establishment of a low O_2 and/or elevated CO_2 environment is critical for the prevention of cut surface browning on many fresh-cut products and equilibrium gas concentrations within a package can be attained quickly by evacuating the package and flushing it with the predicted O_2 and CO_2 equilibrium concentrations This type of modified atmosphere is called an actively modified atmosphere and is necessary for MAP fresh-cut lettuce products which commonly have less than 1% O_2 to slow browning reactions and more than 10% CO_2 Gas flushing packages does not alter the equilibrium O_2 and CO_2 concentrations within a produce package but merely reduces the amount of time required to reach equilibrium conditions Although the use of low O_2

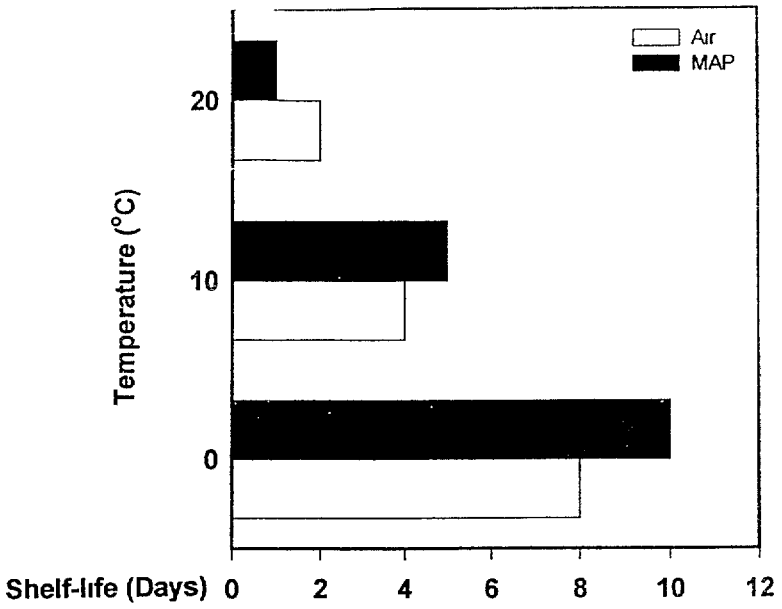
and elevated CO_2 MAP is very effective for reducing cut surface browning of lettuce products it does not work well for other commodities such as fresh-cut fruit



Effects of passive and active atmospheric modification on the O_2 and CO_2 concentrations within a theoretical MAP The passive modification takes nearly 8 days to reach the desired concentrations in the MAP while the active modification the proper mix of gases are introduced to achieve desired levels immediately

Reduced O_2 and elevated CO_2 atmospheres within MAP also extend the shelf-life of fresh-cut products by reducing their respiration rates and slowing use of finite energy supplies that are available in living tissue MAP is not a substitute for temperature management, but merely a supplement to cold storage Low temperatures have a much greater effect on produce respiration rates MAP's are designed to maintain optimal O_2 and CO_2 concentrations within a package and proper functioning is predicated upon storage temperatures being maintained within a specified range Temperatures throughout distribution and marketing must be carefully controlled because, if produce in MAP is exposed to temperatures above its expected storage temperature range, injuriously low O_2 or injuriously high CO_2 levels will be generated and significant shelf-life reduction will occur Reduction in shelf-life may be due to induction of fermentation and/or enhanced growth of lactic acid bacteria both of which cause objectionable off-flavors and odors

The next illustration shows the effects of storage temperature and MAP on the shelf-life of a theorectical perishable commodity, which has an optimal storage temperature of 0 °C (32 °F) At 0 °C the use of MAP extends shelf-life by 2 days or approxiamely 20%, compared to produce stored in air Product held at 10 °C (50 °F) in MAP has a longer shelf-life than product held in air at 10 °C but a signicantly shorter shelf-life than product that is held either in air or MAP at 0 °C This demonstrates that temperature control is more effective than MAP in extending shelf-life At 20 °C (68 °F) MAP products may actually have a **shorter shelf-life** than if they were held in air since anaerobic condition may be generated inside MAP packages at 20 °C and cause accelerated spoilage



General effects of temperature and/or MAP on the shelf life of produce

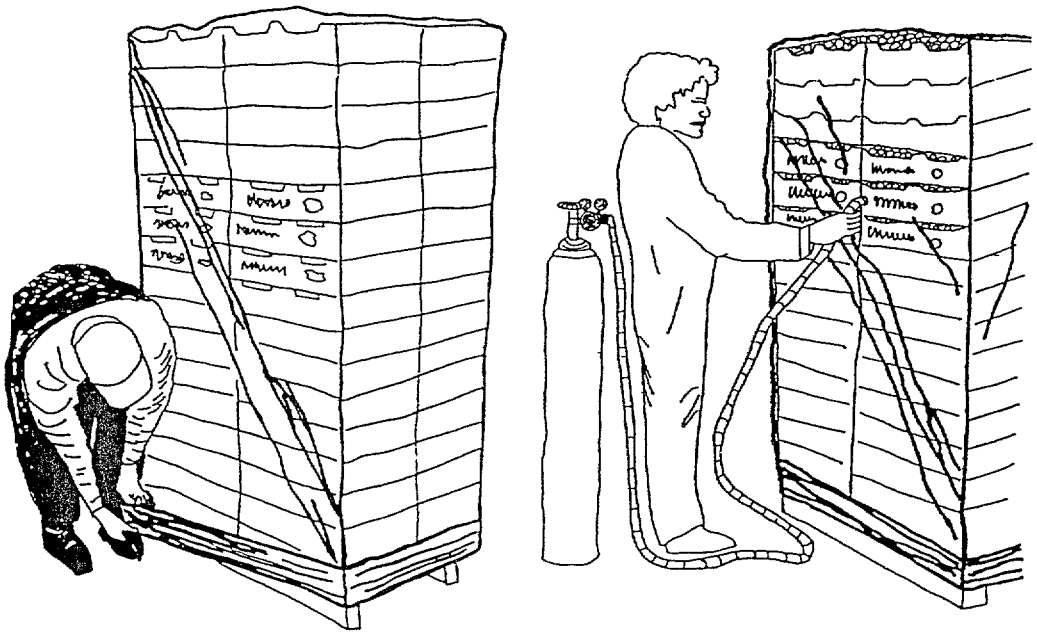
Low O_2 (<5%) and elevated CO_2 (>5%) will also significantly inhibit of the effects of the plant hormone ethylene, which promotes tissue senescence Wounding plant tissue during harvesting operations by cutting slicing or bruising will lead to production of ethylene almost immediately and promote tissue breakdown Rapid establishment of a low O_2 and elevated CO_2 environment within a MAP of produce will reduce the effects of ethylene Numerous industrial attempts have been made to incorporate ethylene absorbing materials into flexible packaging films with the hope of significantly extending the shelf-life of fruits and vegetables This strategy is redundant since low O_2 and elevated CO_2 environments within MAP already significantly diminish the production and effects of ethylene

Elevated CO_2 (>10%CO_2) environments within MAP bring an additional benefit of being fungistatic and are commercially used in the strawberry industry to reduce the growth of *Botrytis cinerea* A properly designed MAP when used in combination with low temperature storage, delays spoilage of fruits and vegetables by slowing the natural processes that lead to tissue death and decay by food spoilage microorganisms Reducing the rapid senescence rate of fruit products via the use of MAP is not particularly effective unless the fruit are harvested before ripening has begun This is because many of the physiological changes associated with fruit ripening are not effected by reduced O_2 and/or elevated CO atmospheres once genetically regulated ripening events have been initiated

Special food safety precautions must be considered when produce which is not acidic (pH >4 6) is packaged in MAP In particular products such as mushrooms should never utilize MAP since at a pH of less than 4 6 and in very low O_2 environments (<2%) *Clostridium botlinnum* may germinate and produce its deadly toxin

Modified Atmosphere Packaging of Strawberries

A single pallet load of strawberries can be sealed within a shroud of 5 mil polyethylene bag and a plastic sheet on the pallet base using wide tape A slight vacuum can be introduced and 15% CO_2 added to the air introduced via a small hose



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DETERMINATION OF THE MOST BENEFICIAL ATMOSPHERE

The optimum atmosphere for extending the shelf-life of a given commodity is determined by the physiology of that commodity, its maturity, the conditions under which it is grown and the expected storage temperature Appendix C contains tables listing the optimal storage atmospheres for fresh vegetables, fresh fruits and fresh-cut produce (Chapter 12 provides detailed information on preparation and postharvest handling of fresh-cut produce) These tables should be used as a starting point and guide from which to begin design of a MAP for any given product Information is included only for produce that is known to benefit significantly from the use of MAP

MAP DESIGN

Once it is determined what atmosphere is appropriate for the commodity you want to package, some simple calculations can help you determine what type of film to use to attain such an atmosphere

The important variables in MAP design are
Product Mass (Weight)
Product Respiration Rate
Film Area
Film Thickness
Desired O_2 and or CO_2 concentrations
Film Oxygen Transmission Rate (OTR) or
CO_2 Transmission Rate (CO_2TR)

The unknown variable is usually film OTR or CO_2TR. Film OTR and CO_2TR are inherent properties of a flexible film and it will determine what flexible packaging material you need to use to achieve the desired atmosphere Once film OTR and CO_2TR are determined then an appropriate film may be selected with some confidence in its ability to deliver the desired O_2 and CO_2 concentrations within the package for that commodity Another important variable to know

is commodity respiration rate The respiration rates of most commodities at various temperatures can be found in USDA Handbook 66 *The Commercial Storage of Fruits, Vegetables and Florist and Nursery Stocks*

MAP Example

You wish to package 2 kg of produce which has a respiration rate of 5 (mL O_2 / kg / h) and you will use a package that is 1 mil thick and has an area or 1800 cm^2 what film OTR will you select to get an atmosphere of 5% O_2 inside the package?

Important Variables

Wt (kg)	2				
Respiration Rate	5 (mL O_2/kg/h)				
Film Thickness	1 (mil)				
Area (cm^2)	1800	Length (cm)x	Width (cm)x	Package Sides	
		30	x 30	x	2
Desired Internal O_2 (%)	0 05 = 5%				
External O_2 (%)	0 21 = 21% Air				

$$\text{OTR (CC/mil/cm}^2\text{/Hr)} = \frac{(2\text{ kg}) \times (5\text{ ml } O_2\text{/kg/Hr}) \times (1\text{ mil})}{(1800\text{ cm}^2) \times (0\ 21 - 05)}$$

OTR (CC/mil/cm^2/Hr) 0 03472

Film OTR values may be reported by manufacturers in various units
To convert OTR (CC/mil/cm^2/Hr) to OTR (cc/100 in^2/day) multiply by 15483 84

OTR (cc/100 in^2/day) = 0 03472 X 15483 84 = **538**

Changing any of the key variables such as the amount of produce you put into the package, film thickness or product respiration rate will effect the equilibrium atmosphere inside the package and it will result in less than optimal MAP conditions A similar calculation can be done to determine

the CO_2 transmission rate (CO_2TR) needed to attain the target CO_2 concentration within a package Once the target OTR and CO_2TR have been determined, the ratio of CO_2TR / OTR can be calcluated Most plastic polymeric films have a ratio greater than one, with low density polyethylene (LDPE) having a ratio of 3 while air has a ratio of 0 8 Each packaging film will have a different ratio depending on the resin or resins used to manufacture the film Once the target ratio has been calculated an appropriate film can be selected based on the physical properties of that film Ask film manufacturers in your locale regarding what packaging materials are available

FILM SELECTION

There are numerous materials that may be used for produce packaging It is best to speak with film manufacturers, often called converters, about your specific needs Film manufacturers should be able to tell you what materials they are currently using and what the OTR and CO_2TR are for any given film that they currently manufacture

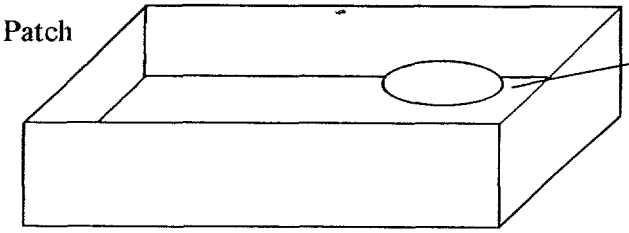
The OTR and CO_2TR of a film is regulated by the choice of materials used in film manufacturing and film thickness Low density polyethylene (LDPE) has been the material of choice for flexible packaging of produce for many years due to its low cost and relatively high OTR. Recently film improvements such as linear low density polyethylene (LLDPE) and ultra low density polyethylene (ULDPE) have appeared These new materials were designed to give film converters the ability to manufacture films with greater consistency in film density and hence give better control of film OTR The newest generation of PE resins to come into use in produce packaging are based on mettalocene technology Mettalocene films have reduced variation in polymer chain length so that better control of film density and are available from Exxon (under the trade name Exact®) and Dow (Affinity®) Mettalocenes OTR are achieved by using these resins These polymers also have superior clarity and create a high quality seal

Another innovative approach to handling high respiration rate commodities which demand a high OTR film is to use microperforated films Microperforated films contain tiny holes which go

straight through the film The atmosphere inside the package is determined by the total surface area of the holes on the package surface The difficulty with manufacturing such films is in how to consistently get the right number and diameter of holes per square centimeter into the film. Currently microperforations are placed in plastic films by mechanical means, sparks or by laser James River recently introduced a new line of micro perforated films with the trade name P-Plus® These films allow for the development of an elevated carbon dioxide environment while maintaining moderate oxygen levels Microperforated films also maintain high relative humidity levels and are very effective in prolonging the shelf life of commodities such cherries and plums which are especially sensitive to water loss and decay Macroperforated in films are packages with larger holes approximately the size of pin holes These type of packages are an excellent way to control water loss and not significantly alter O_2 or CO_2 concentrations within a package

Microporous membranes can also be used in conjunction with flexible films, and the best example of this technology is the FreshHold® patch The microporous membrane is placed over an oxygen impermeable film with a large hole All gas exchange in the package then occurs through the microporous membrane The membrane has very small pores of which are made by incorporating calcium carbonate or silica into the membrane during the manufacturing process The micropores are not aligned and gases must diffuse into the matrix of the membrane, where they may diffuse quickly across the small pores The OTR of the membrane patch can be changed by altering its gauge or by altering the size and number of micropores present Micropore technology is very effective in creating atmospheres elevated in carbon dioxide and moderate in oxygen concentration

The MAP Patch



Other important film properties which should be considered are
- Printability
- Sealability
- Clarity
- Cost
- Strength

New and Emerging MAP Technologies

Currently packaging systems are not responsive to changes in the environment in which a package finds itself A new type of packaging is on the horizon called active packaging Active packaging maintains product safety and quality by adjusting to various handling and distribution conditions

An excellent example of active packaging is a new class of membranes which create modified atmospheres within packages and assure that the product will not use up all the oxygen in the package and become anaerobic, even if temperature is not well maintained These membranes developed and patented by Landec Corporation of Menlo Park, CA, are called Intellimers® or smart films Commonly used films have a preset OTR, and if a product is temperature abused, then oxygen within the package is consumed faster than it can permeate in This leads to off flavor and odor development, as well as an increased risk of food borne illness due to toxin production by anaerobic microbes Landecs' Intellimer® can be manufactured with a preset temperature switch which increases gas permeability (OTR) of the membrane by one thousand fold when temperatures rise above the set temperature limit, thus avoiding anaerobiosis

Another innovative area under active development is incorporation of antimicrobial compounds into films and packaging materials The idea is to have films or packaging materials that will play an active role in reducing the growth of microbes that cause spoilage and foodborne illness In Japan, the Mitsubishi Corporation is currently marketing a Zeolite film that has been demonstrated to significantly reduce microbial populations on contact However, a number of hurdles exist which impede the long-term success of this technology, such as the fact that the film will only be effective where it actually touches the food product Also regulatory and food safety issues exist regarding the migration of these antimicrobial compounds into the foodstuff

Many commodities are physiologically damaged when they are exposed to elevated levels of carbon dioxide or ethylene Traditionally ethylene and carbon dioxide absorbers have been incorporated into packaging systems as a sachet Currently there is an effort to safely incorporate ethylene and carbon dioxide absorbers directly into boxes packing trays and films to protect products from physiological disorders during distribution and handling An example is a product called Peak Fresh® which is a PE film impregnated with mineral particles with the reported ability

to adsorb ethylene We must caution you if you are interested in trying these products since testing by independent laboratories has not yet substantiated these claims

Addresses of Various MAP Film or Resin Manufacturers

Cryovac 100 Rogers Bridge Road Duncan SC 29334 USA

Dow Chemical Co (Affinity®) 2020 Dow Center Midland MI 48674 USA

Exxon Chemical Co (Exact®) Box 3272 Houston TX 77253 USA

Fresh Western Marketing (FreshHold®) Salinas CA 93902 USA

James River Corporation (P-Plus®) 2101 Williams St San Leandro CA 94577 USA

Landec Corporation (Intellimers®) 3603 Haven Ave Menlo Park CA 92045 USA

Mitsubishi Gas Chem 5-2 Marunouchi 2 Chome Chiyoda-Kutoyko 100 JAPAN

COMPARISON OF ESTIMATED COSTS AND EXPECTED BENEFITS RELATED TO IMPROVED PACKING AND PACKAGING OF HORTICULTURAL PRODUCE

Costs and Benefits of using Plastic Crates to handle Horticultural Produce

Costs
Containers
Materials (liners, trays)
Trained labor

Benefits
Reduced losses due to less crushing and lower produce damage, water loss and weight loss
Higher value paid for higher quality packaged produce

Example **Plastic reusable containers with disposable cardboard liners** are used for transport and display during direct marketing in the western U S You have reduced postharvest losses due to lower rate of compression damage (fewer failed packages) compared to typical losses of 10% If you handle 1000 lbs of produce at an average value of $0 95 per lb, you will have 50 additional lbs of produce to market if the crates reduce postharvest losses to 5%

Costs
$15 00 per crate, initial purchase of 40 crates = $600
Liners cost $0 25 each (40 used per 1000 lbs of produce packed 25 lbs/crate) = $10 00
Current cost of inexpensive fiberboard packages ($1 00 each) = $40 00
Labor cost $7 00 per hour, 2 hours to pack 40 crates = $14 00 (same for either packing container)
Total recurring costs for disposable liners = $10

Benefits
50 lbs x $0 95 = $47 50 in additional produce marketed per load
Savings of $40 per load in fiberboard cartons
Total = $87 50

Return on investment
Benefits - recurring costs = $87 50 - 10 = $77 50 profit per load
The cost of $600 for plastic crates is recovered with the first 8 loads, after which you will have an additional profit of of $77 50 per load If you also have the benefit of improved quality due to the investment in improved packaging, profits will be even higher since the market value of the produce will increase

Example 2 **Plastic reusable containers with disposable cardboard liners** are used for transport and display during direct marketing of vegetable crops in Punjab You have reduced postharvest losses due to lower rate of compression damage (fewer failed packages) compared to typical losses of 20% If you handle 1000 kg of produce at an average value of Rs 25/kg you will have 100 additional kgs of produce to market if the crates reduce postharvest losses to 10%

Costs
Rs 200 per crate, initial purchase of 67 crates = Rs 13 300
Liners cost Rs 10 each (67 used per 1000 lbs of produce packed 15 kg/crate) = Rs 670 per load
Current cost of 67 inexpensive sacks each holding 15 kg (Rs 2 each) = Rs 134
Labor cost Rs 80/day, 4 hours to pack 67 crates = Rs 40 (same for either packing container)
Total recurring costs for disposable liners = Rs 670

Benefits
100 kg x Rs25 = Rs 2500 in additional produce marketed per load
Savings of Rs 134 per load in cost of sacks
Total = Rs 2634

Return on investment Benefits - recurring costs = Rs 2634 - Rs 670 = Rs 1964 profit per load
The cost of Rs 13,300 for plastic crates is recovered with the first 7 loads after which you will have an additional profit of of Rs 1964 per load Government subsidies on purchased crates may reduce the cost by 50%, making it possible to recover your investment in only 4 loads If you also have the benefit of improved quality due to the investment in improved packaging, profits will be even higher since the market value of the produce will increase

SOURCES OF PACKAGING EQUIPMENT AND SUPPLIES

bagging equipment	Chinook Packaging Equipment Thomas E Moore Inc
bag sealers	Seal-o-Matic Thomas E Moore Inc
bags paper	Rockford Package Supply Inc Pacific 4/Ranch Brand Supply Co
bags plastic	Adelman-Fisher Packaging Rockford Package Supply Inc
bags net	Northwest Int'l Equipment Co Rockford Package Supply Inc
boxes--berry boxes	Pacific States Box and Basket
--cardboard/fiberboard	Adelman-Fisher Packaging Independence Box Co Inland Container Rockford Package Supply, Inc
--cucumbers tomatoes	Hydro-Gardens Inc
boxes --wirebound	Dyer Fruit Box Mfg Co Elberta Crate and Box Co Franklin Crates Inc Growers Containers Coop Inc
brocolli buncher	Market Farm Implement
ethylene absorber sachets	Ethylene Control Inc International Ripening Corp
fruit protector trays	Rockford Package Supply Inc
insulated pallet covers	International Ripening Corp ThermaGard Inc
pads/foam paper	Rockford Package Supply Inc
polyethylene pallet covers	International Ripening Corp
reusable plastic containers	Buckhorn
scales	Orchard Equipment and Supply Co

	Seal-o-Matic
shrink wrap equipment	Rockford Package Supply Co Seal-o-Matic Hydro-Gardens Inc
staplers	Market Farm Implement Rockford Package Supply Co Seal-o-Matic
tapes, tape dispensers	Rockford Package Supply Co Seal-o-Matic

For addresses and phone/FAX numbers refer to Appendix D

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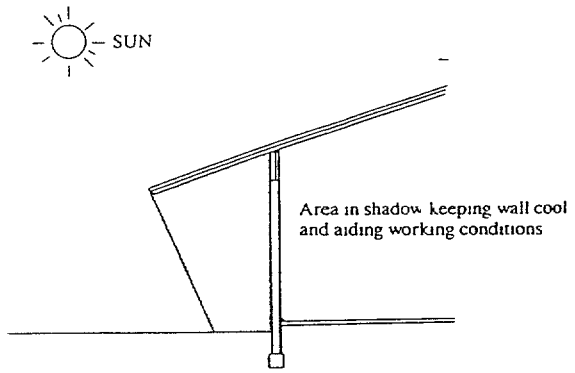
CHAPTER 6

TEMPERATURE AND RELATIVE HUMIDITY CONTROL

Temperature and relative humidity management are sometimes referred to as "Maintaining the Cold Chain" during postharvest handling and marketing Produce should always be cooled as soon as possible after harvest if you want to protect quality and extend shelf life Fresh fruits and vegetables are living tissues separated from the parent plant, which supplied them with water via transpiration Once harvested, produce gains heat through respiration and conduction from the surrounding environment For the highly perishable commodity strawberries, **each one hour delay in cooling results in a 10% increase in decay** Produce exposed to the sun after harvest gains an enormous amount of heat and will have reduced shelf life Tomatoes left in the sun for one hour after harvest will be at least 15 °C (25 °F) hotter than fruit held in the shade And produce left at ambient, dry conditions will lose moisture up to 100 times faster than produce that is moved into a cold room (FAO, 1986)



Cooling involves heat transfer from produce to a cooling medium such as a source of refrigeration Heat transfer processes include conduction, convection, radiation and evaporation If a ready supply of electricity is available, mechanical refrigeration systems provide the most reliable source of cold One

ton of refrigeration capacity requires about 1 horsepower of compressor capacity Fans use about 33% of the energy required for cooling, so don't install fans that are any larger than necessary

This chapter describes traditional cooling technologies including room cooling, forced-air cooling, evaporative cooling and hydro-cooling When electricity is unavailable or too expensive, a variety of simple methods exist for cooling produce Some examples of alternative cooling systems include night air ventilation, radiant cooling, the use of ice and underground (root cellars, field clamps, caves) or high altitude storage Control of relative humidity is an important part of temperature management, as the two combine to reduce water loss and protect produce quality The chapter includes some examples that will help you to determine the costs and benefits associated with temperature and RH management technologies for horticultural produce, and help you decide which cooling method(s) will be most profitable for your operation

FRESH
LOOKING
PRODUCE
=
NUTRITIOUS
PRODUCE

GENERAL DOs AND DON'Ts for MANAGING TEMPERATURE AND RELATIVE HUMIDITY

Cool produce as soon as possible after harvest

Cool using appropriate methods for each commodity (consider water tolerance time required to reach 7/8ths cooling susceptibility to dessication)

Shade should be provided over harvested produce, packing areas, for buildings used for cooling and storage and for transport vehicles

Trees are a fine source of shade and can reduce ambient temperatures around packinghouses and storage areas

Light colors on buildings will reflect light (and heat) and reduce heat load Design buildings with overhangs on the sunny side to provide shade

High pressure sodium lights in packing and cooling facilities will produce less heat and use less energy than incandescent bulbs

The best method to reduce water loss is to increase RH by reducing temperature

Wet the floor of storage rooms to increase the RH inside the room (Do NOT do this when storing onions or garlic)

Use proper containers, suited to the method used for cooling (waxed cartons or wooden boxes for hydro-cooling or icing, boxes with alligned side vents for forced air cooling)

Consider using forced-air coolers inside a cold room to speed cooling and decrease water loss and decay rate

Monitor hydro-cooler water quality, clean and sanitize the cooler each day before use

Do NOT hydro-cool apricots or fresh herbs since these crops are easily damaged

Cool before loading produce into refrigerated trucks (these trailers are designed only to maintain cool temperatures)

Use high quality insulation in coolers, storage rooms and transport vehicles to reduce incoming environmental heat load

Dos and Don'ts continued

Mist water-tolerant vegetables during handling, storage and marketing to decrease the rate of water loss

Be careful when using specialty packaging since these are even more sensitive to temperature abuse

- SO_2 pads increased rate of SO_2 release damages table grapes
- MAPcan become out of control faster increase in CO_2 and rapid decrease in O_2 damages produce

TEMPERATURE MANAGEMENT

During the period between harvest and consumption, temperature control has been found to be the most important factor in maintaining product quality Keeping fruits cool will slow down the changes associated with ripening, and give you more time to market your produce **Generally, for each hour of delay between harvest and cooling, one day of shelf life is lost** (Cantwell, 1998) For highly perishable crops like 'Shasta' strawberries, the percentage of marketable fruit decreases rapidly as the time after harvest at ambient temperature increases Studies at UC Davis have shown that with a 4 hour delay in cooling from 30 °C (86 °F) about 70% of the strawberry crop is marketable, while with an 8 hour delay in cooling, only 40% of the crop is marketable

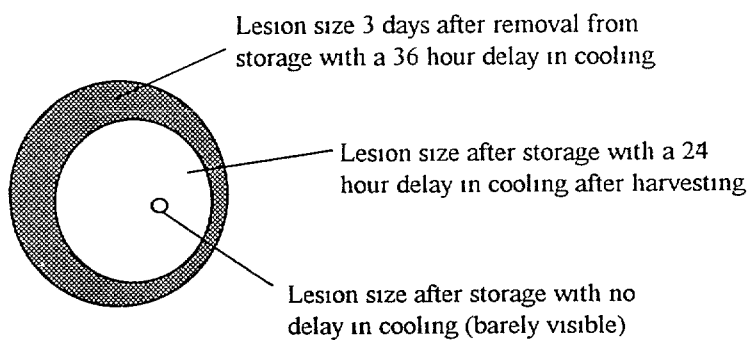
The temperature at which you handle produce will directly effect how long you have to get the produce to market Asparagus has a five day shelf life when handled at 20 °C (68 °F), compared to almost one month when handled at 3 °C (37 °F) When you delay cooling asparagus, the

Effect of temperature on ripening rates of mature-green, breaker, turning and pink tomatoes of standard varieties (from Suslow and Cantwell 1997)

	Days to full red color at the indicated temperatures					
	13 C 55 F	15 C 59 F	18 C 64 F	20 C 68 F	22 C 72 F	25 C 77 F
Maturity Stage						
Mature green	18	15	12	10	8	7
Breaker	16	13	10	8	6	5
Turning	13	10	8	6	4	3
Pink	10	8	6	4	3	2

spears will toughen and quality will decrease The effect of temperature on tomato ripening rates is described below Handling fruits at even higher summer temperatures will further speed the rate of ripening

Temperature also has a direct effect on the rate of decay development Sommer (1992) described the development of decay symptoms on peaches when they were infected with brown rot (*Monolinia fructicola*) When peaches were cooled immediately after harvest 3 days after removal from cold storage decay lesions were less than 2mm wide Any delay in cooling greatly increased the spread of decay



Effect of delays in cooling on the development of Brown Rot symptoms in peaches Peaches were held at 20 °C for 0, 24 or 36 hours before being stored at 0 °C (Adapted from Sommer, 1992)

When cooling horticultural produce, various methods are compared to determine how long it will take for produce to reach 7/8th of its final temperature Each method is suited to specific commodities, based upon their tolerance of direct contact with water and their susceptibility to water loss during cooling In general, room cooling of packaged produce is the slowest method while forced-air cooling is much faster since produce comes into direct contact with cold air as it is pulled through packages For produce that tolerates water contact hydro-cooling is a good choice since it is the fastest cooling method, as ice water can carry away more heat than cold air during the same time period of contact with produce

Once produce is cooled keeping horticultural products at their lowest safe temperature (0 °C or 32 °F for temperate crops or 10-12 °C or 50-54 °F for chilling sensitive crops) will increase storage life by lowering respiration rate decreasing sensitivity to ethylene and reducing water

loss An inexpensive temperature probe can be used to monitor temperature during postharvest handling storage and marketing Chapter 7 focuses on storage practices and Appendix B lists specific temperature and RH recommendations for a wide selection of commodities

COOLING METHODS

Room Cooling

Room cooling is a relatively low cost but very slow method of cooling when electricity for mechanical refrigeration is available When using room cooling, produce is simply loaded into a cold room and cold air is allowed to circulate among the cartons, sacks, bins or bulk load This cooling method is best suited to less perishable commodities such as potatoes, onions, apples and citrus fruits, since highly perishable crops will deteriorate too much before being adequately cooled Room cooling may be all you need if you handle chilling sensitive crops that need to be cooled from early morning harvest temperatures to storage temperatures of 10 to 13 °C (50-55 °F) The design and operation of cold rooms are fairly simple and no special equipment is required

ROOM COOLING

potatoes
apples
onions
citrus
winter squash

It is important to leave adequate space between stacks of boxes inside the refrigerated room in order for produce to cool more quickly About 1 inch (2 5 cm) is sufficient to allow cold air to circulate around individual boxes Produce in vented boxes will cool much faster then produce packed in unvented containers In many small-scale cold rooms, produce has been loaded into the room so tightly that room cooling cannot take place at all, and despite the high cost of running the refrigeration system, the produce temperature never decreases to recommended levels

Stacks of produce inside the cold room should be narrow, about one pallet width in depth (two or three cartons) Fans should be installed to move the cold air throughout the room Air circulating through the room passes over surfaces and through any open space, so cooling from the outside to the center of the stacks is mostly by conduction You'll want to monitor the temperature of the produce within the packages at various locations in the room to determine that the produce is being cool as desired Rearrange the stacks and measure the rate of cooling until you find the right pattern for your cold room

Low cost cold rooms can be constructed using concrete for floors and polyurethane foam as insulation materials Building the storeroom in the shape of a cube will reduce the surface area per unit volume of storage space, also reducing construction and refrigeration costs All joints should be carefully caulked and the door should have a rubber seal around the edges While cooling produce, the ventilation system should be set to create an air flow rate of 100 cfm/ton (5 l/sec/ton) Once cooling is completed, air flow rates should be decreased to the lowest speed that will keep produce cool (20 to 40 cfm/ton is usually sufficient, according to Thompson et al 1998) The greater the refrigerator's evaporator coil area, the less of a temperature difference there will be between the coils and the target room temperature, and the less moisture will be lost from the product as it cools

Room cooling is quite slow, and place-packed produce typically requires twice as long to cool as tray-packed produce

Example Anjou pears (middle of stack)

Place-packed T7/8= 45 days
Tray-packed T7/8 = 21 days

Source
Faubion and Kader 1997

For complete plans on constructing small-scale cold rooms, contact the Small Farm Center, University of California, Davis CA 95616, and ask for the publication entitled *Small-Scale Cold Rooms for Perishable Commodities* by Thompson and Spinoglio (1994)

Times* for 7/8th cooling for selected commodities using room cooling

Commodity	Package type	% vents	Average	Slowest time to 7/8th cool
Apples	wooden box bulk			2-3 days
	wooden box packed			6-8 days
Artichoke	corrugated container		24 hours	
Grapes	wooden lug solid stacked			30 hours
Pears	24 lb lug		16 hours	20 hours
	24 lb lug wrapped		30 hours	39 hours
	telescoping containers			
	1 inch space between	3 5%	16 hours	23 hours
	no space between	5%	24 hours	40 hours
Plums	corrugated container tight fill 28 lb			
	1 inch space between	4%		22 hours
	no space between	no vents		84 hours
Oranges	24 inch deep bulk bins	no side vents	33 hours	
	30 inch deep bulk bins	no side vents	45 hours	

* Times are approximate and should be used only as guides Carefully monitor produce temperature to determine actual rate of cooling for your operation climate equipment type and arrangement of containers
Source Thompson et al (1998)

Forced-Air Cooling

Forced-air cooling pulls or pushes air through the vents in storage containers, greatly speeding the cooling rate of any type of produce (taking 1/4 to 1/10 of the time needed for room cooling) Some cold room have permanent forced-air cooling units built into a side wall A variety of portable forced-air coolers have been designed for use by small-scale growers and handlers

Cooling time depends on the air flow rate, the temperature difference between the produce and the cold air, and produce diameter Small produce such as berries or cherries (about 1" in diameter) will cool almost 6 times faster than 6" diameter melons The fan needs to be big enough to provide an airflow of about 1 cfm/lb (1 liter/sec/kg) against a wide range of static pressures You may have to experiment a bit with fan speed settings and air flow rates, since static pressure will change depending upon the types of containers, width of stacks, air spaces between containers, size and shape of the cold room, and type of packaging materials (liners or wraps) used Doubling the air flow will speed cooling slightly but cost a lot more because you would need a much larger and costlier fan (with 6 to 7 times more horsepower) Reducing air flow by one-half will increase cooling time by about one hour for most commodities, and would dramatically reduce fan motor size and energy costs

Forced-air Cooling

use moist air to decrease water loss of produce during cooling

To reduce cooling time and associated costs, it helps to reduce the initial temperature of the produce by harvesting early in the day (when temperatures are cooler), and by keeping produce shaded during any delays in moving it into the cooler When stacking boxes against the cooler stacks one box wide will cool faster than boxes stacked two or three wide

The produce closest to the cold forced-air will cool faster than produce near the center of the load Cooling this center-placed produce will take about the same time as it takes for the center of large diameter produce to come to the proper temperature You can measure the temperature of the produce with an inexpensive temperature probe Make sure not to stop the cooling process before the warmest produce has reached the desired temperature

The operation of the forced-air cooler should be stopped as soon as the produce is cooled Additional high speed air movement through the cold produce will cause serious water loss unless the air is at nearly 100% RH (but very high RH during forced-air cooling can add moisture to packages and reduce their strength and durability) It is better to closely monitor the forced-air cooler and shut it off or remove produce as soon as it is cooled

Times* to 7/8th cooling for selected commodities using forced-air cooling

Commodity	Type of package	% vents	Flow rate (cfm/lb)	Average time
Artichoke	Corrugated container	9%	1 0	4 hours
			1 5	3 hours
Grapes	Full telescoping	5 8%	0 27	6 hours
			0 4	4 hours
			1 0	2 hours
Nectarines	Corrugated container	6%	0 5	4 hours
	with plastic trays		0 8	3 hours
	Bliss box 2 layers	5%	0 5	6 hours
	with top pad		0 8	4 hours
Pears	Corrugated container	2%	0 3	9 hours
			1 2	3 hours
		5%	0 4	6 hours
			1 0	3 hours
Oranges	Bulk bins slotted bottoms		0 4	6 hours
	2-3 ft deep vertical airflow		1 0	3 hours
Strawberries	Open crates on pallets		0 5	4 hours
			0 8	3 hours
			1 4	2 hours
Tomatoes	Corrugated container	10%	0 6	6 hours
			1 1	4 hours
			1 6	3 hours

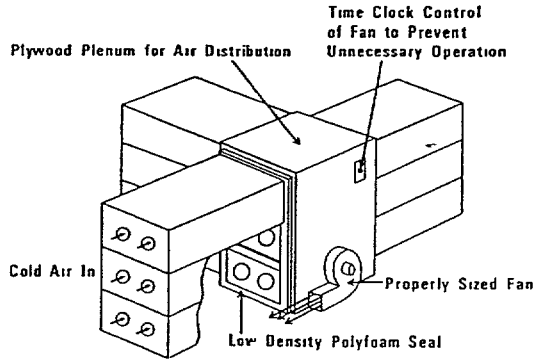
* Times for forced-air cooling are approximate and should be used only as guides Carefully monitor produce temperature to determine actual rate of cooling for your operation climate equipment type and arrangement of containers

Source Thompson J F et al (1998)

Portable forced-air coolers

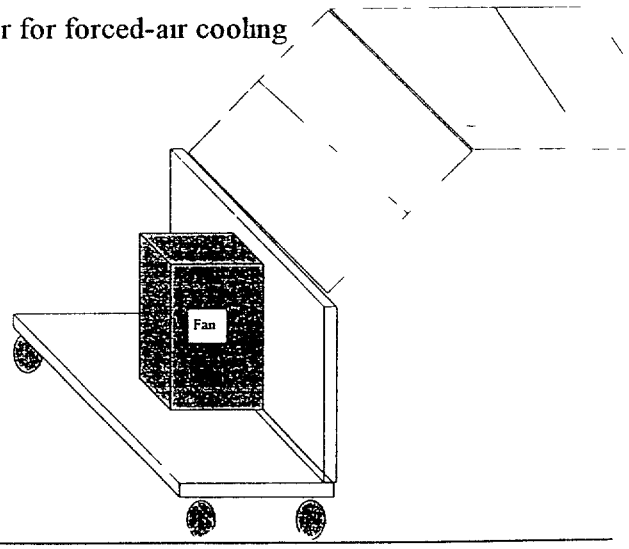
A portable forced-air cooler can be constructed using a canvas or polyethylene sheet The sheet is rolled over the top and down the back of the boxes to the floor sealing off the unit and forcing air to be pulled through the vents of the cartons stacked against the cooler The energy requirements for running the fan will be reduced if the vent area is at least 4% of the surface area of the carton Most good quality fiberboard containers can be vented up to 5% without significant loss of stacking strength

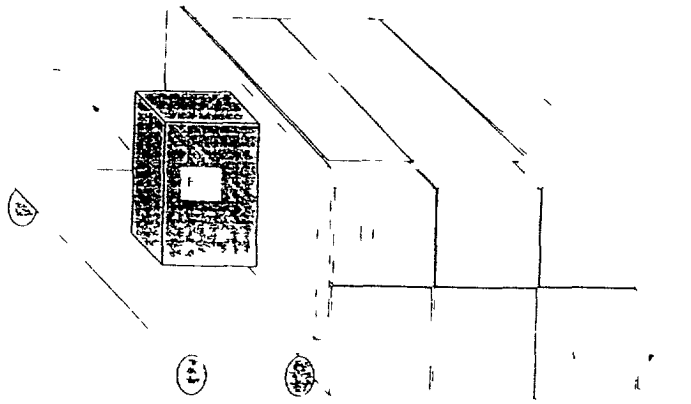
This unit is designed to be used inside a refrigerated storage room Keeping the air inside the cold room humidified will reduce water loss during forced-air cooling A single width of containers allows produce to cool as quickly as possible in the forced-air cooler Setting the cooler up with two layers of containers with alligned vents will slow cooling considerably



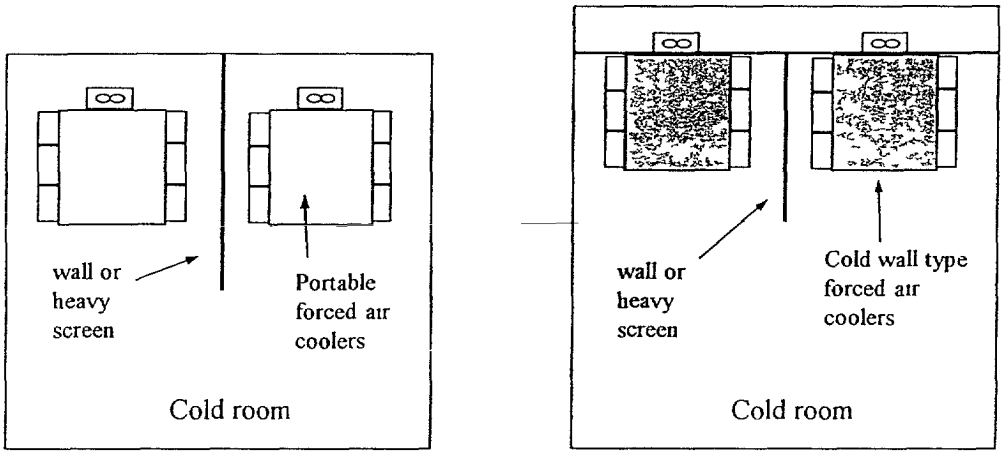
Source Ry R. et al 1979

These illustrations show a portable tunnel type forced-air cooler equipped with a fan to pull air from a cold room through the boxed produce The first illustration shows the cooler in its empty state, with the canvas cover extended (it should be rolled up for storage when not in use) The fan is housed inside the box on the base of the cooler The second illustration shows the cartons of produce set up in a row on each side of the cooler for forced-air cooling



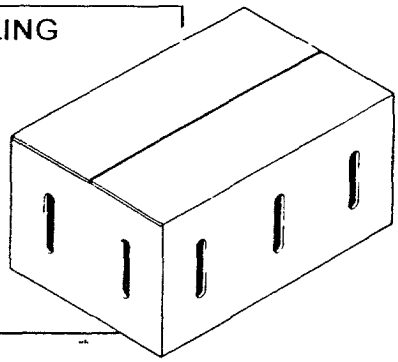


If you are using two forced-air coolers in the same cold room, it is important to separate them (using a screen or temporary wall) so that the warmer produce in a recently loaded cooler does not slow down cooling in the other cooler



VENTED CONTAINER DESIGNED FOR FORCED-AIR COOLING

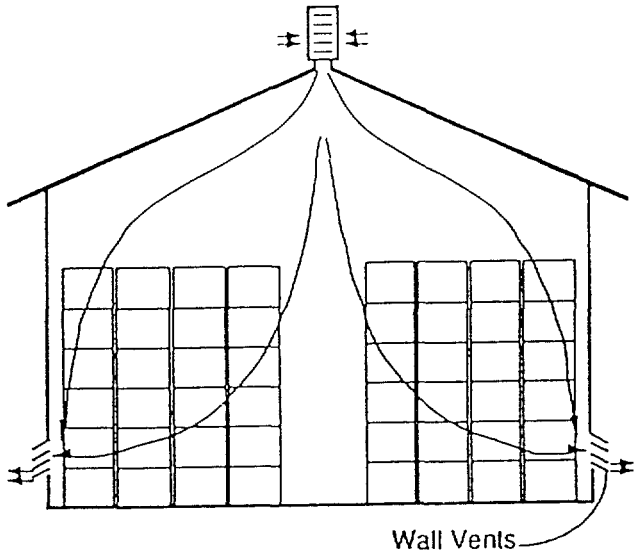
- avoid round vents (they can easily be blocked)
- make vents 1 cm (1/2 inch) wide or larger
- keep vents 4 to 7 cm (2 to 3 inches) from all corners
- vents should be about 5% of the side area



Evaporative Cooling

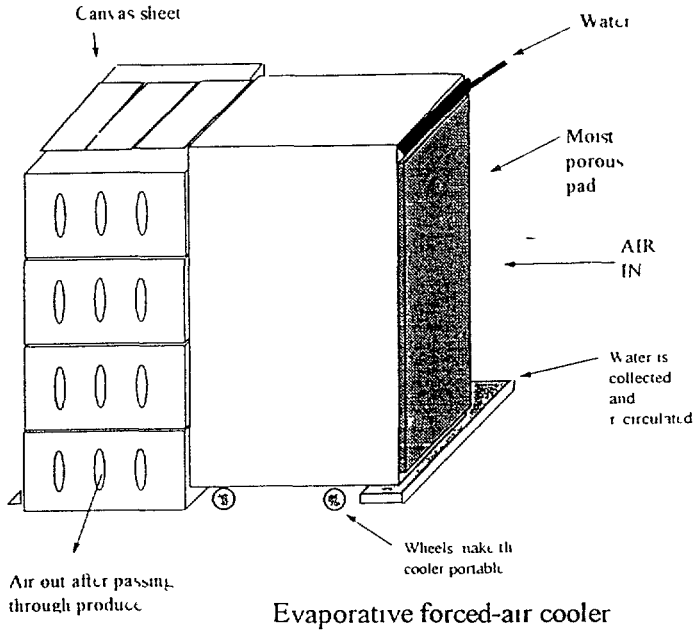
Evaporative coolers (also known as desert coolers) can be constructed to cool the air in an entire storage structure or just to speed cooling in a few containers of produce These coolers are only suitable for lower humidity regions of the world or during dry seasons since the degree of cooling is limited to 1 to 2 °C (2 to 4 °F) above the wet-bulb temperature

Evaporative coolers contain a cooling pad of wood fiber or straw moistened with water Air is pulled through the pad using a fan and the cooled moist moves through produce carrying away the heat it contains



Room sized unit
Source Thompson and Scheuerman 1993

An evaporative cooler can be combined with a forced air cooler for speeding the cooling of small lots of produce in dry regions of the world Evaporative-forced-air coolers are especially suitable for cooling produce that is very sensitive to moisture loss In the example provided here, a small-scale evaporative cooler uses about 4 L (0 5 gallon) of water per minute dripped onto a one square meter (8 square foot) pad, providing enough moist air to cool up to 18 crates of produce in 1 to 2 hours Water is collected in a tray at the base of the unit and recirculated



Evaporative forced-air cooler

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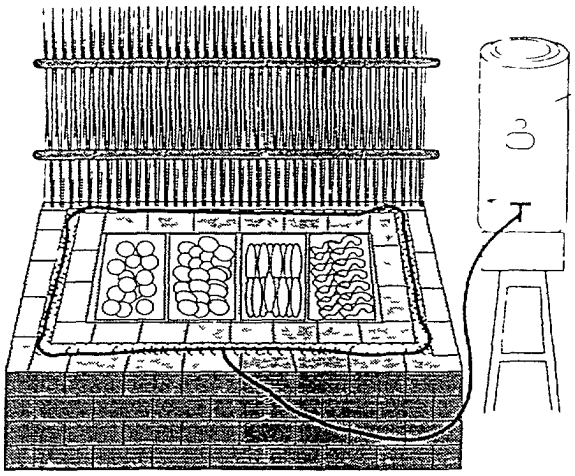
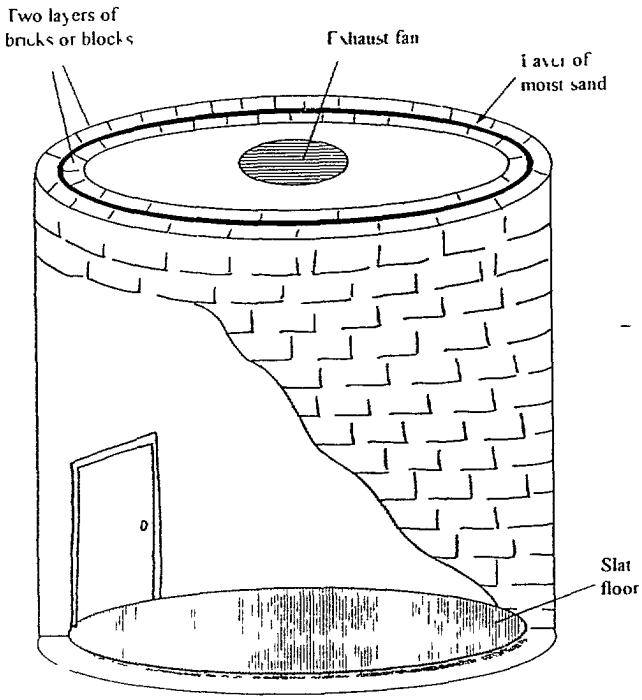
The low cost cooling chambers illustrated below are constructed from bricks The cavity between the walls is filled with sand and the bricks and sand are kept saturated with water Fruits and vegetables are loaded into plastic crates and put inside for storage During the hot summer months in India this chamber is reported to maintain an inside temperature between 15 and 18 °C (59 and 65 °F) and a relative humidity of about 95% PAU has a working model of this cooler at the Department of Agricultural Structures

Improved zero-energy cool chamber the entire rectangular chamber is covered with a rush mat which is also kept moist
Source Roy S K 1989



Larger round storage structure The same methods were used to construct this larger evaporative-cooled storage structure Since a relatively large amount of materials are required to construct this structure it may be economically feasible only when handling high value products



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Hydro-Cooling

Even faster than forced-air cooling is hydro-cooling where water-tolerant produce is either immersed or showered with icy cold water Several designs for hydro-coolers are used by small-scale handlers known as either batch-type or continuous-flow type systems Immersion hydro-coolers usually take longer to cool produce than shower type coolers and are mostly used for bulk produce of a density greater than water (so it won't float) such as cherries One of the benefits of using hydro-coolers is that they can be easily integrated into your packing operations and become a step within a simple packing line

Produce to be hydro-cooled can be spread out in a single or multiple layers, left in open field bins or be packed in vented plastic or wooden boxes Containers need to be vented on the top to allow water to flow into the container and around the produce Waxed cartons can be used, but these are expensive and will sometimes fail when exposed to long hydro-cooling times Always sort before cooling so you won't waste money by cooling culls

Hydro-Cooling

radishes
cherries
peaches
sweet corn
root crops
celery
mangoes

Hydro-cooling requires a lot of power, since the water temperature must be kept very cold (with ice or mechanical refrigeration) The refrigeration capacity you will need depends upon the amount of produce you intend to cool per hour the incoming temperature of the produce, and the external heat the hydro-cooler will have to deal with Little information is available for small-scale users, but if you want to cool 1000 lbs of produce per hour, you will need about 0 4 ton of refrigeration capacity for a 11 °C (20 °F) temperature drop, 0 8 ton for a 24 °C (45 °F) temperature drop, or 1 5 tons for a 39 °C (70 °F) temperature drop (The conversion for changing tons of refrigeration capacity to kilowatts of refrigeration capacity is tons x 3 52 = kW) A hydro-cooler installed in a cold room will require about 30% less refrigeration capacity than an uninsulated cooler installed outdoors (Thompson, 1995)

Commercial hydro-coolers deliver water at a rate of about 10 to 15 gallons per square foot per minute (400-600 L/square meter/minute) A lower flow rate will be sufficient if you are cooling a single layer of bulk produce while double this rate may be necessary if you stack boxes or bins 2

or 3 high in a batch-type cooler If stacking boxes, make sure vents are aligned or the bottom layer of produce will not be cooled The water must run down and **into the containers**, surrounding the produce with constantly moving cold water

When using a hydro-coolers you must pay attention to the rate of cooling, which will depend on incoming produce temperature water temperature flow rate of water and the type of containers used if any Begin by taking temperature measurements (via temperature probe), then you can adjust the rate of produce flow for continuous-flow type or the time you leave containers inside a batch-type hydro-coolers Small diameter produce such as asparagus and radishes will typically be cooled in less than 10 minutes medium sized produce such as peaches and apples will take about 20-25 minutes while large diameter produce such as melons can take one hour

Times* for 7/8ths cooling of selected commodities using hydro-cooling

Commodity	Package type	Hydro-cooler type	Flow rate	Average time
Asparagus	none (bunches)	Immersion		6 minutes
Peaches	47 inch square bins 24 inches deep	Shower	150 gpm/bin	
		free draining		30 minutes
		0 1-inch holes	allowing bin to fill	24 minutes
Pears	open lug	Shower	4 gpm/ft^2	42 minutes
Sweet corn	wirebound crates	Immersion		
		no agitation		46-84 minutes
		plus agitation		28 minutes
		Shower	5 gpm/ft^2	
		free draining		45 minutes

* Times are approximate and should be used only as a guide Carefully monitor produce temperature to determine the actual rate of cooling for your operation climate equipment and package types and arrangements

Source Thompson J F et al (1998)

Hydro-cooler Use and Maintenance

Water is recirculated in hydro-coolers and should be chlorinated with 100 to 150 ppm of available chlorine (60 ml per 40 L or 2 ounces of chlorine bleach per 10 gallons of water) to prevent the spread of decay Several times during use each day test for available chlorine using a chemical test kit and adjust as necessary Organic matter ties up chlorine, so if the produce is especially dirty you will use more chlorine than usual Washing produce before hydro-cooling will decrease this problem

When mangoes are immersed in ice water for only **ten minutes** directly following harvest, pulp temperature is reduced by 10 to 15 °C from an ambient temperature of 40 to 45 °C

Source International Food World

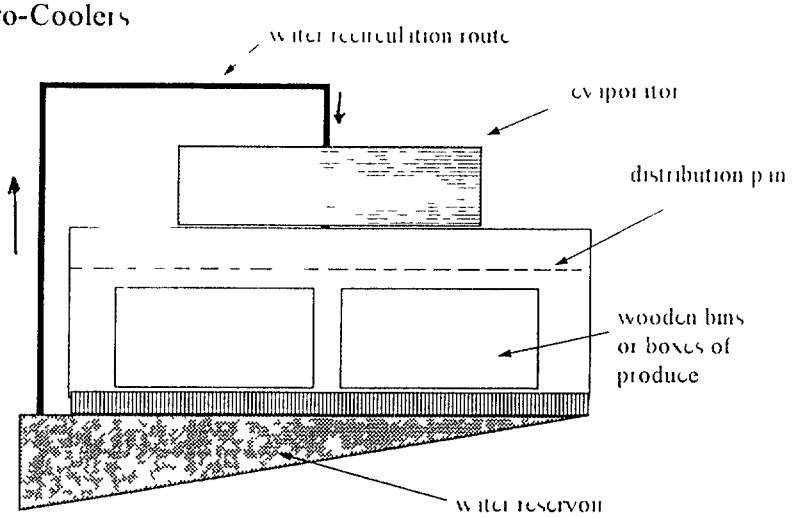
Keep the pH of the water in the range of 6 5 to 7 5 to prevent corrosion problems and the release of toxic chlorine gas Use litmus paper strips or an inexpensive electronic pH meter to measure pH and add muratic acid to decrease pH or lye to increase pH (be sure to follow directions on the labels of these products) At the end of each day the entire cooler should be drained and cleaned Waste water may contain pesticide residues and chlorine, so be sure to follow local regulations on proper disposal methods

About 25% of the energy used to run a hydro-cooler is required to remove heat conducted across exterior surfaces pipes and from the air and another 10% is used to offset the heating caused by the water pump Insulating the hydro-cooler and keeping it in a cool location (inside a cold room or at the minimum in deep shade) will decrease the cost of operation Starting with cooler produce (harvested in the early morning kept in the shade during sorting and packing, using naturally cool well water to pre-rinse warm) will also decrease costs by decreasing cooling times

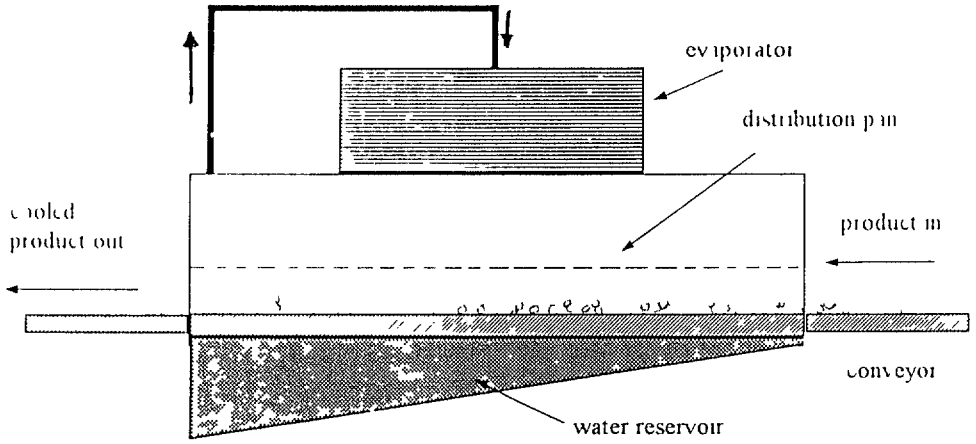
To reduce hydro-cooler costs:

- insulate the hydro-cooler
- set it up in deep shade or inside a cold room
- start with produce harvested in the morning hours

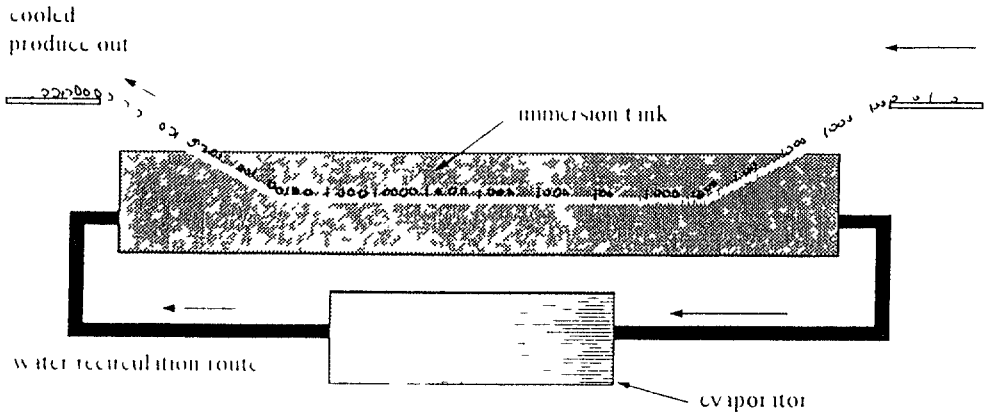
Types of Hydro-Coolers



Batch type hydrocooler (cut-away view)



Continuous flow shower type hydrocooler (cut-away view)



Continuous flow immersion type hydrocooler (cut-away view)

Chilling Injury

While cooling is very important care must be taken to avoid chilling injury in senstitive crops Chilling injury occurs when crops are stored or transported at temperatures lower than those recommended for proper postharvest handling Tropical and subtropical produce is especially sensitive, and chilling injury can be seen regularly in tomatoes, peppers and cucumbers Everyone is familiar with the various symptoms of chilling injury which include failure to ripen (bananas and tomatoes), development of pitting or sunken areas (oranges, melons and cucumbers), brown discoloration of tissues (avocados cherimoyas, eggplant), increased susceptibility to decay (cucumbers tomatoes, zucchini and beans) and lack of flavor development (tomatoes) Any of these symptoms will decrease the value of the produce you have to sell

Many fruit and vegetable crops are susceptible to chilling injury when cooled below 13 to 16 °C (55 to 60 °F) Chilling injury reduces the quality of the product and shortens shelf life Make sure you don't over-cool sensitive produce Symptoms often appear only after the commodity is returned to warmer temperatures during marketing

Prevent chilling injury by keeping these crops at their lowest safe temperature
Source Hardenburg et al 1984

Commodity	Lowest safe temperature °C	°F	Chilling Injury Symptoms
Apples (Jonathan McIntosh)	2-3	36-38	soft scald brown core
Apples (Yellow Newton)	3-4	38-40	internal browning
Asparagus	0-2	32-36	dull grayish limp tips
Avocados (Lula Booth 1 Taylor)	4 5	41	grayish-brown
Avocados (Fuchs Pollock)	13	55	discoloration
Avocados (Fuerte Hass Booth)	7-8	45-46	of the flesh
Bananas	12-13	54-55 ripened	dull color when
Beans (lima)	2-4	35-40	rusty brown specks, spots

Commodity	Lowest safe temperature °C	°F	Chilling Injury Symptoms
Cranberries	2	36	rubbery texture
Cucumbers	7	45	pitting watersoaking decay
Eggplants	7	45	surface scald alternaria rot blackening of seeds
Guavas	4 5	40	pulp injury decay
Grapefruit	10	50	scald pitting watery breakdown
Jicama	13-18	55-65	surface decay discoloration
Lemons	11-13	52-55	pitting red blotch membrane staining
Limes	7-9	45-48	pitting turning tan with time
Mangoes	10-13	50-55	uneven ripening grayish skin
Melons Cantaloupe	2-5	36-41	pitting surface decay
Honey Dew	7-10	45-50	reddish-tan discoloration pitting surface decay failure to ripen
Casaba	7-10	45-50	pitting decay, failure to ripen
Crenshaw Persian	7-10	45-50	pitting decay, failure to ripen
Watermelon	4 5	40	pitting off-flavor
Okra	7	45	discoloration, water-soaked areas pitting decay
Olives (fresh)	7	45	internal browning
Oranges (CA and AZ)	3	38	pitting brown stain
Papayas	7	45	pitting failure to ripen off-flavor decay
Peppers (sweet)	7	45	sheet pitting alternaria rot darkening of seed
Pineapples	7-10	45-50	dull green when ripe
Pomegranates	4 5	40	pitting browning
Potatoes Chippewa Sebago	3	38	sweetening mahogany browning
Pumpkins squashes	10	50	decay alternans rot
Sweetpotatoes	13	55	decay pitting internal browning
Tomatoes ripe	7-10	45-50	water soaking softening decay
mature-green	13	55	poor color when ripe alternaria rot

Use of Ice

Crushed or flaked ice for package icing can be applied directly or as a slurry in water (liquid ice) The ice must come into direct contact with the produce in order to cool, and cannot simply be placed on top of the produce The water used to make ice must be potable (clean) Flaked or crushed ice can be manufactured using commercial machinery, but operation and storage of ice is expensive If you use ice only for a short time during the harvest season, it is probably less expensive to purchase block ice and crush it on site

Using ice in plastic bags to maintain temperature of pre-cooled produce can reduce problems with package damage from soaking, and eliminate waste water flow from ice melt

The use of ice to cool produce provides a high relative humidity environment around the product and can reduce the rate of water loss in commodities sensitive to moisture loss Melting 1 lb of ice made from water has the cooling effect of 144 Btu One lb or kg of ice will drop the temperature of produce 3 times its weight by about 50 °F (28 °C)

Package ice can be used only with water tolerant, non-chilling sensitive products and with water tolerant packages (waxed fiberboard, plastic or wood) Waxed or wooden containers are much more expensive than fiberboard Using ice greatly increases the weight of the load, and some transport vehicles may exceed their rated carrying capacity before they are fully loaded It is estimated that at least 10 lbs of ice must be added to a 20 lb carton of broccoli in order to provide cooling during long distance transport, and even more is required if you desire to have ice left in the container upon arrival at the destination market Melting ice can damage fiberboard containers when produce is handled in mixed loads

PRODUCE SUITED FOR PACKAGE ICING

anise broccoli, brussels sprouts, cabbages, cantaloupes, carrots celeriac,daikon endive escarole green onions leeks, lettuce parsley, peas, spinach, radishes rhubarb, rutabagas, sweet corn, turnips and turnip greens

Source TRANSFRESH 1988

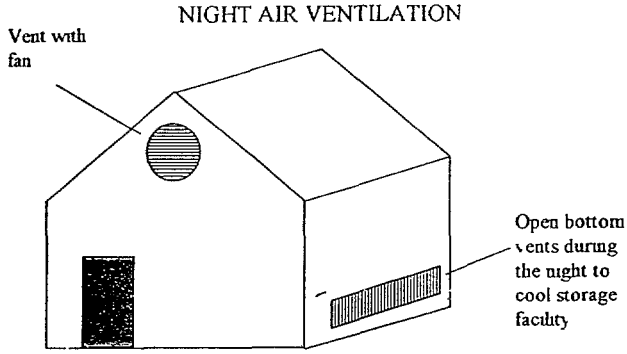
Top ice doesn't do much cooling, but is sometimes used for certain products during transport to help maintain a high relative humidity Top ice can be used only with water tolerant, non-chilling sensitive products and with water tolerant packages (waxed fiberboard, plastic or wood) Top-ice on loads should be applied in rows rather than a solid mass It is important not to block air circulation inside the transport vehicle

ALTERNATIVE COOLING STRATEGIES

Night Air Ventilation

Storage structures can be cooled using night air if the difference in day and night temperature is relatively large The storage facility should be insulated and vents should be located at ground level Vents can be opened at night and fans can be used to pull cool air through the storeroom The structure will best maintain cool temperatures during the heat of the day if it is well insulated and vents are closed early in the morning

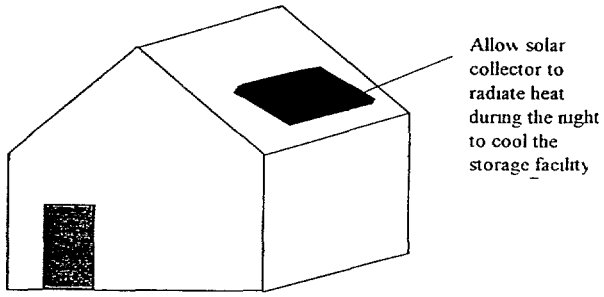
NIGHT AIR VENTILATION



Radiant Cooling

Radiant cooling can be used to lower the air temperature in a storage structure if a solar collector is connected to the ventilation system of the building By using the solar collector at night heat will be lost to the outside environment A hollow, shallow black box with a clear glass cover can transfer heat that rises from the building via infrared radiation to the night sky

RADIANT COOLING



Temperatures inside the structure of 4 °C (about 8 °F) less than night temperature can be achieved The collector must be covered with a light colored blanket or sheet of insulation such as Reflectix® during the day to prevent the accumlation of solar radiation

Use of Well Water

Well water is often much cooler than air temperature in most regions of the world The water temperature of a deep well tends to be in the same range as the average air temperature of the same locality Well water can be used for hydro-cooling chilling sensitive crops and as a spray or mist to maintain high relative humidity in the storage environment

Nature's Cooling Methods

night air
radiation
well water
high altitude

High Altitude Storage

As a general rule, air temperatures decrease by 10 °C (18 °F) for every one kilometer increase in altitude If you have an option to pack or store commodities at higher altitude, costs for cooling and cold storage can be reduced Cooling and storage facilities operated at high altitude require less energy than those at sea level for the same results In California when temperatures in the Central Valley reach 38 °C (100 °F), temperatures in the high Sierra mountains, only about 50 miles away, are likely to be 21 to 24 °C (70 to 75 °F)

RELATIVE HUMIDITY CONTROL

Another aspect to consider when handling fruits and vegetables is the relative humidity of the storage environment Loss of water from produce is often associated with a loss of quality as visual changes such as wilting or shrivelling and textural changes can take place Leafy crops tend to lose water the most quickly If using mechanical refrigeration for cooling the larger the area of the refrigerator coils the higher the relative humidity in the cold room will remain It pays however, to remember that water loss may not always be undesirable, for example if your produce is destined for dehydration or processing to puree or sauces

The rate of water loss can be estimated by using the commodity's transpiration coefficient and the VPD (the vapor pressure deficit, which is dependent upon the difference in temperature between the commodity and its environment and the relative humidity of the air around the commodity) Apples, potatoes, onions, pears and citrus fruits have relatively low transpiration coefficients, while peaches, leeks, carrots, celery brussel sprouts and lettuce have very high transpiration coefficients When handled at the same temperature and RH carrots and lettuce will lose much more water than apples or potatoes Reducing the difference in temperature and/or increasing RH will decrease the rate of water loss

Water loss of 3 to 6% is generally enough to cause a noticeable loss of quality and value Stone fruits (peaches, plums and apricots) look shriveled when they suffer water loss of 4 to 5% **Root crops (carrots, beets, turnips, radishes) will lose water much faster if their tops are left attached, since the leaves will continue to transpire, taking water from the roots** Reducing the rate of water loss slows the rate of shriveling and wilting, causes of serious postharvest losses If you sell produce by weight, every bit of water lost is also lost profits Produce handled and marketed at 27 °C (80 °F) and 60% RH (very adverse conditions, but not uncommon in the southwestern and western US during May through October, or in Punjab in April and May) can lose a lot of water in a short time

Cornell University studies have demonstrated the following water losses for these crops under high temperature/ low humidity conditions

Asparagus	8 4%
Snap beans	4 0 %
Topped beets	3 1%
Topped carrots	3 6%
Cucumbers	2 5%
Summer squash	2 2%

Maximum storage life and maximum percentage water loss before becoming unsaleable (becoming lowest grade or poor quality due to wilting or shriveling) for selected horticultural crops

Commodity	Maximum storage life at optimum conditions	Maximum % water loss before becoming unsaleable
asparagus	2-3 weeks	8
beans (runner)	1-1 5 weeks	5
beets/topped	30-40 weeks	7
beets with tops	2-4 weeks	5
blackberries	1 5 weeks	6
brussels sprouts	4-6 weeks	8
cabbage (Primo)	6-12 weeks	7
cabbage (Decema)	40-50 weeks	10
carrots/topped	40-50 weeks	8
carrots with tops	2-3 weeks	4
cucumber	1 5-2 weeks	5
grapes (Thompson seedless)	4-10 weeks	2
lettuce	1 5-3 weeks	3
onion	30-35 weeks	10
parsnip	25-30 weeks	7
peas (in pod)	2-5 weeks	5
peaches	2-5 weeks	5
peppers	1 5-2 weeks	7
spinach	1 5-2 weeks	3
strawberries	2-3 weeks	7
tomato (1/4 ripe)	2-3 weeks	7

(adapted from Thompson, A K 1996, Hardenburg et al 1984)

Increasing Relative Humidity

For fresh market produce any method of increasing the relative humidity of the storage environment or decreasing the vapor pressure deficit (VPD) between the commodity and its environment will slow the rate of water loss The best method of increasing RH is to reduce the temperature

A common method of increasing RH in a storage room is to add moisture to the air around the commodity as mists, sprays or, at last resort, by wetting the floor Another way is to use vapor barriers such as waxes, polyethylene liners in boxes, coated boxes or a variety of inexpensive and recyclable packaging materials Any added packaging materials will increase the difficulty of

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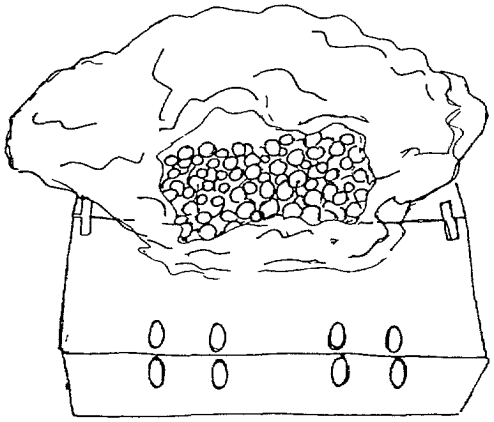
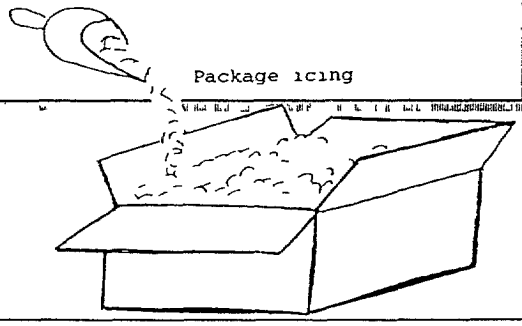
efficient cooling, so vented liners (about 5% of the total area of the liner) are recommended The liner vents must line up with the package vents to facilitate cooling of the produce inside Vented liners will decrease VPD without seriously interfering with oxygen carbon dioxide and ethylene movement



RH CAN BE CONTROLLED BY

- adding moisture to air (water mist or spray)
- regulating air movement and ventilation rates in relation to produce
- maintaining refrigeration coils in a cold room within 1 °C or 2°F of air temperature
- providing moisture barriers (insulation, liners, plastic films)
- wetting floors in storage rooms
- adding crushed ice to packages and displays (for tolerant crops)
- sprinkling produce during retail marketing (leafy vegetables, cool season root crops, immature fruit crops)

Source Kader, 1992



COMPARISON OF ESTIMATED COSTS AND EXPECTED BENEFITS RELATED TO COOLING HORTICULTURAL PRODUCE AND MAINTAINING THE COLD CHAIN DURING HANDLING, STORAGE, TRANSPORT AND MARKETING

Costs
Equipment
Power
Labor

Benefits
Lower postharvest losses
Longer shelf life
Higher quality

McDonald's attributes much of its success to the use of the cold chain and their attention to quality and HACCP

Source Times of India 13 July 1998

Example 1 Two tons of mangoes harvested at the peak of the season (June 15 to 20) are handled either at ambient temperatures (30 to 35 °C) or via an integrated cold chain (15 °C) where cooling costs are relatively high $1000 ($0 25 / lb)

	Ambient temperature	Cold Chain
Postharvest losses	35%	10%
Quality classes	20% highest 50% second 30% lowest	50% highest 30% second 20% lowest
Total volume sold	2600 lbs	3600 lbs
Marketing period	June 15-June 28	June 15 - August 1
Average price/lb	$0 50	$1 25
Sales - cost of cooling	$1300	$3500

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Example 2 1000 kgs of mangoes harvested at the peak of the season (June 15 to 20) are handled either at ambient temperatures (30 to 35 °C) or via an integrated cold chain (15 °C) where cooling costs are relatively high Rs 10,000 (R10/kg)

	Ambient temperature	Cold Chain
Postharvest losses	35%	10%
Quality classes	20% highest 50% second 30% lowest	50% highest 30% second 20% lowest
Total volume sold	650 kg	900 kg
Marketing period	June 15-June 28	June 15 - August 1
Average price/lb	Rs 5	Rs 18
Potential Sales	Rs 3900	Rs 16,200
Sales - cost of cooling	Rs 3900	Rs 6,200

SOURCES OF COOLING AND RH CONTROL EQUIPMENT AND SUPPLIES

air-exhaust doors/ louvers	Industrial Ventilation, Inc Hydro-Gardens, Inc
"Cool-and-Ship" (mobile cooler) plans	North Carolina State University Cooperative Extension Dept of Ag Communications Box 7603, Raleigh NC 27695
evaporative cooling pads	Hydro-Gardens Inc
forced-air cooling systems	Pressure Cool Co
hydro-coolers	Clarkesville Machine Works Inc Northwest Int'l Equipment Co Robic Refrigeration Inc Semco Manufacturing Company
humidifiers	Industrial Ventilation, Inc

ice-makers (3 to 6 ton/day portable)	Semco Manufacturing Company
ice storage	Robic Refrigeration Inc Semco Manufacturing Company
insulation	Jade Mountain Reflectix, Inc
mini-reefers	CMF Corp
portable "hydro-chillers"	Semco Manufacturing Company
radiant barriers (screening, shadecloth)	Real Goods
refrigeration equipment	Calif Controlled Atmospheres Hydro-Gardens, Inc
thermometers, temperature probes	Dickson International Ripening Corporation

For addresses and phone/FAX numbers of suppliers, please refer to Appendix D

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CHAPTER 7

STORAGE PRACTICES AND STRUCTURES

Sometimes you may want to store produce before marketing, either for the short term or over a longer period of time One reason may be that you simply produced more than you can sell (although with production planning and a good marketing plan with multiple options this should not be happening often) You may need to store produce for a few days until you have enough produce to warrant long-distance transport, or while transport to a wholesale market can be arranged through a common carrier For crops such as Barlett pears or blood oranges, a few weeks of cold storage will enhance quality

Another reason to put crops into storage after harvest may be because current market prices are low due to high local production and you anticipate an increase in prices when supplies decrease at the end of the season Or perhaps you produced some crops with the idea of processing them to more stable, value-added products, and would like to do the processing after the rush of the production season has passed

> The red pigment of blood oranges can be developed by storing the fruits for 6 weeks after harvest at a temperature of 0 to 4°C (32 to 39°F)
>
> Source Singh 1998

There are few key factors to consider when storing fresh produce Some cultivars have a naturally longer storage potential than others of the same commodity If you are considering produce storage, you should first determine which varieties will give you the best results The range of storage potential (postharvest performance rating according to maximum market life in weeks) is illustrated by selected stone fruits grown in California

Fruit/Cultivar	Maximum market life at 0 °C (32 °F)
Nectarines	
August Red	6 weeks
Autumn Grand	2 - 3
Early Diamond	5
Fairlane	3
Flamekist	3
Granderli	6
Independence	5 - 6
May Grand	6
Summer Red	5
Peaches	
August Sun	2 - 3
Autumn Gem	1
Coronet	4
Fairtime	2
Fay Elberta	3 - 6
Kern Sun	5
Kings Lady	2
Snow Flame	5
Suncrest	2
Plums	
Angeleno	4 - 5
Catalina	6
Durado	1
Grand Rosa	3
Kelsey	2
Red Beaut	1 - 2
Royal Diamond	5 - 6
Simka	3

Source Crisosto 1996

Indian banana cultivars vary greatly in keeping quality The following have been rated—

very good Nendran

good Monthan, Poovan

poor Basrai, Chakrakali

Source Singh 1998

Next, lowering the temperature to the lowest safe handling temperature is of paramount importance Even if you cannot provide the exact recommended conditions, any effort to lower temperature will be rewarded by longer shelf life, reduced losses and higher quality during marketing

Finally, always handle produce gently and never store produce unless it is of the best quality Damaged produce will lose water faster and have higher decay rates in storage when compared to undamaged produce

CABBAGES STORED FOR 2 MONTHS IN KOREA

	Storage at 20 °C	Storage at 30 to 35 °C (ambient)
weight loss	3 6%	8 9%
weight of decayed produce	1 2%	33 5%
% marketable	95 2%	57 6%

	Non-wounded heads	Wounded heads
weight loss	8 2%	20 6%
weight of decayed produce	3 1%	18 4%
% marketable	88 7%	61 0%

Source Thompson A K 1996

This chapter describes the principles of proper storage and some of the simple storage practices and small structures that can be used on your own farm to make sure your crops are stored under conditions that will provide the maximum shelf life and maintenance of quality and value If you prefer, larger storage structures can be used, perhaps by sharing the costs of construction and maintenance with others who are working cooperatively to market similar crops It is important to follow recommendations for temperature, relative humidity (see Appendix B) and ventilation for specific commodities to ensure that the crops you store will be of high quality after storage

Storage of Mangoes:

Varieties such as Alphonso and Dasheri can be kept successfully in cold storage for 40 to 60 days at a temperature of 9 °C (48 °F).

Source Singh 1998

GENERAL DOs AND DON'Ts FOR STORAGE OF HIGH QUALITY HORTICULTURAL PRODUCE

Store only high quality produce, free of damage, decay and of proper maturity (not over-ripe or under-mature)

Know the requirements for the commodities you want to put into storage, and follow recommendations for proper temperature, relative humidity and ventilation

Harvest most crops before a hard freeze, and don't handle crops for storage when they are wet

Cure root, tuber and bulb crops before storage

Avoid lower than recommended temperatures in storage-- many commodities are susceptible to damage from freezing or chilling

Do NOT overload storage rooms or stack containers too close together

Provide adequate ventilation in the storage room

Provide shade for storage structures or paint buildings white or silver to reflect heat

Overhanging roof extensions on storage structures are very helpful in shading the walls and ventilation openings from the sun's rays, and in providing protection from rain An overhang of at least 1 meter (3 feet) is recommended

Keep storage rooms clean

Storage facilities should be protected from rodents by keeping the immediate outdoor area clean, and free from trash and weeds

Containers must be well ventilated and strong enough to withstand stacking Do NOT stack containers beyond their stacking strength

Monitor temperature in the storage room by placing thermometers at a variety of locations

Dos and Don'ts continued

Don't store onions or garlic in high humidity environments

Store crops in a dark room This is especially important for potatoes, since light will stimulate solanine production (a toxic compound not destroyed by cooking)

Avoid storing ethylene sensitive commodities with those that produce ethylene

Avoid storing produce known for emitting strong odors (apples, garlic, onions, turnips, cabbages, potatoes) with odor-absorbing commodities

Inspect stored produce regularly for signs of injury, water loss, damage and disease Remove damaged or diseased produce to prevent the spread of problems

RECOMMENDED STORAGE TEMPERATURE/RELATIVE HUMIDITY COMPATIBILITY GROUPS

The four principal concerns regarding product compatibility

- Temperature
- Moisture
- Ethylene
- Odor

Please refer to the tables in Appendix B for specific storage recommendations and approximate shelf-life for each commodity

The following groups of commodities can be safely stored together since they have similar requirements for temperature and RH Notice that some of the crops produce odors or ethylene and should be kept away from commodities sensitive to these compounds

Be especially careful not to store chilling sensitive crops at low temperatures Not only will you waste the money you spend on excess cooling, but you may have nothing of value to sell when

you remove them from storage Damage symptoms will usually show up within a few days after you take the crops out of low temperature storage Tomatoes suffering from chilling injury will be so damaged by *Alternaria* (black spots and sunken pits) that customers will be unlikely to buy from you again See Chapter 6 for a list of symptoms suffered by each crop

Compatibility Groups (source McGregor, 1989)

Group 1 Fruits and vegetables, 0 to 2°C (32 to 36°F), 90 95% relative humidity Many products in this group produce ethylene

apples
apricots
Asian pears
Barbados cherry
beets topped
berries (except cranberries)
cashew apple
cherries
coconuts
figs (not with apples)
grapes (without sulfur dioxide)
horseradish
kohlrabi
leeks
longan
loquat
lychee
mushrooms
nectarines
oranges (Florida and Texas)
parsnips
peaches
pears
persimmons
plums
pomegranates
prunes
quinces
radishes
rutabagas
turnips

Citrus treated with biphenyl may give odors to other products

Group 2 Fruits and vegetables, 0 to 2°C (32 to 36°F), 95 100% relative humidity Many products in this group are sensitive to ethylene

amaranth
anise
artichokes
asparagus
bean sprouts
beets
Belgian endive
berries (except cranberries)
bok choy
broccoli
brussels sprouts
cabbage
carrots
cauliflower
celeriac
celery
cherries
corn sweet
daikon
endive
escarole
grapes (without sulfur dioxide)
horseradish
Jerusalem artichoke
kiwifruit
kohlrabi
leafy greens
leeks (not with figs or grapes)
lettuce
lo bok
mushrooms
onions green (not with figs grapes mushrooms rhubarb or corn)
parsley
parsnips
peas
pomegranate
raddichio
radishes
rhubarb
rutabagas
salsify
scorzonera
snow peas
spinach
turnips
waterchestnut
watercress

these products can be top-iced

Group 3 Fruits and vegetables 0 to 2°C (32 to 36°F), 65 75% relative humidity Moisture will damage these products

garlic
onions dry

Compatibility Groups continued

Group 4 Fruits and vegetables 4 5°C (40°F) 90 95% relative humidity

cactus leaves
cactus pears
caimito
cantaloupes
clementine
cranberries
lemons
lychees
kumquat
mandarin
oranges (Calif and Arizona)
pepino
tamarillo
tangelos
tangerines
ugli fruit
yucca root

citrus treated with biphenyl may give odors to other products
can be top iced

Group 5 Fruits and vegetables 10°C (50°F) 85 90% relative humidity Many of these products are sensitive to ethylene These products also are sensitive to chilling injury

beans
calamondin
chayote
cucumber
eggplant
haricot vert
kiwano
malanga
okra
olive
peppers
potatoes storage
pummelo
squash summer (soft shell)
tamarind
taro root

Group 6 Fruits and vegetables, 13 to 15°C (55 to 60°F) 85-90% relative humidity Many of these products produce ethylene These products also are sensitive to chilling injury

atemoya
avocados
babaco
bananas
bitter melon
black sapote
boniato
breadfruit
canistel
carambola
cherimoya
coconuts
feijoa
ginger root
granadilla
grapefruit
guava
jaboticaba
jackfruit
langsat
lemons
limes
mamey
mangoes
mangosteen
melons (except cantaloupes)
papayas
passionfruit
pineapple
plantain
potatoes new
pumpkin
rambutan
santol
soursop
sugar apple
squash winter (hard shell)
tomatillos
tomatoes ripe

citrus treated with biphenyl may give odors to other products

Group 7 Fruits and vegetables, 18 to 21°C (65 to 70°F) 85-90% relative humidity

jicama
pears (for ripening)
sweetpotatoes
tomatoes mature green
watermelon
white sapote
yams

separate from pears and tomatoes due to ethylene sensivity

Moisture loss rate of horticultural produce

Some crops will loss water more quickly than others, due to their high surface area (leafy vegetables), or naturally thin skin (summer squash) These commodities will require extra care to reduce water loss during storage and marketing The loss of protective wax during handling and packing (tomatoes cucumber, peppers) or damage via cuts or bruises will increase the rate of water loss in all commodities Misting or wetting the floor of the storage room will help increase the relative humidity around the produce and decrease the rate of water loss See Chapter 6 for more ideas for controlling RH during postharvest handling and storage

Ethylene in the storage environment

Ethylene will cause are wide range of damage symptoms in sensitive commodities Avoid handling or storing ethylene sensitive commodities with those that produce ethylene during ripening

Undesireable effects of ethylene on sensitive crops include

- Accelerated senescence (spinach, herbs, broccoli)
- Accelerated ripening (climacteric fruits)
- Loss of green color (snap beans broccoli, cucumber, leafy greens)
- Induction of leaf disorders (russet spotting in lettuce, death of leafy greens)
- Isocoumarin formation (bitter taste in carrots)
- Sprouting (potatoes)
- Abscission of florets (broccoli)
- Browning of pulp and/or seeds (eggplant, sweetpotato)
- Toughening (asparagus, turnips)
- Poor flavor (watermelon, parsnips, sweetpotato)
- Reduced effectiveness of CA storage (apples)

Sources of ethylene
Internal combustion engines
Ripening fruits
Leaks from ripening rooms
Propane powered forklifts or other equipment
Decomposing or wounded produce
Cigarette smoke
Rubber materials exposed to UV light or heat

Products that are ethylene producers or ethylene sensitive

Ethylene producers

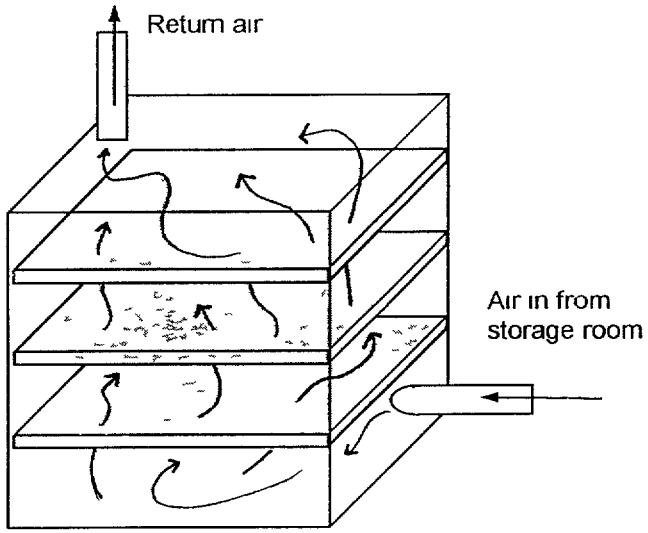
apples
apricots
avocados
bananas ripening
cantaloupes
cherimoya
figs
guavas
honeydew melons
kiwifruit ripe
mamey
mangoes
mangosteen
nectarines
papayas
passionfruit
peaches
pears
persimmons
plantains
plums
prunes
quinces
rambutan
tomatoes

Measuring ethylene

- Sensitive measurement of ethylene gas is still expensive requiring chromatographs costing from $US 7000 to $10 000 (required for levels <1 ppm)
- Low cost gas sampling tubes giving colorimetric reactions can be read down to1 ppm (satisfactory for ripening room operations)

Ethylene sensitive

bananas unripe
Belgian endive
broccoli
brussels sprouts
cabbage
carrots
cauliflower
chard
cucumbers
cut flowers
eggplant
florist greens
green beans
kiwifruit unripe
leafy greens
lettuce
okra
parsley
peas
peppers
potted plants
spinach
squash
sweetpotatoes
watercress
watermelon
yams



ETHYLENE SCRUBBER place Purafil® pellets ($KMnO_4$) in shallow layers on screen trays sealed inside a solid wooden box Air must flow through 3 or 4 trays of pellets for successful removal of ethylene gas

Overcoming undesireable effects of ethylene

- Eliminating sources of ethylene (combustion engine exhaust ripening fruits)
- Ventilation (one air change per hour)
- Chemical removal by filtering air in storage (potassium permanganate scrubbers, UV lamps, activated charcoal catalytic oxidizers)
- Inhibiting ethylene effects
  (controlled atmospheres-- low O_2/ high CO_2 reduces ethylene production rates)

Odor producers and odor absorbers

Some commodities should not be stored with others due to their tendency to give off or absorb odors released by other produce The following is a list of combinations to avoid during long distance transport, storage and marketing

Products which produce or absorb odors

Odor produced by	Will be absorbed by
apples	cabbage carrots celery figs onions meat eggs dairy products
avocados	pineapples
carrots	celery
citrus fruit	meat eggs dairy products
ginger root	eggplant
grapes fumigated w/ sulfur dioxide	other fruits and vegetables
leeks	figs grapes
onions dry	apples celery pears
onions green	corn figs grapes mushrooms rhubarb
pears	cabbage carrots celery onions potatoes
potatoes	apples pears
peppers green	pineapples
strongly scented vegetables	citrus fruit

STORAGE STRUCTURES

There are a wide range of storage structures used throughout the world to successfully store horticultural produce In general the structure needs to be kept cool (refrigerated, or al least ventilated and shaded) and the produce put into storage must be of high initial quality

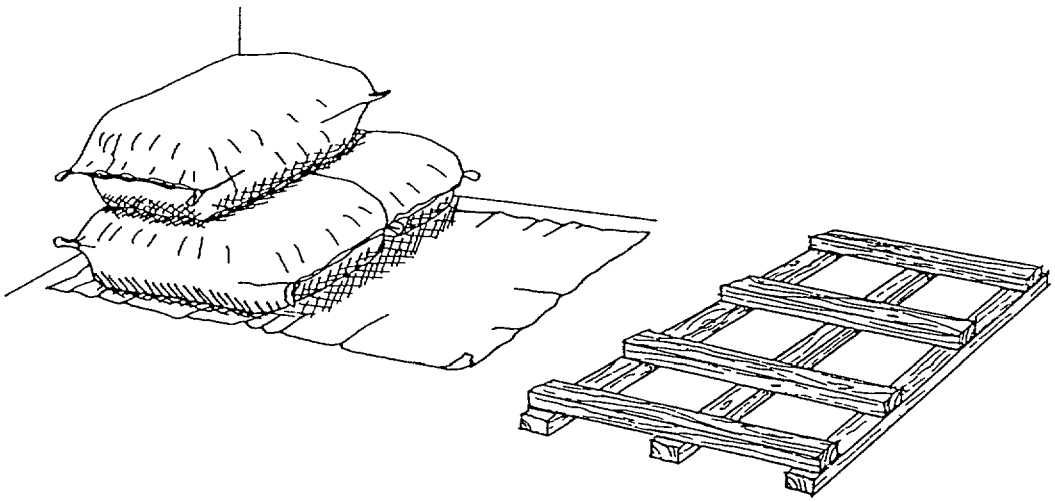
Effect of surface color and orientation on effective outside temperature of a storage building

	Effective Temperature	
Outside air	35 °C	95 °F
Light colored south wall	46	115
Dark colored south wall	57	137
Dark colored flat roof	77	170

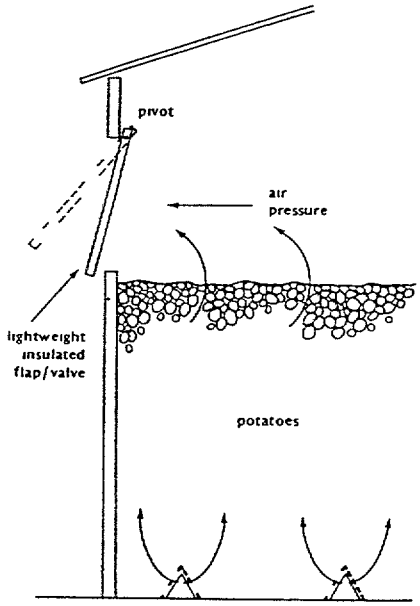
Source Thompson J F 1992

The air composition in the storage environment can be manipulated by increasing or decreasing the rate of ventilation (introduction of fresh air) or by using gas absorbers such as potassium permanganate ($KMnO_4$ an inexpensive compound that will absorb ethylene gas) or activated charcoal (more expensive than $KMnO_4$)

Placing materials on the floor beneath sacks or cartons of produce prevents dampness from reaching produce suited to dry conditions in storage This helps to reduce the chance of fungal infection, while also improving ventilation and/or sanitation in the storeroom Some examples of useful materials follow



Ventilation in storage structures is improved if air inlets are located at the bottom of the store while air outlets are at the top A simple, light-proof exhaust vent is a pressure-relief flap



Source Potato Marketing Board (no date)

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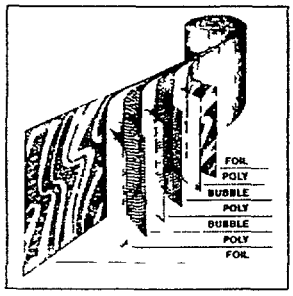
Insulation

Any type of building or facility used for storage of horticultural crops should be insulated properly for maximum effectiveness A well insulated refrigerated building will require less electricity to keep produce cool If the structure is to be cooled by evaporative or night air ventilation, a well insulated building will hold the cooled air longer

The amount of total insulation on the walls of storage buildings usually ranges from R20 to R40, and even higher amounts of insulation are used in the ceiling of new buildings (up to R60)

Insulation R-values are listed below for some common building materials R refers to resistance to heat conduction, and the higher the R-value, the higher the material's resistance to heat conduction and the better the insulating property of the material You will notice that most common building materials provide little or no insulation on their own Therefore, in order to adequately insulate storage buildings you will need to add an appropriate thickness of insulation The materials listed are readily available from local building supply companies Costs will vary depending upon the amount purchased, with discounts for large volumes



Relectix is a new lightweight insulation material made from 2 layers of foil covered bubble wrap that has an extremely high R-value (R14) for a 1/4 inch thick sheet when used to insulate the inside of a roof It is very easy to install and is especially useful for insulating windows since it reflects 97% of radiant heat to which it is exposed The cost is approximately $0 50 per square foot

R-values of Common Building Materials and Types of Insulation

Material	1-inch thickness (2 5 cm)	Full thickness of material
Building materials		
solid concrete	0 08	
8-inch concrete block open core		1 11
8-inch concrete block with vermiculite fill		5 03
lumber (fir or pine)	1 25	
metal siding		<0 01
3/8-inch plywood		0 47
1/2-inch plywood		0 62
Masonite particleboard	1 06	
25/32-inch insulated sheathing		2 06
1/2-inch Sheetrock		0 45
1/2-inch wood lapsiding		0 81
Types of Insulation		
Batt and blanket insulation		
glass wool mineral wool fiberglass	3 50	
Fill-type insulation		
cellulose	3 50	
glass or mineral wool	3 00	
vermiculite	2 20	
sawdust or wood shavings	2 22	
Rigid insulation		
plain expanded extruded polystyrene	5 00	
expanded rubber	4 55	
expanded polystyrene molded beads	3 57	
aged expanded polyurethane	6 25	
glass fiber	4 00	
polyisocyranuate	8 00	
wood or cane fiberboard	2 50	
Reflectix®	14 0	
Foamed-in-place insulation		
sprayed expanded urethane	6 25	

Source Boyette M D no date
and unpublished marketing materials of insulation suppliers

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Commercially constructed cold rooms can be quite expensive, but fortunately the small-scale operator has many choices Cold rooms can be self-constructed, purchased as prefabricated units (new or used), or made from refrigerated transportation equipment such as railway cars, highway vans or marine containers A disadvantage when using any transport vehicle for cold storage is that they are not designed to provide high relative humidity environments Wetting the floor or the walls can help increase RH but can lead to increased corrosion, mold development and reduced equipment life

Rail Cars
- very sturdy, well insulated
- refrigeration powered by electric motor
- relatively low ceiling
- high cost of getting rail car to farm site

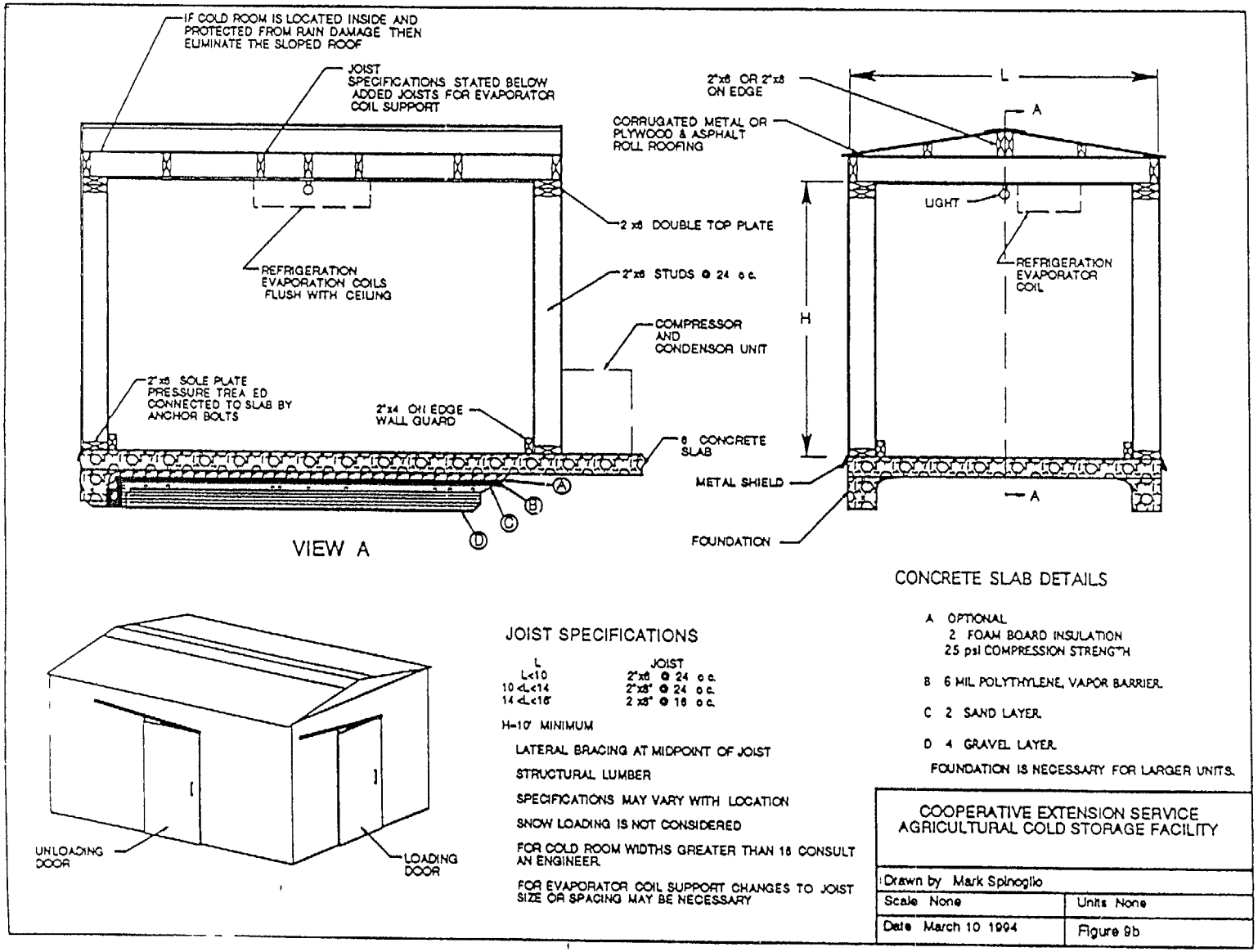
Highway Vans
- portable if wheels are left on
- refrigeration powered by diesel engine
- limited insulation, often leak air
- small fans may not provide adequate ventilation

Marine Containers
- sturdy deep T-beam floors
- sufficient fan capacity for room cooling
- refrigeration powered with 220 or 440 volt three-phase electricity

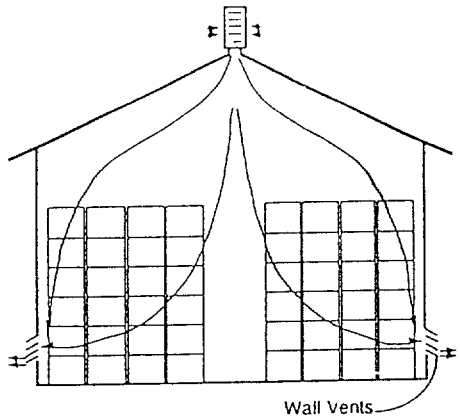
Source Thompson J F 1992

Illustrated on the next page is the basic plan for a self-built cold room. For storage facilities that are refrigerated, using outside air for ventilation is wasteful of energy For these systems, a simple recirculation system can be designed by adding a fan below floor level and providing a free space at one end of the storeroom for cool air to return to the inlet vents For more detailed information about determining the cold room size best suited to your operation, evaluating choices when purchasing or building a cold room, refer to Thompson, J F and Spinoglio, M 1994 Small-scale cold rooms for perishable commodities Family Farm Series, Small Farm Center, University of California, Davis

A Typical Cold Room (Source Thompson and Spinoglio 1994)

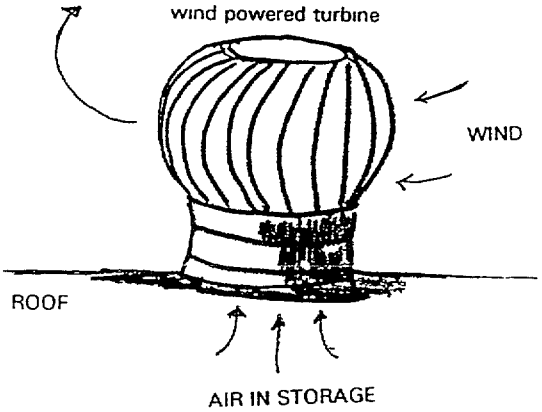


An evaporative cooler located in the peak of a storage structure can cool an entire room of stored produce such as sweetpotatoes or other chilling sensitive crops The vents for outside air should be located at the base of the building so that cool air is circulated throughout the room before it can exit



Source Thompson and Scheuerman 1993

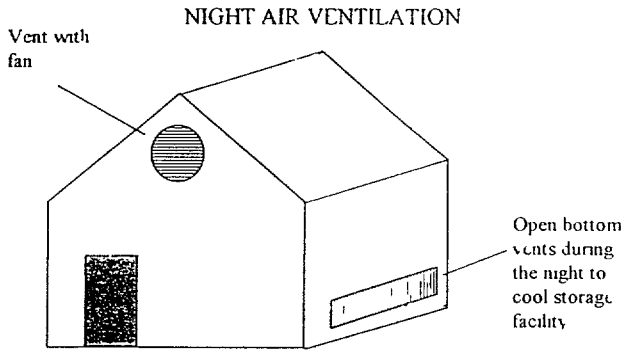
Where electricity is not available, wind-powered turbines can help increase air circulation and keep storerooms cooler by pulling air up through the building Hot air inside the room will naturally move upwards toward the roof peak and exit through the vents in the turbine, creating wind which will spin the turbine and pull more warm air out of the storage room



The turbine illustrated here can be constructed of sheet metal that is twisted to catch the wind, and attached to a central pole that acts as the axis of rotation The turbine should be placed on the peak of the roof of a storage structure

Night air ventilation

Storage structures can be cooled by ventilating at night when outside air is cool For best results, air vents should be located at the base of the storage structure An exhaust fan located at the top of the structure pulls the cool air through the storeroom Vents should be closed at sunrise, and remain closed during the heat of the day

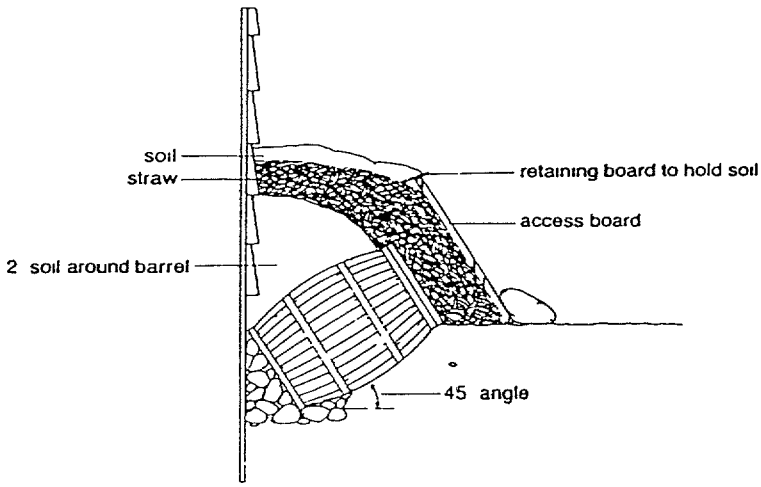


Facilities located at higher altitudes can be especially effective, since air temperature decreases as altitude increases Increased altitude therefore can make evaporative cooling, night cooling and radiant cooling more feasible

Underground storage

One of the simplest methods for storing small quantities of produce is to use any available container, and create a cool environment for storage by burying the container using insulating materials and soil The example provided here uses a wooden barrel and clean, dry straw for insulation

Storage barrel



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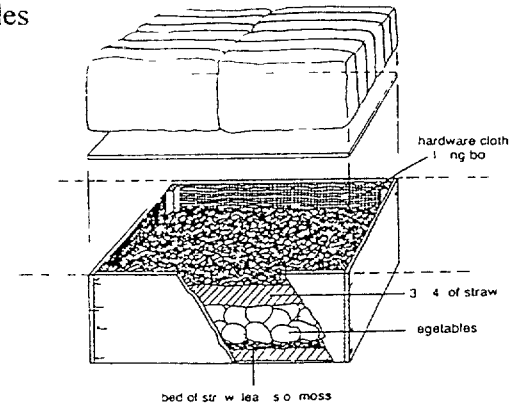
Potato Pit Storage in India

Dig a pit in a shady place, sprinkle it with water for a few days to cool the soil, then line the pit with neem leaves Add a bamboo chimney to provide ventilation

Source Choudhury 1998

Wooden box lined with hardware cloth and covered with straw bales

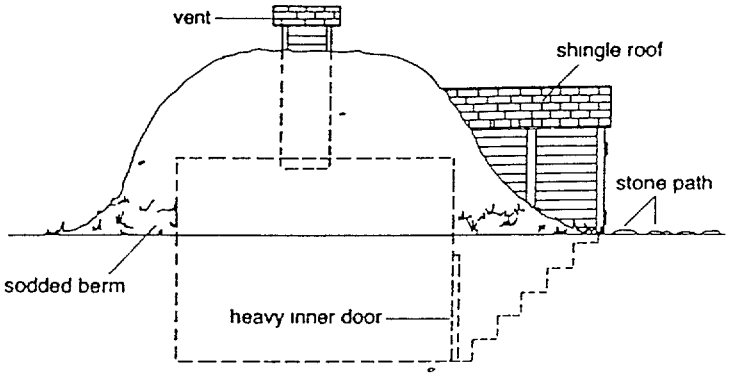


Source Bubel M and Bubel N 1979

A root cellar can be constructed by digging out a pit to a depth of about 2 meters (7 to 8 feet) and framing the sides with wooden planks The example illustrated here is about 3 by 4 meters (12 by 15 feet) in size, with a 35 cm square (one foot square) wooden chute as a roof vent

Produce suitable for root cellaring
Source Hart 1995

Apples
Beets
Cabbage
Carrots
Cauliflower
Celery
Chinese cabbage
Endive
Grapefruit
Grapes
Horseradish
Kale
Onions
Oranges
Parsnips
Pears
Peppers
Potatoes
Pumpkins
Rutabagas
Squash (winter)
Tomatoes (mature green)
Turnips



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STORAGE OF ROOT AND TUBER CROPS

Root and tuber crops account for a the majority of horticultural crops grown worldwide for food, and luckily, can be easily stored using simple structures The recommended storage conditions for root and tuber crops are listed in the following table Potatoes for processing are best kept at intermediate temperatures to limit the production of sugars which darken when heated during processing Potatoes meant for consumption must also be stored in the dark since the tubers will produce chlorophyll (turning green) and develop the toxic alkaloid solanine if kept in the light Potatoes stored for use as "seed" are best stored in diffuse light (CIP 1981) The chlorophyll and solanine that accumulate will aid to protect the seed potatoes from insect pests and decay organisms

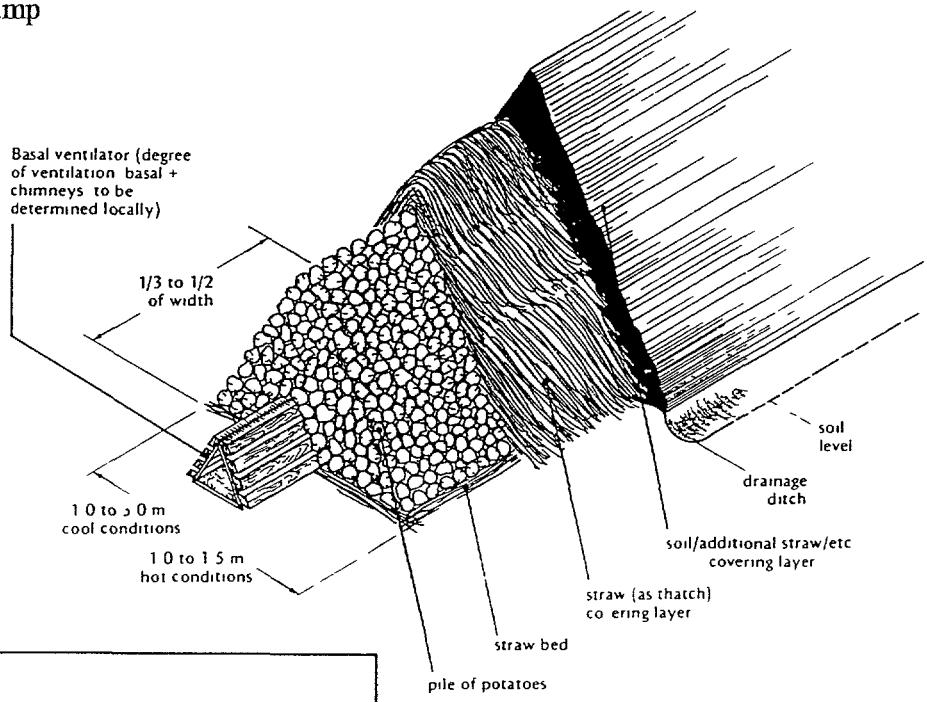
Tropical root and tuber crops must be stored at temperatures that will protect the crops from chilling, since chilling injury can cause internal browning, surface pitting and increased susceptibility to decay

	Temperature		RH(%)	Potential storage duration
	°C	°F		
Potatoes				
Fresh market	4-7	39-45	95-98	10 months
Processing	8-12	47-54	95-98	10 months
Seed potatoes	0-2	32-36	95-98	10 months
Cassava	5-8	41-47	80-90	2-4 weeks
	0-5	32-41	85-95	6 months
Sweetpotato	12-14	54-58	85-90	6 months
Yam	13-15	55-59	near 100	6 months
	27-30	80-86	60-70	3-5 weeks
Ginger	12-14	54-58	65-75	6 months
Jicama	12-15	54-59	65-75	3 months
Taro	13-15	55-59	85-90	4 months

When storing potatoes, a field storage clamp is a low cost technology that can be designed using locally available materials for ventilation and insulation The example illustrated here has a wooden ventilator box and uses clean straw for insulation The entire pile of potatoes and straw is covered with a layer of soil, which should not be highly compacted Gently wetting the soil during hot, dry periods can assist via evaporative cooling

In very cold regions, a second layer of straw and soil can be added In hot regions less soil is needed, but more ventilation can be added by constructing chimney type air outlets at the top of the clamp Locating the clamp under trees or providing a roof or other protection from rainfall is a good idea if you will be storing produce during the rainy season

Field storage clamp



Field clamp/Pit storage

Maximum storage time 6 months
Maximum volume 500 kg
Use several clamps if you have more produce to store

Source CIP 1981

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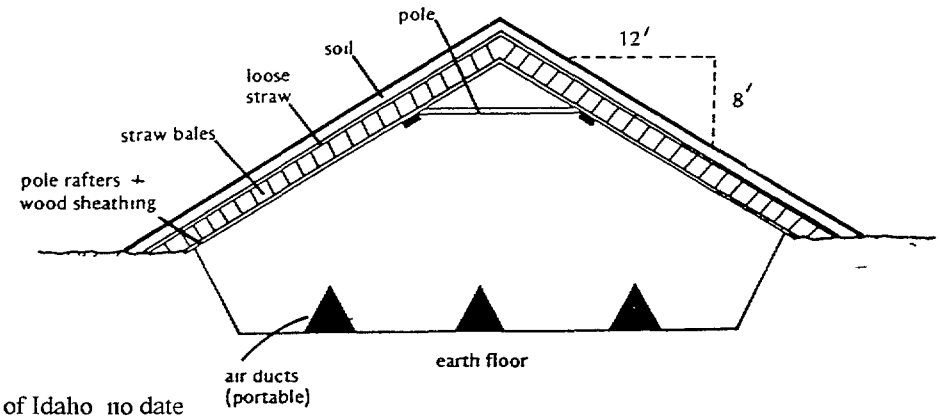
For large quantities of potatoes a self-supporting A-frame storehouse can be constructed A pit is dug about 2 5 m (10 feet) deep and wooden air ducts are placed along the earthen floor The roof of the building is constructed of wood then covered with straw and soil When loading potatoes into bulk storage, make sure the crop is evenly distributed Uneven loads will slow air movement in some areas of the storage room and lead to higher storage losses



Source University of Idaho no date

Onions, garlic and dried produce are best suited to low humidity in storage Onions and garlic will sprout if stored at intermediate temperatures, so if you can't keep them cold, storage life will be greatly reduced Pungent types of onions will store longer than mild onions, which are rarely stored for more than one month The following table lists the storage conditions recommended for these crops

Storage Conditions	Temperature		RH	Potential storage duration
	°C	°F	%	
Onions	0-5	32-41	65-70	6-8 months
	28-30	82-86	65-70	1 month
Garlic	0	32	70	6-7 months
	28-30	82-86	70	1 month
Dried fruits and vegetables	<10	<50	55-60	6-12 months

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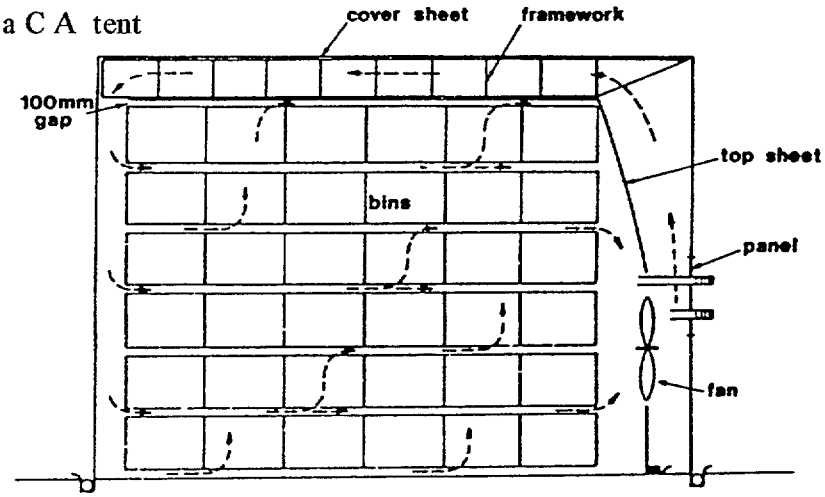
Controlled Atmosphere (C A) Storage

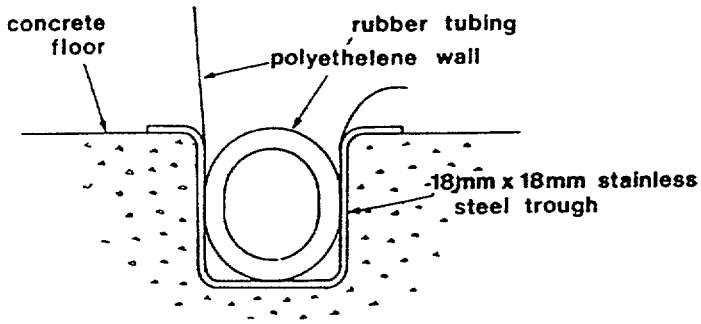
The cost of construction of a CA storage room is about 5% higher than for the same sized conventional cold room CA storage is more expensive since the storage room must be completely gas sealed and gas composition must be monitored constantly to prevent damage to the produce Refer to Appendix C for recommended atmospheric composition, temperature and storage life for specific commodities suited to CA storage

A lower cost approach for controlled atmosphere storage of pallet loads of produce is also possible using a semi-permanent set-up for creating a gas-seal inside a conventional cold room Any number of pallets can be accomodated inside a plastic tent The gas seal is provided by a small trough constructed of sheet metal laid in a rectangular pattern into a concrete floor of a storage structure during construction A very thick (7-mil) polyethylene sheet is put over the pallet load of produce, and the sheet is sealed by pushing a long piece of rubber tubing into the trough

Typical layout of a C A tent (cross-section)



Layout of a seal in the trough on the storeroom floor



Source McDonald 1982

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COMPARISON OF ESTIMATED COSTS AND EXPECTED BENEFITS RELATED TO STORAGE OF HORTICULTURAL CROPS

Costs
Storage structure
Suitable packages
Temperature/RH management
Labor
Power

Benefits
Longer shelf life, extended marketing period
Higher market prices due to off-season sales

Example 1 A variety of edible and decorative squash is grown and harvested in the U S in September The market price during September is $0 25/lb, while the price during the holiday season (Halloween, Thanksgiving and Christmas) is an average of $0 60/lb A simple underground storage structure, cooled by the natural properties of soil, deep shade and night air ventilation, is constructed to store 1000 lbs of squash for up to 3 months (in bulk, stacked on pallets) Useful life of the root cellar is 20 to 25 years Assume that the produce loses 10% of its weight over 3 months, and the remaining 900 lbs is sold at $0 60/lb

Costs $180 for labor for root cellar construction
$400 for materials (treated lumber for framing, ceiling, door, ventilation shaft and fan), floor and walls are bare soil
Power for fan (runs for 6 hours per night for 3 months) = $15 00

Benefits
(Expected sales during the holiday season) - (typical sales in September) =
(900 lbs x $0 60/lb) - (1000 x$0 25) =
$540 -250 = $290

The entire cost of construction of the root cellar is paid for during the first two years of operation, each additional year of operation results in an additional profit when produce is sold during the holiday season $290 - $15 = $275

Example 2
Ash gourd is grown and harvested in September and October The market price during this time is Rs 1 /kg, while the price during the festival season in November and December is an average of Rs 7/kg A simple underground storage structure, cooled by the natural properties of soil, deep shade and night air ventilation, is constructed to store 8 quintals of squash for up to 3 months (in bulk, stacked on pallets) Useful life of the root cellar is 20 to 25 years Assume that the produce loses 10% of its weight over 3 months, and the remaining 720 kg is sold at Rs 7/kg

Costs Rs 800 for labor for root cellar construction
Rs 6600 for materials (treated lumber for framing, ceiling, door, ventilation shaft and fan), floor and walls are bare soil
Power for fan (runs for 6 hours per night for 3 months) = Rs 100

Benefits
(Expected sales during the festival season) - (typical sales in September) =
(720 kgs x $Rs 7/kg) - (800 x Rs 1/kg) =
Rs 5040 -Rs 800 = Rs 4240

The entire cost of construction of the root cellar is paid for during the first two years of operation, each additional year of operation results in an additional profit when produce is sold during the holiday season Rs 4240 - Rs 100 = Rs 4140

SOURCES OF STORAGE EQUIPMENT AND SUPPLIES

C A equipment	California Controlled Atmospheres
ethylene absorbers filters scrubbers	DeltaTRAK Inc Ethylene Control Inc International Ripening Corp TUBAMET AG
fans, ventilation systems	Industrial Ventilation, Inc
12-volt evaporative coolers, air-conditioners, ceiling fans	Alternative Energy Engineering Jade Mountain, Inc
humidifiers	McCormick Fruit Tech International Ripening Corp
hygrometers (to measure RH)	International Ripening Corp
insulation	Reflectix, Inc
solar powered evaporative coolers	Jade Mountain Inc
solar powered fans and storage ventilators	Alternative Energy Engineering
temperature alarm/timer	International Ripening Corp
temperature recorders	Monitor Company

thermometers temperature/RH meters	DeltaTrak International Ripening Corp McCormick Fruit Tech Post-Harvest Technologies

For Addresses/Phone numbers please refer to Appendix D

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CHAPTER 8

PRODUCE TRANSPORTATION

Produce must often be transported as part of fresh handling, whether from the field to the packinghouse, from the packinghouse to storage facility, or to various destination markets During transport, produce must be stacked in ways that minimize damage, then be braced and secured An open air vehicle can be loaded in such a way that air can pass through the load, and provide some cooling of the produce as the vehicle moves Traveling during cooler hours (night and early morning) can reduce the heat load on a vehicle that is transporting produce

Refrigerated transport is highly recommended for most perishable horticultural produce Temperature management is especially critical during long distance transport, and proper air flow is the most important factor in ensuring that the load stays cool Loads must be stacked to enable proper air circulation to carry away heat from the produce itself as well as incoming heat from the atmosphere and off the road Transport vehicles should be well insulated to maintain cool environments for pre-cooled commodities and loads should be braced away from the side walls and back door of the trailer

Average road temperatures can be much higher than air temperatures during hot months of the year In the western U S , road surface temperatures can be 22 °C (40 °F) higher than the air temperature, making it difficult for refrigerated vehicles to maintain recommended temperatures

Transit times under these conditions should be as short as possible, since deterioration will increase as temperatures increase

Mixed loads can be a serious concern when recommended temperatures are not compatible (for example, when transporting chilling sensitive fruits with commodities that require very low temperatures) Try to avoid this situation, since either some of the produce will be injured by chilling or some of the produce will deteriorate more quickly than when handled at the recommended low temperature and your investments in postharvest handling technologies will largely be wasted

Another problem arises when ethylene producing commodities and ethylene sensitive commodities are transported together High ethylene producers (such as ripe bananas, apples, cantaloupe) can induce physiological disorders and/or undesirable changes in color, flavor and texture in ethylene sensitive commodities (such as lettuce, cucumbers, carrots, potatoes, sweet potatoes) Using ethylene scrubbers installed in the vehicle can reduce this problem during transport

C A Transport

avocadoes
stone fruits
pears
mangoes
asparagus
tangerines

In 1996 only 2 5% of US produce imports/exports were shipped using controlled atmosphere In addition to regular shipping charges carriers charge a standard flat fee of $1500 ($1 50 per carton for a typical 1000 carton load) making C A transport viable only for high value commodities

This chapter describes postharvest technologies for transporting horticultural commodities via open and refrigerated loads Quality and food safety can be protected by using proper loading methods and patterns, recommended features of refrigerated vehicles, and bracing techniques We have included a sample calculation of how you can determine the refrigeration capacity required for transporting for a specific load of produce Completing the chapter is a simple example of the costs and benefits of using ice when transporting produce designed to assist you to complete the worksheets to determine the return on investment when adopting specific postharvest transport practices for your operations

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GENERAL DOS AND DON'TS FOR TRANSPORTING HIGH QUALITY PRODUCE

Do NOT overload vehicles

Prevent compression damage to produce by avoiding over-filling of containers (rounded sides or bulge-packing) and stacking heavier produce at the bottom of the load

Use strong packages (half the stacking strength of a corrugated fibreboard container can be lost during a five day trip in a high humidity environment)

Avoid rough handling during loading and unloading

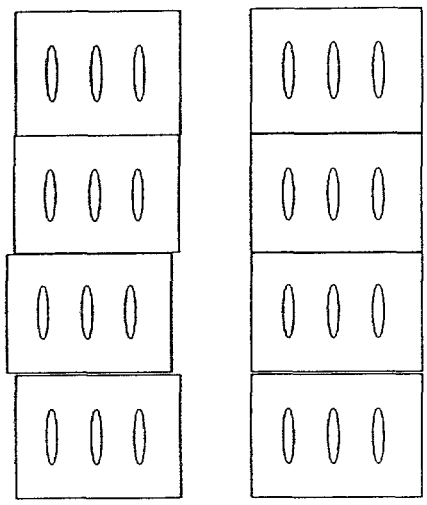
When stacking containers, be sure to align them properly (most of the strength of a corrugated box is in the corners) A one inch overhang will decrease stacking strength by 15 to 34%

Prevent vibration damage by using air suspension systems -- these will provide a more gentle ride during transportation

Using suitable trays, place packing, use of plastic bags, container liners, or placing a soft pad at the top of a full box can reduce vibration damage

Make sure the vehicle has adequate ventilation to prevent heat gain during transport

Use a pre-loading checklist to ensure the vehicle is ready to use successfully



Well alligned stack of cartons has the strongest stacking strength possible

DOS AND DON'TS FOR REFRIGERATED TRANSPORT

Ensure that vehicles are well-insulated and have doors that seal tightly and securely

Run through the check-list for refrigerated transport before handling each load

Look for recommended design features when purchasing new or used transport vehicles

Pre-cool refrigerated vehicles to suit produce requirements

Load only pre-cooled produce into vehicles from a refrigerated dock

Do NOT allow delays when loading on an open dock-- delays will cause heat gain, especially if produce is exposed to full sun

Turn off the refrigeration unit while loading from a open dock (leaving the unit on may cause ice to form on the refrigeration coils, blocking air circulation during transport)

Use high quality vented containers and load produce to ensure adequate air movement through the load to remove the heat generated by produce respiration

Do NOT block air flow under or anywhere else in the load

Monitor the supply air temperature and the return air temperature for obtaining the best performance of refrigeration units

Avoid mixed loads if possible, or install ethylene scribbers to prevent damage to ethylene sensitive commodities

Do NOT tranport chilling sensitive commodities when thermostats are set below 12-15 °C (53- 59 °F)

Load produce away from the side walls to prevent heat gain from the external environment

Make sure mixed sizes of containers or unpalletized produce does not block lengthwise air flow

Do NOT turn off the refrigeration unit during delays in transport

Dos and Don'ts continued

Brace the load at least 5 cm (2") away from the side walls and at least 10 cm (4") away from the rear door

Use a portable temperature recorder to verify temperature management during transport

TRNASPORTATION METHODS

Open Vehicles Bulk loads of produce should be carefully loaded so as not to cause mechanical damage Vehicles can be padded or lined with a thick layer of straw Woven mats or sacks can be used in the beds of small vehicles Other loads should not be placed on top of the bulk commodity Never stand upon the produce during loading or unloading

TRANSPORTING OPEN LOADS

Provide a thick layer of insulation and cushioning for bulk loads

Load packaged produce in uniform stacks, braced securely to prevent damage

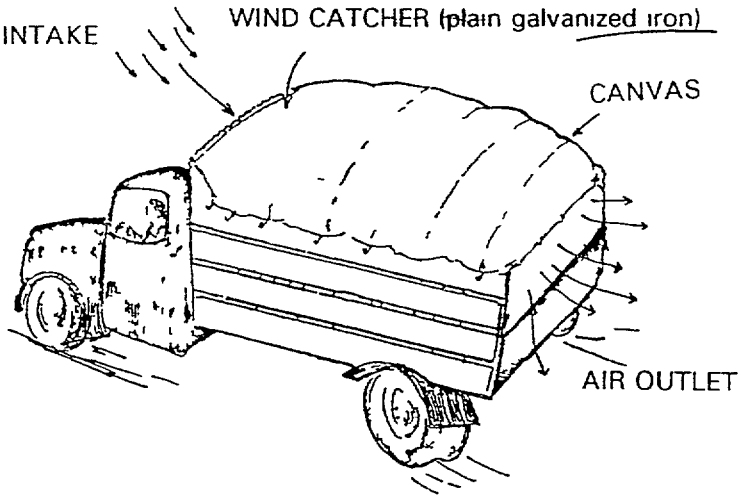
Construct a wind catcher for moving air into the vehicle during transport

Provide channels for passive air movement beneath and up through the load (exiting at the rear of the vehicle)

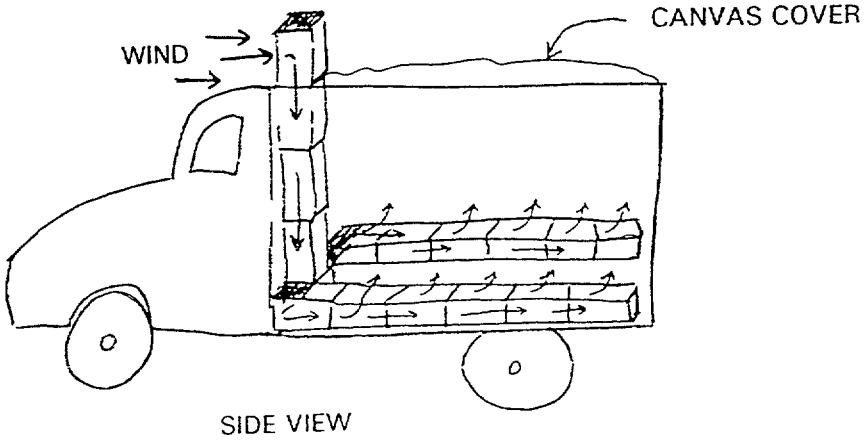
Provide shade for the load with a silver or light-colored canvas cover

Cooling open loads is desirable whenever possible A truck ventilating device can be constructed for an unrefrigerated open vehicle by covering the load loosely with canvas and fashioning a wind catcher from sheet metal The scoop should be mounted at the front of the bed and should reach somewhat higher the the height of the cab High transportation speeds and/or long distance transport during dry weather run the risk of causing excess drying of the crop

Ventilating systems have been designed for hauling bulk loads of fresh produce The first illustration shows a metal wind catching device which funnels air into a load covered by a canvas sheet The second example was designed by R Kasmire to transport fresh fava beans in Iran The wind catcher and ducts were constructed using wooden crates After removing their end panels the crates were wired together into the pattern shown below Air flows upward through the load during transport, helping to keep the produce from overheating This system has also been used in pick-up trucks and for hauling bulk greens and green beans Best results are obtained when transporting during the early morning hours, before sunrise



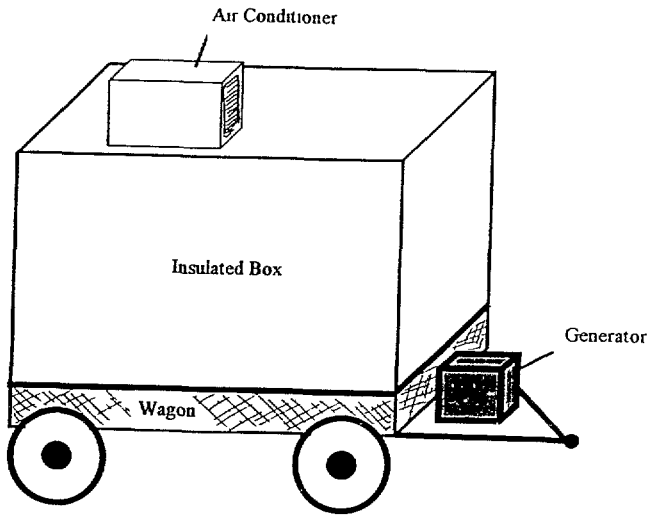
Source Pantastico 1980

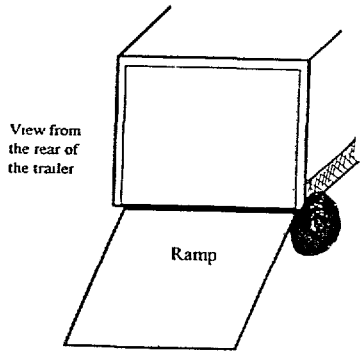


Portable Field-to-Market Coolers

This simple trailer cooler was constructed using a room-sized air conditioning unit powered by a diesel generator and an insulated storage box The trailer can either be built as a unit with wheels or the cooler can be loaded upon a pre-existing wagon or low-boy trailer

The cooler is designed to be loaded at the field during the morning hours (when the air temperatures and produce temperatures are relatively low) and used to pre-cool produce during the period between harvest and packing or between field-packing and immediate marketing



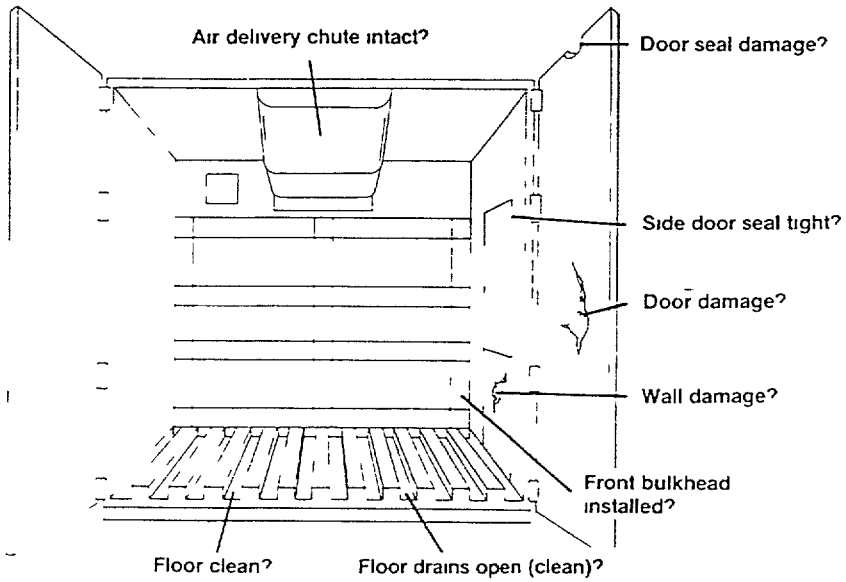


Similarly an insulated cooler box was designed by Mejia (1991) to fit into a long-bed pick-up truck Two standard pallet loads of produce can be cooled to 5 °C (40 °F) in about 4 hours from an ambient air temperature of 29 °C (85 °F) Mejia's design uses a stationery 3 ton mobile home air conditioning unit to which the cooler box is connected after being loaded with produce in the field Once produce is cooled the box is sealed and transported to market

REFRIGERATED TRANSPORT

Small-scale postharvest cold transport can be accomplished using a cargo van fitted with a high powered air conditioning system If a pre-cooler is not available, a 4000 to 5000 Btu window model air conditioning unit can cool produce by 17 °C (30 °F) compared to the outside air temperature It is a good idea to humidify the environment by misting the air with cool water or covering open crates of produce with wet towels or wet burlap cloth

The condition of the inside of a refrigerated trailer affects its ability to maintain desired temperatures during transport When renting, leasing or hiring an independent vehicle to transport your produce, you should always inspect the trailer before loading, and check these features Any damage will let heat in and make temperature management much more difficult Even when the buyer pays for shipment, checking for problems will save you time and money by helping you avoid losses and produce damage during transport



Source Kasmire and Hinsch 1987

Inside width adequate for load?
Inside height adequate for load?
Door height adequate for load?
Load bars used to secure load?
Trailer precooled before loading?
Refrigeration unit operates satisfactorily?

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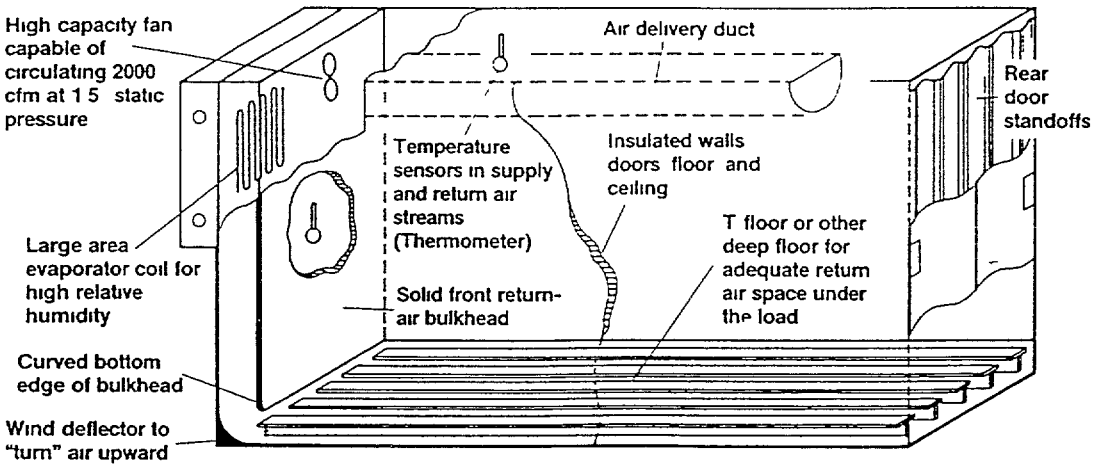
Refrigeration Systems Components (Source Kasmire and Hinsch 1987)

For Optimum Transit Temperature Management, Refrigerated Trailers Need These Features



Pre-cooling vehicles before loading

- Vehicles to be loaded at refrigerated docks should be pre-cooled to their desired thermostat set point
- Vehicles to be rapidly loaded (15 to 20 minutes) at non-refrigerated docks should be pre-cooled to about 2 °C (5 °F) above their desired thermostat set point
- Vehicles that will be loaded slowly (30 minutes or more) at non-refrigerated docks should be pre-cooled to about 2 ° C (5 °F) lower than a temperature halfway between ambient air temperature and the desired set point

This will prevent accumulation of excess moisture on the vehicle s inner surfaces and reduce subsequent cycling of the refrigeration unit

Source Picha 1997

Estimating Refrigeration Requirements

If you ever have any doubt that a refrigerated vehicle is of adequate capacity for the load you want to transport calculate the number of Btus of heatload that must be handled by the refrigeration system to keep the load cool Ashby (1995) contains all the tables and sample calculations to assist you to calculate heatload for your commodity and suitation

First you will need to calculate
1) **Hf** the amount of field or sensible heat left in the commodity and the package When produce is properly pre-cooled, this is very low, since the temperature differential is low

Hf (Btu)=
specific heat of the produce & container
x weight of the produce & container
x temperature differential

2) **Hr** the produce's heat of respiration

Hr (Btu) =
respiration rate at average transit temperature
x time (in days)
x weight (in tons)

3) **Hl** the amount of heat leakage through the walls and floor of the trailer Heat transfer coefficients have been calculated for specific vehicles by their manufacturers, and depends on many things including type and thickness of insulation, size and shape of the vehicle As a vehicle ages and insulation breaks down, the coefficient tends to increase The estimate of heat transfer for a new 48-foot trailer with 2 5" of foam sidewall insulation is 140 Btu/ degree °F/hour The temperature differential refers to the difference between the thermostat setting and the average outside temperature

Hl (Btu) =
the coefficient of heat transfer
x temperature differential
x time (hours)

4) How much heat can be absorbed by the refrigerant you are using

Mechanical refrigeration units are rated according to the number of Btus per hour the unit can remove when the temperature is 100 °F outside versus 35 °F inside the trailer

One pound of ice will absorb 144 Btus of heat
One pound of liquid nitrogen will absorb approximately 175 Btus of heat

Sample calculations for a load of produce
Use these tables to calculate the amount of refrigeration needed to cool your load of produce

Specific heat above freezing for selected perishables (from ASHRAE 1990)

Apples	0 87 Btu/ lb / °F
Cantaloupe	0 93
Green beans	0 91
Grapes	0 86
Potatoes	0 82
Summer squash	0 95

Approximate Heat of Respiration (from ASHRAE 1990) in Btus/ ton / 24 hours

	32 °F	40 °F	60 °F	70 °F
Apples	700	1 350	4 900	5 700
Cantaloupe	1 200	2 050	7 950	12 000
Green beans	7 250	10 300	38 100	49 200
Grapes	600	1 200	3 500	7 200
Potatoes (cured)		2 600	4 850	6 950
Summer squash	2 700	3 600	18 250	20 050

Assumptions
Assume a refrigerated 24 ft trailer will be loaded with apples in 30 lb fiberboard boxes The trailer can hold 600 boxes, for a total produce weight of 18,000 lbs (9 tons) The boxes weigh 2 lbs each, so the total weight of the boxes is 1,200 lbs The specific heat of most wood and fiberboard boxes is 0 44 Btu / lb / °F

The specific heat of the apples is 0 87 Btu/ lb /° F, at a loading temperture of 52 °F The desired load temperature is 32 °F and the thermostat is set at 34 F to avoid freezing damage Average load temperature is assumed to be 40 °F Transit time is three days during which outside average aur temperature is 75 °F The heat transfer coefficient for the trailer is 80 Btu /°F / hour

Hf (apples) = 0 87 Btu / lb /°F x 18,000 lbs x 20 °F = 31,320 Btus
Hf (boxes) = 0 44 x 1,200 x 20 = 10,560
Hf (total) = 41,880 Btus

Hr = 1,350 Btu / ton /day x 3 days x 9 tons = 36,450 Btus
Hl = 80 Btu / °F /hour x (75 °F- 34 °F) x 72 hours = 236,160 Btus

Hf (total) + Hr + Hl = the amount of Btus the refrigeration unit must remove in three days
41,880 + 36,460 + 236,160 = 314,500 Btus

Amount of mechanical refrigeration needed = 314,500 Btu / 72 hours = 4368 Btu/ hour
Amount of ice needed = 314,500 Btu / 144 Btu / lb = 2,184 lbs

Refrigerated Vehicles-- Pre-loading Checklist

___ Refrigeration unit operating properly?

___ Thermostat calibrated?

___ Refrigeration air chutes and ducts properly installed and in good repair?

___ Door seals in good condition?

___ Doors seal tightly when closed?

___ Walls free of cracks and holes?

___ Front bulkhead installed?

___ Floor drains open?

___ Inside of vehicle clean and odor-free?

___ Floor grooves free of debris?

___ Inside height, width, length adequate for load?

___ Load braces and other devices available to secure load?

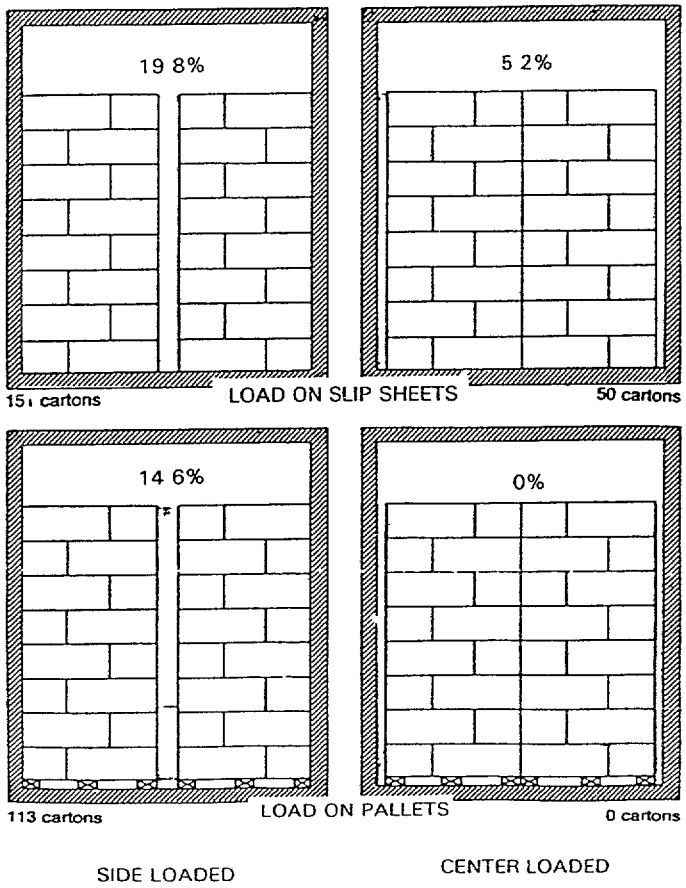
___ Is the vehicle trailer pre-cooled (or pre-warmed)?

Source Ashby 1995

STACKING PATTERNS/PALLET AND SLIP SHEET LOADS

Containers should be loaded so that they are away from the side walls and the floor of the transport vehicle in order to minimize the conduction of heat from the outside environment In the diagrams below the numbers of cartons refer to how many cartons would be in contact with the walls and floor of the truck when fully loaded

Only the load on the bottom right is fully protected from heat transfer The use of pallets keeps the cartons off the floor while center-loading leaves an insulating air space between the pallet loads and the outside walls

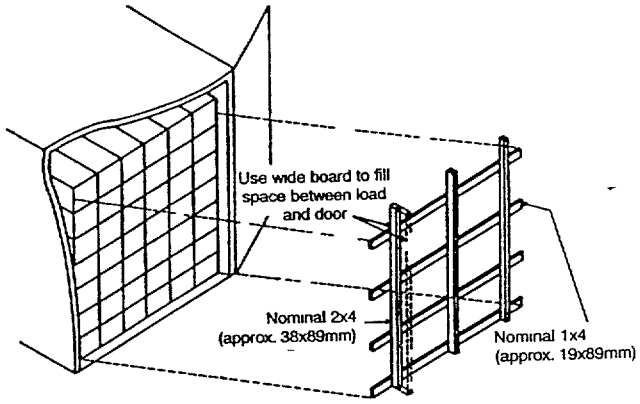


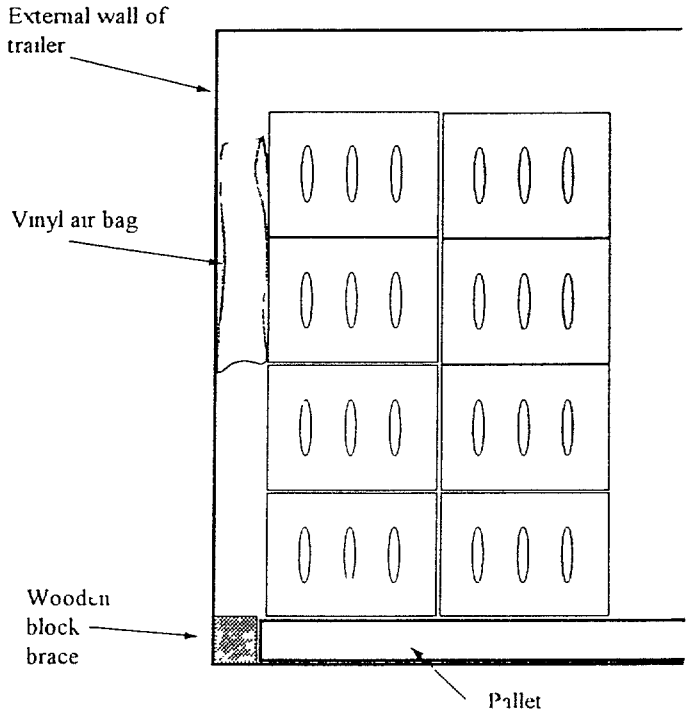
Source Ashby B H et al 1987

BRACING THE LOAD

There should always be an air space between the last stack of produce and the back of the transport vehicle The load should be braced to prevent shifting against the rear door during transit If the load shifts, it can block air circulation, and fallen cartons can present great danger to workers who open the door at a destination market A simple wooden brace can be constructed and installed to prevent damage during transport

Wooden brace (rear door)





Wooden braces for side walls can be used, but they are heavy and can become expensive to build and transport Air-filled bags made of vinyl can provide excellent bracing and 5 cm of added insulation (2" thick) against side walls The bottom of the pallets are braced with wood blocks to prevent load shifting

COSTS AND BENEFITS OF USING ICE FOR COOLING DURING TRANSPORT TO MARKET

Costs
Ice
Reduced amount of produce per load
(all other expenses are assumed to be the same)

Benefits
Reduced water loss
Reduced decay rates
Higher quality during marketing
Longer shelf life

Example 1

		with ice	no cooling
1/2 ton pick-up load of mixed lettuces		750 lbs	1000 lbs
cartons @ $2 50 each (20 lbs/carton)		38 cartons = $95	50 cartons=$125
ice ($0 50/10 lbs)	$0 05/lb	250 lbs = $12 50	0
water loss/decay rate		5%	10%
losses		(37 50 lbs)	(100 lbs)
Produce available to sell		712 5 lbs	900 lbs
Quality grades	highest ($1 19/lb)	90% =$742)	60%=($535)
	second ($0 69 lb)	10% =($49)	30%=($186)
	lowest ($0 25/lb)	0%	20% =($45)
Market value		$812	$766
Costs containers		($95)	($125)
ice		($12 50)	0
Potential net sales per load		$704 50	$641

USE OF ICE DURING TRANSPORT
Remember to consider the added weight of the ice when calculating vehicle loads

Use package ice or apply ice in channels or windrows (do not block air flow by applying in a uniform solid layer)

Avoid setting the thermostat too low in a refrigerated vehicle (below 2 °C or 35 °F)--this will cause ice to freeze solid and create a barrier to air flow

Example 2 Transporting fresh peas in wooden crates from Punjab to Gujarat State in December

	with ice	no cooling
Market location	Gujarat	Punjab
open load of fresh peas	500 kg	700 kg
crates @ Rs 20 (20 kg/crate)	25 crates= Rs 500	35 crates = Rs 700
ice (Rs 25/100 kgs) Rs 0 25/kg	250 kg = Rs 65	0
water loss/decay rate	5%	15%
losses	(25 kg)	(105 kg)
Produce available to sell	475 kg	595 kg
Market value	Rs 20/kg	Rs 5/kg
	Rs 9500	Rs 2975
Costs containers	(Rs 500)	(Rs 700)
ice	(Rs 65)	0
Potential net sales per load	Rs 8935	Rs 2275

Profits will depend upon the cost of transport Fees for freight can be quite high (up to Rs 6000 per load) before the use of ice for cooling peas in December becomes unprofitable

SOURCES OF TRANSPORT EQUIPMENT AND SUPPLIES

ethylene absorbers	DeltaTRAK Inc
ethylene scrubbers	TUBAMET AG
ice-packs ice wraps	Aladdin Industries Inc
freezable gel-filled or water-filled bags	Cargo Technology Corp
"cool guard"	IFC
loading guide	TransFRESH Corp
mini-reefers (slip in cooler for pick-ups)	CMF Corp
refrigeration system	Carrier Transicold
temperature/humidity data loggers	DeltaTRAK Inc Dickson Sensitech Inc
temperature recorders	DeltaTRAK Inc Dickson
therma-cover	ThermaGard, Inc
transport services	Roadway Express SeaLand Service, Inc

For addresses and phone/FAX numbers for suppliers please refer to Appendix D

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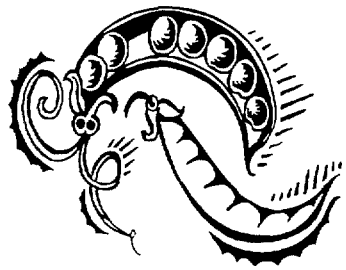
CHAPTER 9



POSTHARVEST INTEGRATED PEST MANAGEMENT

Many of the practices described so far in Part I are valuable because they help reduce pest problems during postharvest handling, storage and marketing The first line of defense against insects and disease is good management during production Monitoring to determine actual pest levels and a combination of appropriate genetic, biological, cultural, physical and chemical controls is usually enough to prevent serious pest damage The second defence is careful harvesting and preparation for market in the field, since most diseases can't gain a good start without easy entry through cuts, bruises or injuries Next, sorting out damaged, over-ripe or decaying produce will limit contamination of the remaining, healthy produce Finally, even when the greatest care is taken, sometimes produce must be treated to control insects or decay-causing organisms

Postharvest IPM Tools
Genetic pest resistance
Biological yeasts, antagonistic bacteria
Cultural sanitation, decrease mechanical damage
Physical sorting, heat treatment, temperature and RH management
Chemical chlorinated wash water, pesticides

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This chapter will review some of the postharvest technologies related to pest control and outline the practices recommended for postharvest Integrated Pest Management (IPM) Also provided is information that will help you to identify pest problems and implement specific postharvest IPM methods and treatments

GENERAL DOs AND DON'Ts FOR POSTHARVEST IPM

Consider the entire system (production, harvest, postharvest and marketing) when developing pest management strategies

PRE-HARVEST
Begin with cultivars offering some natural resistance to the pests you expect to have to deal with in your region

Plant only good quality, clean seed or stock

Use appropriate cultural practices during production to assist the produce to avoid and/or resist pest attack (proper planting density, fertilization, irrigation, pH modification, weeding, pruning, thinning, ventilation/air movement through the canopy)

Monitor fields/orchards to determine actual pest levels before implementing pest controls

Use a combination of appropriate pest control methods (biological control, chemical pesticides, protectants, sanitation practices)

Keep fields and orchards free of debris and discarded produce Eradicate diseased produce

HARVEST
Avoid damage during harvest by handling produce gently

Harvest at the proper maturity for produce to have the maximum resistance against pests

Use sharp, clean tools for harvest and trimming processes

Do's and Don'ts continued

CURING
Cure root, tuber and bulb crops to heal harvest wounds and increase resistance to pests

PACKINGHOUSE
Sort to remove any damaged, decayed over-mature or under-ripe produce

Wash or clean produce to remove soil and debris and to reduce the amount of innoculum on surfaces

Trim senescent leaves from vegetables and remove dried flower parts from fruits

Use appropriate postharvest treatments to manage pest problems (chemicals, heat, hot water, pesticides)

PACKING
Avoid over-use of liners that constrict air flow in the package and contribute to condensation (free moisture) and poor cooling efficiency

Use ventilated plastic bags as liners for produce highly susceptible to water loss

STORAGE
Avoid ethylene damage to sensitive commodities by using ethylene scrubbers and avoiding mixed lots of produce in storage

Keep produce at its lowest safe temperature for maximum pest management

Avoid chilling injury by keeping sensitive commodities at appropriate moderate temperatures

Keep leafy vegetables, carrots, and cool season vegetables at very high relative humidity (98-100%) to reduce incidence of decay

Store certain fruits at slightly lower RH than commonly recommended in order to reduce decay

Store onions and garlic at low humidity to reduce decay (60-70% RH)

Most diseases cannot gain a good start without your help

- wounds, cuts, bruises
- chilling injury
- free moisture on produce surface
- advanced stages of ripening or senescence

Common Postharvest Diseases

FUNGAL DISEASES

A variety of fungal diseases cause the greatest market and storage losses

Disease organism	Scientific name	Affects these crops
Alternaria black rot	*Alternaria citri*	citrus
Alternaria rot	*Alternaria alternata*	tomatoes peppers
	Alternaria sp	stone fruits
Black rot	*Physalospora obtusa*	apples pears quinces
	Endocondiophora frimbriata	sweet potatoes
Blue mold	*Penicillium expansum*	apples pears quinces
	Penicillium italicum	citrus
	Penicillium sp	grapes berries stone fruits
Bitter rot	*Glomerella cingulata*	apples pears quince
Brown rot	*Monolinia fructicola*	stone fruits
Buckeye rot	*Phytophthera* sp	tomatoes peppers
Bull's eye rot	*Pezicula malicorticus*	apples pears quince
Cladosporium rot	*Cladosporium hebarum*	grapes small fruits
Crate rot	*Rhizoctonia carotae*	carrots
Fusarium tuber rot	*Fusarium* spp	potatoes
Fusarium wilts	*Fusarium* spp	potatoes
Fusarium rot	*Fusarium* spp	leafy vegetables root crops onions melons beans

Fungal diseases continued

Disease organism	Scientific name	Affects these crops
Gray mold	*Botrytis cinerea*	grapes berries stone fruits tomatoes peppers leafy vegetables root crops onions melons beans
Green mold	*Penicillium digitatum*	citrus
Late blight	*Phytophthora infestans*	potatoes tomatoes peppers
Rhizopus rot	*Rhizopus* sp	leafy vegetables root crops onions melons beans sweetpotatoes
	Rhizopus stolonifer	tomatoes peppers grapes berries stone fruits
Sour rot	*Geotrichum candidum*	citrus stone fruits tomatoes peppers
Stem end rot	*Phomopsis citri*	citrus
	Diplodia natalinsis	citrus
Watery soft rot	*Sclerotinia sclerotiorum*	leafy vegetables root crops onions melons beans
White rot	*Botryosphaeria ribis*	apples pears quince

Bacterial Diseases

In general bacteria cause few losses in tree fruits or small fruits Potatoes are highly susceptible to bacterial disease when injured during harvest or handling The following bacterial diseases are most common and cause the greatest market and storage losses

Disease organism	Scientific name	Affects these crops
Bacterial soft rot	*Erwinia* sp	Leafy vegetables root crops beans onions peppers melons cucumbers tomatoes
	Erwinia carotovora	potatoes
Brown rot	*Pseudomonas solanacearum*	potatoes
Ring rot	*Cornybacterium sepedonicum*	potatoes
Slimy soft rot	*Clostridium* spp	potatoes

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Viral and Nematode Diseases
These tend to be uncommon and of minor importance with the following exceptions

Disease organism	Scientific/common name	Affects these crops
Net necrosis	potato leaf roll virus	potatoes
Root knot nematode	*Meloidogyne* spp	potatoes carrots root crops

Source Moline 1984

PRE-HARVEST AND HARVEST PRACTICES

Genetic Factors and Planting

Begin by planting cultivars offering some natural resistance to the pests you expect to have to deal with in your region Plant only good quality, clean seed or stock Paying more for certified seed or planting materials will pay off in reduced costs for pest management and lower losses due to disease

Genetic resistance to pest problems differs by variety

	Problem	Low or no resistance	Good to high resistance
Potatoes	Gangrene'	'Blanka' 'Gracia 'Vanessa'	'Golden Wonder'
Berries	*Botrytis cinerea*	soft varieties	firm fruited varieties
Onions	neck rot	sweet varieties	pungent varieties

Field and Orchard Management

As discussed in Chapter 2 keeping the field and orchard clean will prevent the buildup of pests and disease organisms and minimize the opportunities for the produce to be attacked Keep fields and orchards free of debris and discarded produce Eradicate diseased produce by burning or removing waste Using appropriate cultural practices during production will assist the produce to avoid and/or resist pest attack Proper planting density will reduce susceptibility to pests, avoiding over-fertilization and over-irrigation will keep plants healthy You may need to prune to ensure proper ventilation and adequate air movement through the canopy Thinning not

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only improves fruit size and quality, but protects trees from damage caused by over-weight branches

Monitoring pest levels during production can save you a lot a expense by limiting your treatments to those that are actually necessary for pest control Sampling kiwifruit sepals 4 months after fruit set for *Botrytis cinerea* (gray mold) can predict incidence in storage If less than 6% of fruits are determined to be infected no pre-harvest fungicides are required (Michailides and Morgan 1996)

MATURITY AT HARVEST AND PEST MANAGEMENT

Harvesting at the proper maturity will ensure that produce has the maximum level of natural protection against pests and diseases As discussed in Chapter 3, this moment will differ for various commodities Under-mature and over-ripe produce is often more susceptible to diseases and insect damage than produce at prime maturity As produce ripens, the flesh and skin softens and offers less protection against pests And when produce bruises more easily pests are allowed easy entry

TEMPERATURE AND RH MANAGEMENT

The importance of proper cooling cannot be over-emphasized Chapter 6 provides many examples of how reducing temperature also reduces disease problems

Handle and store at proper RH While high humidity in the storage environment is important for maintenance of high quality produce, free water on the surface of commodites can enhance germination and penetration by pathogens When cold commodities are removed from storage and left at higher ambient temperatures, moisture from the surrounding warm air condenses on the colder product's surfaces A temporary increase in ventilation rate (using a fan) or increasing exposure of the commodity to drier air can help to evaporate the condensed moisture and to reduce the chances of infection

> Remember
> Serious disease problems can result from over-cooling chilling sensitive commodities

Decay in fruits can be increased if free water is available from condensation and drips onto the produce These fruits and vegetables will decay less when held at a lower RH than the typical recommendation of 95-99% (Spotts, 1984)

apples	88% RH
grapes	60%
pears	90-95%
persimmon	75-83%
squash (winter)	40%
strawberry	85-90%
sweetpotatoes	79%

Remember, also, that increased rooting and decay will occur in onions and garlic when these crops are handled or stored in a high humidity environment

POSTHARVEST TREATMENTS

Heat and Cold

Certain fungi and bacteria in their germination phase are susceptible to cold, and infections can be reduced by treating produce with a few days of storage at the coldest temperature the commodity can withstand without incurring damage *Rhizopus stolonifer* and *Aspergillus niger* (black mold) can be killed when germinating by 2 or more days at 0 °C (32 °F) On the other hand, brief hot water dips or forced-air heating can also be effective, especially for reducing the microbial load for crops such as plums, peaches, papaya cantaloupe and stone fruits sweetpotatoes and tomatoes See Chapter 4 for specific recommendation for heat treatments in the packinghouse

Cold treatments can control some insect pests and are currently used for the control of fruit flies Treatment requires 10 days at 0 °C (32 °F) or below or 14 days at 1 7 °C (35 °F) or below so treatment is only suited to commodities capable of withstanding long-term low-temperature storage such as apples pears, grapes kiwifruit and persimmons For produce packed before cold storage treatment, package vents should be screened to prevent the spread of insects during handling

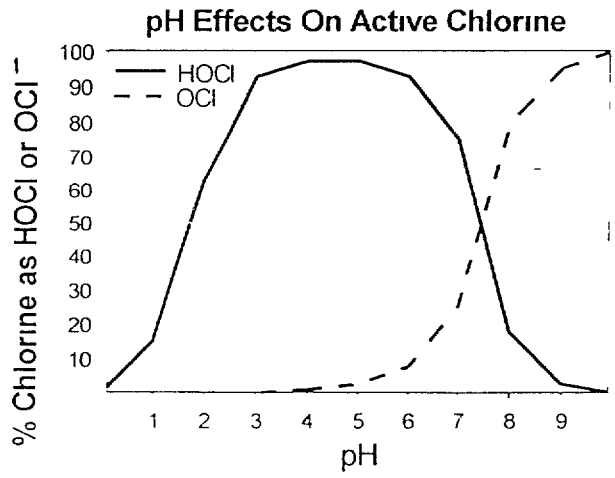
Control of storage insects in nuts and dried fruits and vegetables can be achieved by freezing, cold storage (less than 5 °C or 41 °F) heat treatments or the exclusion of oxygen (0 5% or lower) using nitrogen Packaging in insect-proof containers is needed to prevent subsequent insect infestation

Hot water dips or heated air can also be used for direct control of postharvest insects In mangoes an effective treatment is 46 4 °C for 65 to 90 minutes depending on size Fruit should not be handled immediately after heat treatment Whenever heat is used with fresh produce clean cool water showers or forced cold air should be provided to help return the fruits to their optimum temperature as soon as possible after completion of the treatment Refer to the current USDA *APHIS Plant Protection Quarantine Treatment Manual* for the latest information and details on heat treatments

SANITATION

Washing produce with chlorinated water can prevent decay caused by bacteria mold and yeasts on the surface of produce Calcium hypochlorite (powder) and sodium hypochlorite (liquid) are inexpensive and widely available The effectiveness of the treatment will be decreased if organic matter is allowed to build up in the wash water The effectiveness of chlorine increases as pH is reduced from pH 11 to pH 8, but at lower pH chlorine becomes unstable

Fruits and vegetables can be washed with hypochlorite solution (25 ppm available chlorine for two minutes) then rinsed to control bacterial decay Alternatively these commodities can be dipped in hypochlorite solution (50 to 70ppm available chlorine) then rinsed with tap water for control of bacteria yeasts and molds Follow local regulations on disposal of chlorinated waste water



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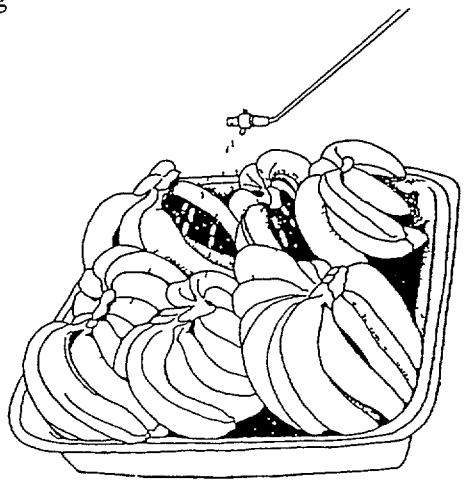
PESTICIDES

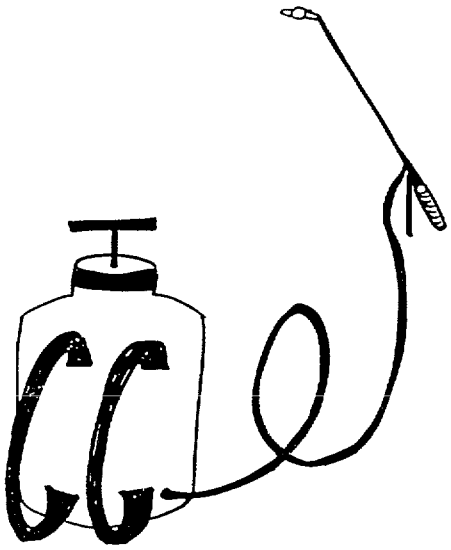
A wide variety of chemicals are available for postharvest pest management They are used in various ways-- as dips, sprays, dusts or applied on a pad of absorbent paper Always follow label instructions and be aware that recommendations for use may differ by state and commodity When using chemical pest controls you need to consider cost availbility, regulations for proper use, and residue tolerances Recently many chemical controls have been banned due to concerns over residues and the possible consequences for human health Others, such as benomyl are no longer registered for postharvest applications Whenever possible it is a good idea to try to reduce your reliance on chemical controls

When using chemicals in solution in the field on packinghouse, make sure you get good coverage by applying to the run-off stage Always use potable water for spraying— recent *Cyclospora* outbreaks in raspberries in Guatamala were traced to contaminated water used to apply pesticides The low cost, simple equipment illustrated here can ensure postharvest chemicals are applied as intended The tray has perforations on the base to allow the solution to drain and the produce to dry before further handling



Some plant materials are useful as natural pesticides The pesticidal properties of the seeds of the neem tree (as an oil or aqueous extract) are becoming more widely known and used throughout the world Native to India neem (*Azadirachta indica*) acts as a powerful pesticide on food crops but appears to be completely non-toxic to humans mammals and beneficial insects (NRC 1992) Any "natural pesticide" must be shown to be safe for humans before its approval by regulatory authorities

Bioneem (developed by Ringer Corp Minneapolis MN US) currently has EPA registration in all US states except AZ CA and NY but only for use on ornamentals The EPA has also approved a neem-based biological pesticide developed by Tata Oil Mills Ltd (TOMCo) for use on a wide range of food crops fruits and grains during production We expect to hear more about this bio-pesticide in the next few years and eventually to be able to use it safely in postharvest horticulture applications



CONTROLLED / MODIFIED ATMOSPHERE TREATMENTS

For commodities that tolerate high CO_2 levels 15 to 20% CO_2-enriched air can be used as a fungistat to control decay-causing pathogens, such as *Botrytis cinerea* on strawberry blueberry blackberry fresh fig and table grapes during transport See Chapter 5 for a description of the method for modified atmosphere packaging within a pallet cover

Low O_2 and/or high CO_2 have been used to kill certain insects in commodities that can tolerate these conditions The effectiveness of insecticidal atmospheres depends upon the temperature relative humidity, duration of exposure and life stage of the insect The following are some examples from Mitcham et al (1997)

Insecticidal atmospheres (0 5% or lower O_2 and/or 40% or higher CO_2) have been shown to be an effective substitute for methyl bromide fumigation to disinfest dried fruits, nuts and vegetables

The first and third instars of the greenheaded leafroller (*Planotortrix excessana*) and the first and fifth instars of the brownheaded leafroller (*Ctenopseustis obliquana*) and the light brwon apple moth (*Epiphyas postvittana*) are completely killed in 2 months when apples are stored at 0 5 °C in 3% O_2 and 3% CO_2

The eggs of the apple rust mite (*Aculus schlechtendali*) and the European red mite (*Panonychus ulmi*) are killed in 5 3 months when apples are stored at 2 8 °C in an atmosphere of 1% O_2 and 1% CO_2

Codling moth larvae (*Cydia pomonella*) are killed in 3 months when apples are stored at 0 °C, 1 5-2% O_2 and less than 1% CO_2

In kiwifruit the adult two-spotted spider mite (*Tetranychus urticae*) is killed by 40°C 0 4% O_2 and 20% CO_2 in only 7 hours

When persimmons are stored at 20 °C 0 5% O_2 and 5% CO_2, the third instar of leafrollers (*Planotortrix excessana*) is killed in 4 days and the larvae and adult mealy bug (*Pseudococcus longispinus*) is killed in 7 days

Sweetpotato weevil (*Cylas formicarius elegantulus*) has been controlled at ambient temperature in stored tropical sweetpotatoes by treatment with low oxygen and high carbon dioxide atmosheres At 25 °C (76 °F), storage in 2 to 4% O_2 and 40 to 60% CO_2 results in 100% mortality of adult weevils in 2 to 7 days

Codling moth (*Cydia pomonella*) in stone fruits can be controlled at 25 °C (76 °F) by using atmospheres of 0 5% oxygen and 10% carbon dioxide for 2 to 3 days (adult or egg) or 6 to 12 days (pupa) Normal color and firmness changes during ripening are not affected by treatment

COSTS AND BENEFITS OF POSTHARVEST IPM PRACTICES

Costs
materials
labor
power

Benefits
reduced decay rates or insect losses
longer shelf life
improved quality

Example 1
Harvest 1000 lbs of green beans, sort, cool and pack beans for marketing in California within one week Postharvest IPM in this case involves a quick hot water dip to reduce disease problems during storage and marketing

	Minimal pest controls	Postharvest IPM
labor for harvest (5 hours at $7 50/hr)	$35	$35
labor for sorting/grading	$12	$12
hot water treatment (0 5 minutes at 52 °C)		$10
ice bath		$10
postharvest losses	20%	5 %
amount available to market	800 lbs	950 lbs
market value	$0 50/lb	$0 79/lb
	$400	$750
costs labor	($47)	($47)
pest control	0	($20)
Potential net sales	$353	$683

Example 2
Harvest 400 kg of french green beans sort cool and pack beans for marketing in India within one week Postharvest IPM in this case involves a quick hot water dip followed by an ice bath to reduce disease problems during storage and marketing

	Minimal pest controls	Postharvest IPM
labor for harvest (6 hours @ Rs 80/day)	Rs 50	Rs 50
labor for sorting/grading		Rs 30
hot water treatment (0 5 minutes at 52 °C)		Rs 200
ice bath		Rs 200
postharvest losses	20%	5 %
amount available to market	320 kg	380 kg
market value	Rs 10/kg	Rs 20/kg
	Rs 3200	Rs 7600
costs labor	(Rs 50)	(Rs 80
pest control	0	(Rs 400)
Potential net sales	Rs 3150	Rs 7120

SOURCES OF PEST MANAGEMENT EQUIPMENT AND SUPPLIES

automatic chlorine dispenser	Orchard Equipment and Supply Co
fungicides	Brogdex Co
sprayers knap-sack, backpack	A M Leonard Orchard Equipment and Supply Co Northern
sulfur dioxide pads	Zellerbach

For addresses and phone/FAX numbers of suppliers, please refer to Appendix D

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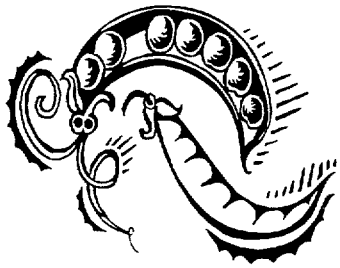
CHAPTER 10



FOOD SAFETY FOR FRESH PRODUCE

The number one issue among consumers, is maintenance and improvement of fresh produce safety from field to fork Fresh fruits and vegetables are often thought of as healthful, nutritious foods having no risk of foodborne illness associated with their consumption However, recent food borne illness outbreaks in the U S have been traced to fresh fruits, vegetables and juices These incidents have caused growers, shippers, distributors, retailers and importers to reevaluate fresh fruit and vegetable production and handling practices

The probability of getting sick from eating a raw fruit or vegetable is very low, but a small probability does exist Reducing the risk of food-borne illness from consumption of fresh fruits and vegetables is the responsibility of everyone, including growers, shippers, processors and consumers

> Wholesale buyers are starting to expect documentation of prevention and critical control point programs for food safety down to the farm level In the immediate future, agricultural producers will be charged with establishing and documenting methods of risk reduction and prevention ' Suslow (1997)

It might help to remind consumers that the health benefits derived from eating at least 5 servings of fresh fruits and vegetables daily far outweigh the very small probability of contracting food borne illness

Preventing contamination of fresh fruits and vegetables by human pathogens and dangerous levels of chemical residues is the best way to assure that foods are wholesome and safe for human consumption This chapter will provide information on 1) potential hazards during production of raw produce, 2) sanitary postharvest handling of produce and 3) Hazard Analysis Critical Control Points (HACCP) principles as applied to handling fresh produce

General DOs and DON'Ts of Fresh Produce Food Safety

Grazing animals, feedlots or other sources of fecal contamination should **NOT** be present on or adjacent to production land

Prior land use should be investigated to assure that toxic compounds such as pesticides or heavy metals are **NOT** present at dangerous levels in production soil

Fertilizers should have no detectable levels of human pathogens Proper composting or use of inorganic fertilizers is highly recommended

Irrigation water should have no detectable human pathogens, or unacceptable levels of pesticide residues, heavy metals or toxic compounds

Employ only professional, licensed pesticide applicators

Monitor and document all pesticide, fungicide and herbicide use, and maintain a safe period between application and produce harvest

Dos and Don'ts continued

Keep harvested produce up off the bare soil

Avoid exposure to moist soil There is an increased risk of aflatoxin infection, a carcinogenic toxin in nuts (pistachios and thin shelled almonds are especially susceptible)

Provide field latrine and hand wash stations for field workers

Monitor and enforce field worker good personnel hygiene practices

Use only clean and sanitary field containers

Continuously monitor chlorine concentrations and pH of hydrocooling or wash water

Clean and sanitize field tools, containers and packing lines on a frequent and scheduled basis

Clean and sanitize forced air coolers, cold storage rooms and cooler drain tiles on a frequent and scheduled basis

Clean and sanitize transport trucks on a frequent and scheduled basis

Only use cleaning compounds and sanitizers that are approved for food contact surfaces

Use transportation that is dedicated to hauling only produce Do **NOT** use trucks which have been used to transport live animals

FOOD SAFETY RISKS ASSOCIATED WITH PRODUCE

Physical Hazards Examples of physical hazards which may become imbedded in produce during production handling or storage are such things as

fasteners (staples nails, screws, bolts)

pieces of glass

wood splinters

Chemical Hazards Examples of chemical hazards which may contaminate produce during production handling or storage are such things as

pesticides, fungicides herbicides, rodentacides

machine lubricants from forklifts or packing line equipment

heavy metals (Lead, Mercury, Arsenic)

industrial toxins

compounds used to clean and sanitize equipment

Human Pathogens There are four main types of human pathogens associated with fresh produce

soil associated pathogenic bacteria (*Clostridium botulinum*, *Listeria monocytogenes*)

feces associated pathogenic bacteria (*Salmonella spp* , *Shigella spp* *E coli* O157 H7 and others)

pathogenic parasites (*Cryptosporidium* *Cyclospora*)

pathogenic viruses (Hepatitis, Enterovirus)

Food Safety Risks Associated With Fresh Produce

Physical Hazards

Chemical Hazards

Human Pathogens

Many of these pathogens are spread via a human (or domestic animal) to food to human transmission route Handling of fruits and vegetables by infected field-workers or consumers, cross contamination use of contaminated irrigation water use of inadequately composted manure or contact with contaminated soil are just a few of the ways that transmission of human pathogens to food can occur

FOOD SAFETY HAZARDS DURING THE PRODUCTION OF FRESH PRODUCE

While produce quality can be judged by outward appearance on such criteria as color, turgidity and aroma food safety can not Casual inspection of produce cannot determine if it is in fact safe and wholesome to consume Management of growing conditions are paramount in preventing the contamination of fresh produce by physical hazards, harmful chemicals and human pathogens

Land Use

The safety of food grown on any given piece of land is not only influenced by the current agricultural practices but also by former land use practices Heavy metals and pesticide residues may remain in soils for long periods of time Production land soil should be tested to assure that dangerously high levels of these compounds are not present Former land use should also be investigated to assure that the production land was not used for hazardous waste disposal or for industrial purposes that may have left behind toxic residues If production land was previously used for agricultural purposes, pesticide use records should be reviewed to assure that proper pesticide management practices were followed Production acreage should not have been previously used as a feed lot or for animal grazing since fecal contamination of the soil may be extensive

MANAGE GROWING CONDITIONS AND HARVESTING OPERATIONS TO PREVENT CONTAMINATION OF FRESH PRODUCE

Fertilizers

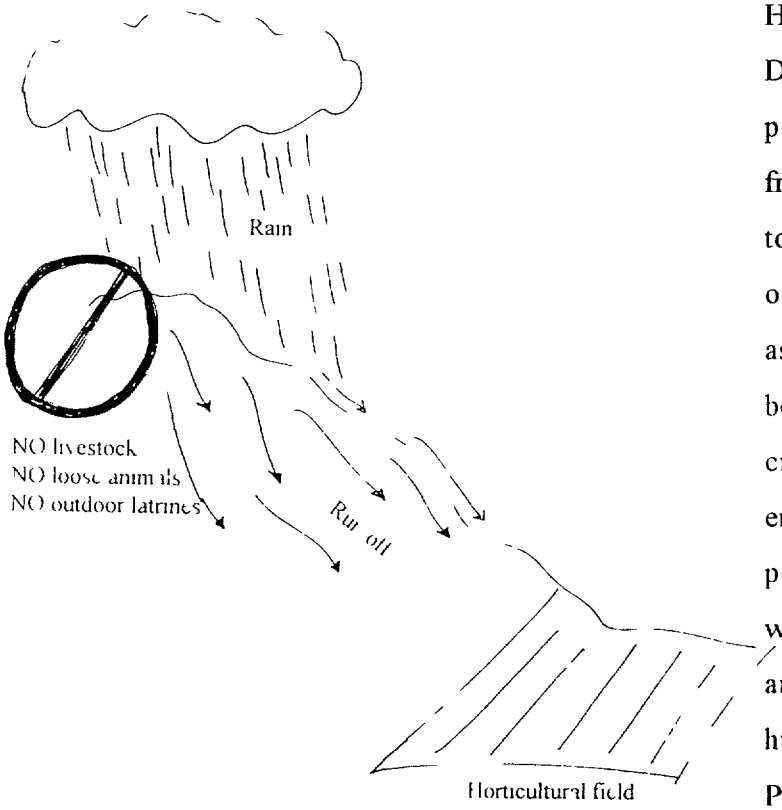
Improperly or non composted organic fertilizers are a potential source of human pathogens Human pathogens may persist in animal manures for weeks or even months Proper composting (the heat treatment the manure undergoes as it breaks down) will reduce the risk of potential food borne illness Unfortunately the persistence of many human pathogens in untreated agricultural soils is currently unknown Use of inorganic fertilizers which have been certified to be free of heavy metals and other chemical contaminants is recommended

Irrigation Water

Irrigation water is another potential way contaminants may be brought in contact with fruits and vegetables Well water is less likely to be contaminated with human pathogens than surface water supplies, however all irrigation water sources should be periodically tested for contamination by pesticides and human pathogens Overhead irrigation systems are more likely to spread contamination since contaminated water is applied directly to the edible portions of fruits and vegetables

Pesticide Usage

All pesticide usage should be done in strict accordance with manufacturer recommendations as well as federal and state ordinances Monitoring and documentation of proper pesticide usage should be done to prevent unsafe levels or illegal residues from contaminating fruits and vegetables All pesticide applications should be documented and proper records of application as well as tests for residues should be available and reviewed by management on a regular basis



Harvest Operations

During harvesting operations field personnel may contaminate fresh fruits and vegetables by simply touching them with an unclean hand or knife blade Portable field latrines as well as hand wash stations must be available and used by all harvest crew members Monitoring and enforcement of field worker personnel hygiene practices such as washing hands after using the latrine are a must to reduce the risk of human pathogen contamination Produce once harvested should not

be placed upon bare soils before being placed in clean and sanitary field containers Field harvesting tools should be clean, sanitary and not be placed directly in contact with soil Field containers should be cleaned and sanitized on a regular basis as well as being free of contaminants such as mud industrial lubricants, metal fasteners or splinters

Provide soap and clean water so that harvesters can wash their hands after using field latrines

SANITARY POSTHARVEST HANDLING OF PRODUCE

Depending upon the commodity, produce may field packaged in containers that will go all the way to the destination market or be temporarily placed in bulk bins, baskets or bags which will be transported to a packing shed Employees, equipment, cold storage facilities, packaging materials and any water which will be contacting the harvested produce must be kept clean and sanitary to prevent contamination

Employee Hygiene

Gloves, hairnets and clean smocks are commonly worn by packinghouse employees in export oriented packing sheds The cleanliness and personnel hygiene of employees handling produce at all stages of production and handling must be managed to minimize the risk of contamination Adequate bathroom facilities and handwash stations must be provided and used properly to prevent contamination of produce by packinghouse employees Shoe or boot cleaning stations may also be in place to reduce the amount of field dirt and contamination which enters the packing shed from field operations Employee training regarding sanitary food handling practices should be done when an employee is hired and reviewed before they begin work each season

Equipment

Food contact surfaces on conveyor belts, dump tanks etc should be cleaned and sanitized on a regular scheduled basis with food contact surface approved cleaning compounds A 200 parts per million sodium hypochlorite (bleach) solution is an excellent example of a food contact surface

Avoid the use of steam when cleaning equipment

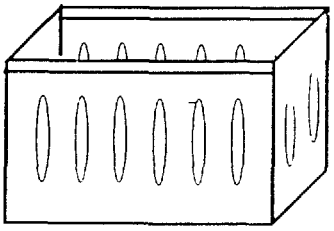
sanitizer Sanitizers should be used only after thorough cleaning with abrasion to remove organic materials such as dirt or plant materials Use of steam to clean equipment should be avoided since steam may actually cake organic materials and form a biofilm, which renders equipment almost impossible to sanitize Steam may also aerosolize bacteria into the air and actually spread contamination throughout the packing house facility

Cold Storage Facilities

Cold storage facilities and in particular refrigeration coils, refrigeration drip pans, forced air cooling fans, drain tiles, walls and floors should be cleaned and sanitized on a frequent and regular basis The human pathogen *Listeria monocytogenes* can proliferate quite well at refrigerated temperatures and may contaminate produce cold stored produce if condensation from refrigeration units or ceilings drip on to the produce Placing warm product with field heat into a cold room with insufficient refrigeration capacity will cause a temperature rise in the room and as the room cools a fog or mist will occur As the water condenses out of the air and onto walls and ceilings, contamination from walls may end up dripping onto stored produce

Packaging materials

All packaging materials should be made of food contact grade materials to assure that toxic compounds in the packaging materials do not leach out of package and into the produce Toxic chemical residues may be present in some packaging materials due to use of recycled base materials Empty packages such as boxes and plastic bags should be stored in an enclosed storage area to protect them from insects rodents dust, dirt and other potential sources of contamination These actions protect not only against the potential loss of valuable materials but protects the integrity and safety of these materials



Plastic field bins and totes are preferred to wooden containers since plastic surfaces are easier to clean and sanitize, which should be done after every use If containers are not cleaned and sanitized after every use, they may become contaminated and then contaminate the next products which are placed in the container Wooden containers or field totes are almost impossible to sanitize since they have a porous surface and wooden or metals fasteners such as nails fiom wooden containers may accidentally be introduced into produce Cardboard field bins if reused should be visually inspected for cleanliness and lined with a polymeric plastic bag before reuse to prevent the risk of cross contamination

Wash and Hydrocooling Water

All water which comes in contact with produce for washing or hydrocooling must be safe to drink Water should contain between 100 and 150 parts per million total chlorine and have a pH of between 6 and 7 5 Chlorine use prevents the potential for cross contamination of all produce in the washing or hydiocooling system, it will not sterilize the piodue Scientific studies have demonstrated that washing produce in cold chlorinated water will reduce microbial populations by 100 to 1000 fold, but sterility is never achieved because microorganisms adhere so voraciously to the surface of produce and may be present in microscopic nooks and crannies on the surface of produce Rinsing produce with cold chlorinated water will significantly reduce the number of microorganisms present on the produce but it will not remove all bacteria Therefore, human pathogens can not be completely removed from produce by washing it in cold chlorinated water

Refrigeiated Transport

Produce is best shipped in temperature controlled refrigerated trucks Maintaining perishables below 5°C even while being transported to destination markets will extend shelf-life and significantly reduce the giowth rate of microbes including human pathogens Temperatures used for tranporting chilling sensitive produce will not protect against the growth of most pathogens Trucks used during transportation should be cleaned and sanitized on a regular basis Trucks which have been used to transport live animals, animal products or toxic materials should neveı be used to transport produce

HAZARD ANALYSIS CRITICAL CONTROL POINTS (HACCP)

HACCP is a food safety system first developed by the Pillsbury Co to reduce the risk associated with the food eaten by astronauts during space flights HACCP is a system approach which

- identifies potential sources of contamination in food production systems
- establishes methods for detecting the occurrence of contamination
- clearly prescribes what corrective actions will be take to prevent consumption of contaminated food items

HACCP is a systems approach method to assure the safety of a food product, it is NOT a means of assuring food quality

The seven basic principles of HACCP are
Assessment of Hazards
Determine Critical Control Points (CCP) to Control the Identified Hazards
Establishment of Limits at each CCP
Establishment of CCP Monitoring Procedures
Establishment of Corrective Actions to be Taken When CCP Exceed Set Limits
Establishment of Record Keeping Systems to Document the HACCP Program
Establishment of Procedures to Verify that the HACCP is Functioning Properly

1 *Assessment of Hazards*

Each unit operation should be evaluated to identify potential sources of microbial, chemical and physical hazards which may be introduced into produce Areas which should be evaluated are growing and harvesting operations, packing shed operations packaging material and storage as well as distribution This process is best accomplished by a team of both management and production personnel

Example Hydrocooling water contamination (microbial or chemical)

2 *Determine Critical Control Points (CCP) to Control the Identified Hazards*

The next step in developing a HACCP program is to draw a flow diagram for your specific operation and then determine where each of the identified hazards may be monitored Each point that will be monitored to control specific hazard is now designated a Critical Control Point (CCP) *Example* Chlorine injection system on hydro cooler

3 *Establishment of CCP Limits*

Once CCP have been identified, tolerance limits must be set to determine when corrective action needs to be taken Tolerances must be observable and measurable

Example Hydro-cooler water must have a chlorine level of 100-150 ppm total chlorine and a pH of 6 0-7 5

4 *Establishment of CCP Monitoring Procedures*

How often monitoring will be done how measurements will taken and what documentation will be prepared must next be clearly defined

Example Hydro-cooler water pH and chlorine levels will be monitored using a test kit hourly and continuously with a strip chart recorder that has been calibrated daily Hourly pH and chlorine level measurements will written down and be available for inspection at the hydro-cooler

5 *Corrective Action When Deviations From CCP Limits Occur*

When a deviation from the prescribed limits occurs corrective action must be taken to eliminate the potential contamination All deviations and corrective actions must be noted in a written form.

Example Chlorine levels were determined to be below 25 ppm. Hdyro-cooling of product was stopped, chlorine levels were adjusted and all produce that had been hydro-cooled in since the last in within critical limit chlorine measurement was taken were rehydro-cooled

6 *HACCP Record Keeping Systems*

All paper work related to the HACCP system must be keep in an orderly and accessible manner Records that should be kept include

- Production Records
  - Supplier Audits
  - Pesticide Usage and Testing Results
  - Irrigation Water Test Results etc
- Harvesting Records
  - Harvest Dates and Lot Numbers
  - Total Number of Boxes Harvested, etc

All Critical Control Point Monitoring Records

Storage and Distribution Records

Temperature Monitoring

Truck Cleanliness, etc

Deviation File HACCP Deviations and Corrective Actions Taken

7 *HACCP Verification*

Periodic HACCP plan review including review of CCP records, deviations and random sampling to verify that the HACCP program must be done to assure that HACCP program is functioning properly This review should be done either on a monthly or quarterly basis

Food safety is becoming an ever more important aspect of produce marketing especially for those producers who wish to export Ensuring that produce is safe to eat is in the best interest of everyone since we are all consumers Investment in food safety programs will add cost to producing fresh fruits and vegetables, however it assures the long term success of a company much like a good insurance policy While food safety programs cannot ensure the safety of all products they signifcantly reduce the probablity and risk of food borne illness

The following is an example of a CCP in a model HACCP program. The Critical Control Point (CCP) identified as #3 requires the careful monitoring of the pH and Cl level in wash water

HACCP Model

FLOW PROCESS	HAZARD CATEGORY	CCP	CRITICAL LIMIT	MONITORING	FREQ	CORRECTIVE ACTION	RECORD KEEPING	VERIFICATION
Washing	Microbial	#3 Water Cl_2 and pH	Free CL_2 2 7 ppm Total Cl_2 100-150 ppm pH 6 0-7 0	Test kit Continuous strip chart	Once/ hour	Manually adjust water chemistry Repair system Hold produce from last correct reading and rewash	Chlorine/ pH records	Random sampling QA audit Microbio logical counts

INFORMATION RESOURCES

To obtain more information about produce food safety programs contact the following organizations

Davis Postharvest Consulting
Produce Food Safety Systems
P O Box 72711
Davis CA 95617
Phone (530) 400-0430
FAX (530) 756-5440
davispc@jps net

International Fresh-Cut Produce Association
"Food Safety Guidelines for the Fresh-cut Produce Industry 3rd Edition"
1600 Duke Street Suite 440
Alexandria, VA 22314
Phone (703) 299-6282

United Fresh Fruit and Vegetable Association
"Industrywide Guidance to Minimize Microbiological Food Safety Risks for Produce"
727 N Washington St
Alexandria, VA 22314
Phone (703) 836-3410

University of California
FoodSafe Program
Davis, CA 95616
Phone (530) 752-2647

Western Growers Association
"Voluntary Food Safety Guidelines for Fresh Produce"
P O Box 2130
Newport Beach, CA 92658
Phone (714) 863-1000

SOURCES OF FOOD SAFETY EQUIPMENT AND SUPPLIES

HACH Company (Microbiological testing supplies water quality test kits and portable systems
P O Box 608
Loveland CO 80539
In the U S (800) 227 4224 or FAX (970) 669 2932
Outside the U S (970) 669 3050 or FAX (970) 669 2932

International Ripening Corporation (Temperature recorders 'HACCP Manager' equipment)
1185 Pineridge Road
Norfolk, VA 23502
Phone (800) 472-7205

REFERENCES

Ashby B H 1989 Regulations governing sanitation in vehicles transporting food USDA Transporation Tips/ Office of Transporation OT-ID No 12

Beuchat L R 1996 Pathogenic micro-organisms associated with fresh produce *J Food Prot* 59 204-216

Harris, L (ed) 1997 *Perishables Handling* Special Issue No 91 Food Safety

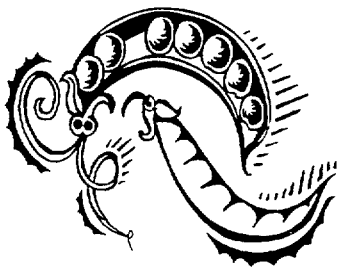
Rushing, J W 1996 Implementation of a HACCP program in a commercial fresh market tomato packinghouse A model for the industry *Dairy Food and Environmental Sanitation* 16(9) 549-553

Suslow, T V 1997 Microbial Food Safety an emerging challenge for small-scale growers *Small Farm* News June/July 7-10

United Fresh Fruit and Vegetable Association 1997 *Industrywide Guidance to Minimize Food Safety Risks for Produce* Alexandria VA UFFVA

Western Growers Association 1997 *Voluntary Food Safety Guidelines for Fresh Produce* Newport Beach CA WGA

WORKSHEETS



PART I COSTS AND BENEFITS of FRESH HANDLING PRACTICES

Comparison of estimated costs and expected benefits related to adopting postharvest technology for fresh handling and marketing

If you need more facts to fill out any worksheet, it is recommended that you select one specific commodity that you produce, and actually use the new practice on one row of vegetables or on a small group of trees for one season or any suitable period of time During this time collect information on yields, losses, grades of produce harvested, costs of labor, materials and equipment, and power requirements for your own operation in comparison to your current practice Some of your expenses will not be affected at all, while others will be added or no longer be necessary when you change practices

INSTRUCTIONS

Make copies of these blank worksheets and use a complete set for each commodity you produce and market If you want to compare various postharvest technologies you may need to use several copies of the worksheets for each commodity

Overhead costs should be reported by month, by season or by year, depending upon how you generally allocate costs of operation The idea is to be able to determine how much of your overhead costs can be assigned to the commodity of interest For example, if you produce and handle only one commodity, it will take on 100% of your overhead If you produce and market equal amounts of 3 commodities, each can be assigned 1/3 of the total overhead

Most of the costs for the topics listed in Worksheet 3 will have several components including capital costs (equipment or facilities), and recurring costs (supplies, labor and purchased power or fuel for running equipment)

Worksheet 1 Collect some basic information

Commodity _____

Variety _____

1 Overhead Costs

Salaries (managers, office staff, etc)	Rs_____
Office expenses and supplies	Rs_____
Maintenance parts and repairs	Rs_____
Utilities (gas, electric)	Rs_____
Communications (Telephone FAX, e-mail)	Rs_____
Rent	Rs_____
Other	Rs_____
Total =	Rs_____

Overhead costs affiliated with this commodity
(base on the percent this commodity compared to your total production)

_____% Rs_____*

2 General information related to each practice

Base upon previous experience with the commodity, your CSAM results (see Appendix A) or estimates provided by other producers/shippers, produce buyers, published literature on postharvest technology, cost/benefit examples provided in each chapter of this workbook or information available from your local Extension Service Many recommended PHTs will reduce losses by minimizing decay mechanical damage, and weight loss

Current Practice (describe)_____

New Practice (describe)_____

	Current practice	New practice
Expected yields	_____kg	_____kg
Estimated physical losses		
amount of culls during pre-sorting	_____%	_____%
losses due to pests	_____%	_____%
losses due to mechanical damage	_____%	_____%
weight loss during handling/storage	_____%	_____%
Sum of losses	_____kg	_____kg
How much will you have to sell? (Expected yields - Estimated sum of losses)	_____kg	_____kg
Expected grades (should add up to the amount above)		
highest	_____kg	_____kg
second	_____kg	_____kg
lowest	_____kg	_____kg

3 Market Prices (obtain from your buyers or past history)
Expected price per kg (wholesale)

highest grade_____ Rs_____

second grade_____ Rs_____

lowest grade_____ Rs_____

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Expected price per kg (retail)

highest grade_____ Rs_____

second grade_____ Rs_____

lowest grade_____ Rs_____

Worksheet 2 Comparison of Direct Costs

Does one practice cost more than the other for production, preparation for market, postharvest handling, materials, power, equipment, storage, transport, marketing, etc ? Calculations should be based on expected yield, postharvest losses, hourly labor costs, and expected volumes to be handled Specific details for recommended practices are included in the examples found at the end of each chapter of the book, with those costs that are expected to change listed individually under each category If you find there are additional costs associated with your operation, please add these to the list

Current Practice _____

New Practice _____

	Current practice	**New practice**
Pre-Harvest		
seeds or planting materials	Rs_____	Rs_____
land preparation/planting	Rs_____	Rs_____
cultivation (pruning, thinning, mulching, etc)	Rs_____	Rs_____
preharvest treatments (pesticides, etc)	Rs_____	Rs_____
irrigation	Rs_____	Rs_____
fertilization	Rs_____	Rs_____
other_____	Rs_____	Rs_____

	Current practice	New practice
Harvest and Market Preparation		
labor and equipment for harvesting	Rs_____	Rs_____
field packing	Rs_____	Rs_____
curing	Rs_____	Rs_____
other_____	Rs_____	Rs_____
Packinghouse Operations		
pre-sorting	Rs_____	Rs_____
washing/cleaning	Rs_____	Rs_____
sizing/grading	Rs_____	Rs_____
waxing	Rs_____	Rs_____
pest management	Rs_____	Rs_____
sanitation	Rs_____	Rs_____
packaging materials	Rs_____	Rs_____
packing	Rs_____	Rs_____
other_____	Rs_____	Rs_____
Temperature/RH Management		
pre-cooling	Rs_____	Rs_____
cooling	Rs_____	Rs_____
storage	Rs_____	Rs_____
other_____	Rs_____	Rs_____
Transportation		
vehicles	Rs_____	Rs_____
fuel	Rs_____	Rs_____
cooling	Rs_____	Rs_____
other_____	Rs_____	Rs_____

	Current practice	New practice
Destination Handling		
ripening	Rs_____	Rs_____
re-sorting	Rs_____	Rs_____
display	Rs_____	Rs_____
other_____	Rs_____	Rs_____
Other Costs		
marketing (fees, sales labor)	Rs_____	Rs_____
promotional activities	Rs_____	Rs_____
food safety program	Rs_____	Rs_____
other_____	Rs_____	Rs_____
Total Direct Costs	Rs_____	Rs_____
*Overhead Costs for this commodity	Rs_____	Rs_____
Total Costs	Rs_____	Rs_____
Total costs per kg of produce for sale	Rs_____	Rs_____

Worksheet 3 Comparison of Benefits

Base upon expected yields and quality, amount of produce available for sale at various grades, and expected prices per kg collected in Worksheet 1 (kgs of produce at each grade x price/kg = expected sales at each grade) Do the calculations for either wholesale or retail prices or a combination if you will sell both ways

Current Practice _____

New Practice _____

	Current practice	**New practice**
1 Expected sales (wholesale)		
highest grade	Rs_____	Rs_____
second grade	Rs_____	Rs_____
lowest grade	Rs_____	Rs_____
Subtotal Sales (wholesale)	Rs_____	Rs_____
2 Expected sales (retail)		
highest grade	Rs_____	Rs_____
second grade	Rs_____	Rs_____
lowest grade	Rs_____	Rs_____
Subtotal Sales (retail)	Rs_____	Rs_____
3 Total Expected Sales	Rs_____	Rs_____

4 Comparative Advantage

(Total Expected Sales - Total Costs = Comparative Advantage)
refer to the total costs calculated for each practice in Worksheet 2

Current practice Rs_____ **- Rs**_____ **= Rs**_____ (a)

New practice Rs_____ **- Rs**_____ **= Rs**_____ (b)

	Current practice	New practice
Which practice is most profitable, and can provide the best economic opportunity?	Rs_____ (a)	Rs_____ (b)

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Worksheet 4 Recovery of Invested Capital (ROIC)

If the new postharvest technology costs more than your current practice, how long will it take to pay for your investment in the new practice? An excellent return on investment would be a recovery time of less than one month, while a slower return may require an entire season (3 to 5 months) Any longer recovery period usually would not be considered a good return on investment

Current Practice _____ _____

New Practice _____

1 **Difference in total direct costs** for new practice = Rs_____
(Actual capital outlay for new equipment and facilities, plus power costs, supplies and labor requirements for the new practice when compared to costs for the current practice over the entire season see Worksheet 2)

2 Interest rate (if capital is borrowed) = _____% per annum, or _____% per month
Cost of capital at three months = Rs _____
Cost of capital at six months = Rs _____

3 **Difference in sales** using the new practice = Rs_____per month
(Subtract total expected sales using the current practice from total expected sales using the new practice see Worksheet 3, divide the difference by number of months of sales)

4 **Calculate ROIC in months to recover invested capital**

(**Difference in total direct costs** + any interest paid)
_____ = Months to pay for investment

Difference in Sales per month

(Rs_____ + Rs_____)
_____ = _____ Months
Rs _____ per month

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CHAPTER 11

INTRODUCTION TO PART II
SMALL-SCALE PROCESSING

There are many reasons to become familiar with the many technologies used for processing horticultural crops Economic opportunities abound for enterprising small agri-business people worldwide Processing produce to a fresh-cut or preserved state can **add value** to produce that commonly sells for a low price in its fresh state Starting a small-scale processing operation **provides new jobs** for your community, requires only a small capital investment in equipment and supplies, and can result in a fast return on investment When conditions are not suitable for storage or immediate marketing of fresh produce, processing **reduces perishability**

While storage of fresh produce requires special facilities and cooling equipment, constant temperature and RH management and strong, ventilated storage containers, processed horticultural product can be stored in any cool, dark location, has a much longer shelf life, and often increases your marketing options You can avoid selling your fresh produce at the lower prices offered during glut periods or during the usual season for fresh market, and decrease some of the costs associated with fresh handling, storage and transport Processed products can then be offered for sale during periods when the fresh produce is not available or is in short supply, or during holiday periods when people purchase food gifts and use specialty processed foods for their celebrations

Typical quality problems and sources of losses when processing horticultural products include some of the same problems encountered when handling fresh produce as well as problems related to the use of inappropriate processing methods and packaging practices

Typical quality problems and sources of losses when processing horticultural products

Harvesting at improper maturity
Inadequate sorting to remove diseased and contaminated produce
Inadequate washing and cleaning of produce before processing
Improper trimming (removing too much or too little of the inedible portions)
Use of improper processing methods
Misuse of processing methods (incorrect times or temperatures for processing)
Inadequate or inappropriate packaging materials

The second part of this book will assist you to identify and utilize scale-appropriate, cost-effective postharvest technologies for horticultural produce to

- Reduce postharvest losses due to weight loss, decay and physical damage
- Maintain produce quality and economic value during processing and storage
- Assure food safety during processing
- Increase income by adopting postharvest technologies that are profitable for your small-scale operation

Many horticultural crops can be successfully processed to high quality food products using simple technologies Being technically able to process produce however, is often quite different than being able to do so and make a profit The key element is always the market, and what consumers want to buy and eat, and whether they will pay you enough for the processed product to cover your costs and leave you a profit In some regions of the world canned and dried products are shunned Consumers may believe processed foods are less nutritious or somehow unnatural In other countries, some processed products are given high value, and producers may grow purely for processors Organic apples in the US sell for $30 to $75 more per ton as compared to conventionally grown fruit

Freezing produce is relatively easy, but requires higher capital investment by processors (in the equipment for freezing and maintaining low temperatures during handling, storage, shipping and

marketing) and has a higher cost for consumers (home freezers) Another factor are your costs for labor and the power for processing Labor costs may differ by the level of skills required for processing various products, while power costs will depend upon the method chosen and the time required for processing

Once you have identified a processed product that is valued by your potential customers, you must have a reliable supply of high quality fresh produce When you are also the grower this will simplify planning and procurement You can process only the fresh produce you can't sell immediately after harvest or deliberately sort for the various markets (highest grade for fresh market, seconds for processing) Processing is not the way to get rid of your culls, however, although sometimes you can salvage some produce with purely cosmetic problems or minimal defects Drying or canning over-mature, stringy green beans or over-ripe tomatoes is sure to give your customers something to complain about Care must be taken to sort out decayed or infested produce, since one strawberry or one tomato with a fungal infection or will contaminate the flavor of your entire batch of juice **Always begin with produce of high quality**, since processing will not improve visual, textural or flavor quality Produce for processing must be harvested at the proper maturity and handled very gently during transport to the processing facility and during sorting operations (ripe fruits, red tomatoes, fresh young vegetables are very delicate) Pretreatments are often used to preserve color, flavor and fesh texture, and all these costs must be considered

WORKSHEETS

Worksheets are provided the end of Part II of the book to assist you to calculate the costs and benefits associated with handling and processing horticultural products and determine potential profits Processed products depend upon high quality fresh ingredients, so the postharvest handling steps for fresh produce discussed in Part I are still very important considerations and are part of the costs you will encounter Worksheet 5 focuses on collecting basic information needed for producing and marketing products of any kind (overhead expected yields, estimated postharvest losses, anticipated market prices) Worksheet 6 requires that you calculate and list the actual direct costs incurred when you grow, handle, store and/or process a horticultural crop

Worksheet 5
Basic Information

Worksheet 6
Costs

Worksheet 7
Benefits

Worksheet 8 ROIC

Much of this you should know from your day-to-day recordkeeping for running your business Worksheet 7 outlines expected benefits in terms of sales and profit, and Worksheet 8 helps you to determine the return on investment (leading you through the calculation of how long it will take to recover invested capital) If you are not sure of the market prices you may receive, you can do the calculations for a worst case (lowest price) and best case (highest price) scenario and determine whether your investments will be worthwhile within that range of possible outcomes

PROCESSING METHODS

When choosing a processing method you must consider the type of produce, the costs associated with the method and the market demand for the prcessed product Fresh-cut technologies are the most complex and can be expensive, and must be undertaken with great care to protect food safety The processing methods that are more commonly used by small-scale produce handlers include dehydration (drying), fermenting, juicing, freezing, pickling in acid or salt, preserving in oil or sugar canning and bottling

FRESH-CUT (minimally or semi-processed) Cleaning, trimming, coring slicing or otherwise processing fresh produce to a "ready to eat" state adds value but also increases perishability and requires special packaging and excellent temperature management Shelf life is typically reduced to 7 to 14 days and refrigeration is critical throughout the marketing period See Chapter 12 for details

DEHYDRATION Removal of water from most fruits and vegetables increases shelf life, and drying reduces weight and volume which reduces the cost of storage and transport Most dried products are packaged in air-tight containers (plastic bags or glass or plastic bottles), while some can be covered with edible oil and bottled See Chapter 13 for details

FERMENTATION Popular throughout the world as a food preservation method, and over 3,500 individual fermented foods have been described by Campbell-Platt (1987) The details of fermentation are too complex to be covered in this book

JUICING Many fresh fruits and some vegetables can be processed into excellent juices either alone or in combination Juices must be heat processed to stabilize flavor and color then canned bottled or frozen to reduce perishability See Chapter 14 for details

FREEZING One of the best methods for preserving natural color flavor and nutritive value Two excellent references are the *Ball Blue Book* (1995), and *Keeping the Harvest* (Chioffi and Mead, 1991) Details on freezing are not offered in this book, since it is difficult to manage a freezing operation profitably on a small scale Inadequate packages or fluctuating temperatures can lead to immediate quality deterioration (soft, mushy produce) and a single power failure can be a disaster

PICKLING Peserving in vinegar or brine is defined as pickling Olives and cucumbers can be salt or brine cured to add value and increase shelf life Recipes vary widely and are often related to the region of the world where processing was first undertaken Vinegar is used for vegetable pickles (cucumbers, gherkins, hot peppers, tomatoes, onions, cole crops) fruit pickles (peaches, pears, watermelon rind), relishes and chutneys See Chapter 14 for details

PRESERVING IN OIL or SUGAR Specialty products such as peeled garlic, fruit jams and chutneys are preserved in oil or sugar Processing can add value and greatly increases shelf life and marketing options See Chapter 14 for details

CANNING/BOTTLING Produce can be canned or bottled alone or in combinations, in its raw state or after cooking High acid products such as most fruits tomatoes, pickles and preserves can be heat processed in a boiling water bath (100 °C or 212 °F), while low acid products such as vegetables must be processed at 115 °C or 240 °F in a steam pressure canner Specialty product preparations (juices, preserves, jams, pickles) are often bottled to increase shelf life, enhance display qualities (labels, bottle style) and increase marketing options See Chapter 14 for details

INFORMATION SOURCES FOR FOOD PROCESSING

Many useful reference books are available to guide you in selecting appropriate techniques and methods for processing your fresh produce The Ball Corporation publishes *The Ball Blue Book Guide to home canning, freezing and dehydration*, which is an excellent source of basic information for anyone who is new to food processing A catalog of postharvest processing equipment is available from Intermediate Technology Publications (9 King Street, London WC2E 8HW, UK) Included are driers, storage containers, cleaners, hand mills, power mills, shellers, decorticators (seed removers), oil processing equipment, fruit presses, and root crop cutters/graters Sources of specific processing equipment and supplies are listed at the end of Chapters 12 through 14

GENERAL REFERENCES

Azami S and Battcock, 1994 Crop processing small enterprise and the eradication of poverty *Postharvest News and Information* 5(3) 27N-38N

Ball Corporation 1995 *The Ball Blue Book Guide to home canning, freezing and dehydration* Muncie, Indiana Alltrista Corp

Chioffi N and Mead, G 1991 *Keeping the Harvest Preserving your fruits vegetables and herbs* Pownal, VT Storey Communications Inc

Fellows P and Hampton, A 1992 *Small-Scale Food Processing a guide to appropriate equipment* London Intermediate Technology Publications/CTA

CHAPTER 12

FRESH-CUT PRODUCE

Produce which has been cleaned, cored, peeled, chopped, sliced, or diced and then packaged may be considered fresh-cut produce Fresh-cut processing involves adding value to a raw agricultural commodity by preparing them for consumer use Fresh-cut is currently the fastest growing produce market segment in North America and Europe Consumers of such products may be retail consumers or food service establishments such as restaurants, hotels or hospitals Fresh-cut products are attractive to consumers because they offer uniform piece size, convenience, reduced preparation time and 100% of the product is usable This reduces labor costs, storage space requirements and training costs at food service establishments All these factors have lead to the rapid growth of this industry

Contrary to other food processing techniques such as drying or canning, fresh-cut processing does not extend the shelf-life or preserve the produce In fact, fresh-cut products are even more perishable and susceptible to the effects of temperature abuse than the whole products from which they are derived Fresh-cut products must be kept continuously at temperatures between 0 and 5 °C during processing, distribution and marketing If temperature abuse occurs, significant quality losses and spoilage occurs quickly This chapter will cover the general steps involved in producing high quality and safe fresh-cut produce

GENERAL DOS AND DON'TS FOR HIGH QUALITY FRESH-CUT PRODUCE

Certify that raw ingredient suppliers are using Good Agricultural Practices

Use only the highest quality produce as raw ingredients

Do not use diseased, decayed or over mature raw ingredients

Always follow Good Manufacturing Practices

Carefully monitor and maintain appropriate wash water pH and chlorine levels

Monitor and maintain wash water temperatures near 0 °C

Keep cutting and coring blades as sharp as possible

Always keep finished products between 0-5 °C

Continuously monitor ingredient and finished product temperatures

Use appropriate flexible packaging materials, well suited to your product and markets

Maintain first-in first-out ingredient and finished product rotation

Assure food safety by implementing a HACCP program

Prevent temperature abuse during distribution and marketing

PRODUCT PREPARATION

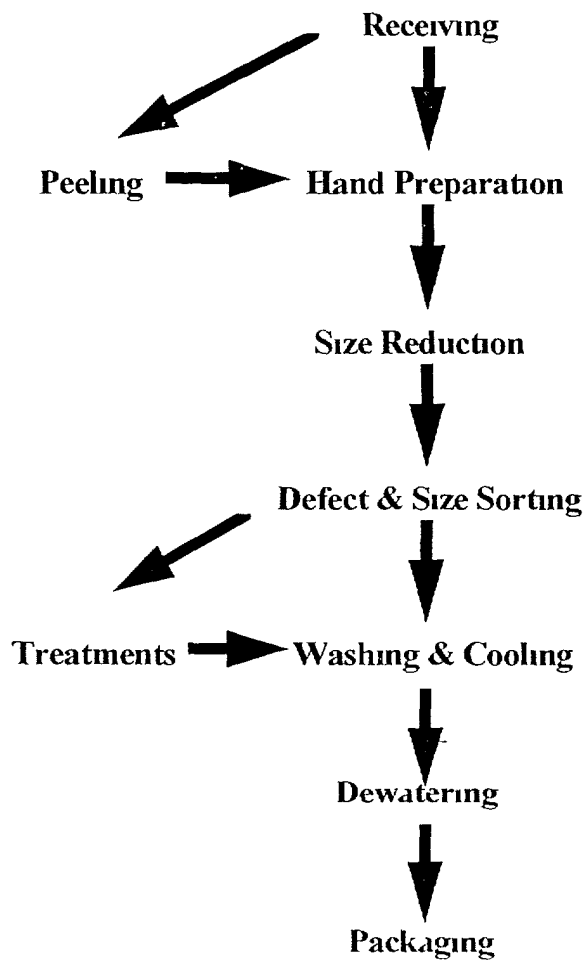
Fresh-cut product preparation involves various steps which can be broken into specific unit operations Each unit operation must be performed properly to assure that finished product quality shelf-life and food safety are satisfactory Temperature management cleanliness and expeditious handling are primary considerations when processing fresh-cut produce Each of the unit operations will be described briefly and its importance detailed

UNIT OPERATIONS IN FRESH-CUT PROCESSING

Raw Material Receiving and Storage

Ingredient Inspection

The quality of fresh-cut product is highly dependent on the quality of bulk commodities used for processing Poor quality ingredients will yield poor quality finished fresh-cut products Produce being received for processing should be sampled and tested for receiving temperature incidence of defects (i e bruising, blemishes, freeze damage in transit, etc) and insect infestation Dock facilities should be enclosed, well illuminated and refrigerated Written specifications and sample plans should be used to inspect incoming bulk commodities and any variance from the specified quality should be immediately noted and brought to the attention of the processing management personnel



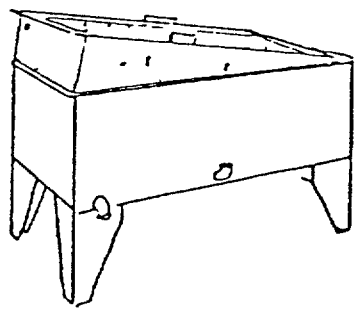
Upon acceptance of raw materials the lot should be tagged with the date of receipt on each box or bin to assure first in first out

inventory rotation The accepted product should be quickly moved into the appropriate temperature storage room Permanent records of the amount and quality of each lot should be documented and be available to bulk commodity buyer and processing management team Many problems can be avoided by rejecting inferior quality product on the receiving dock and not allowing it into cold storage or the processing room If you are buying produce from another grower it is especially important to keep good records and do inspections before accepting incoming produce

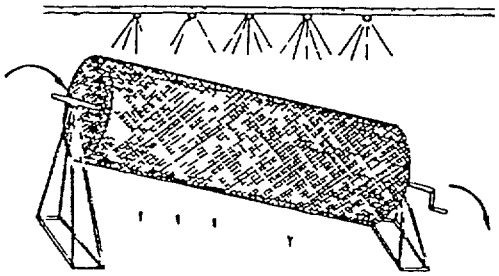
Product Flow Bulk commodities should be segregated from finished products to prevent cross contamination Incompatible commodities should also not be stored in the same cooler together (e g apples and lettuce) Intermediate stage commodities (e g , whole peeled onions or carrots) are best stored with bulk commodities, as further processing and washing will be done Stored in-process intermediates should also be date labeled to assure first in first out inventory rotation Processing lines should be laid out in a linear fashion with as few 90° angles and vertical drops as possible Treating whole bulk commodities and intermediate fresh-cut products as gently as possible during processing is important to minimize unnecessary bruising and stress which may reduce product quality and shelf life Reusable plastic totes or bulk bins may be used to move or store product **BUT** they must be properly labeled (i e Food Only), as well as cleaned and sanitized on a regular basis

Preliminary Washing and Sorting

Fruit and vegetable products are sometimes received with caked on dirt or dust Washing and even scrubbing some commodities and then rinsing in cold chlorinated water may be necessary to remove dirt and reduce microbial populations before cutting The rotary drum washer shown here can speed up the cleaning



of large amounts of small -sized produce Immediately removing any fruits or vegetables that show signs of decay from the processing line will also help keep reduce microbial contamination



Peeling

Some commodities such as carrots, onions and most fruit require peeling to remove tough fibrous skin before cutting There are numerous peeling methods used in the canning and frozen food industry However most are not appropriate for fresh-cut products

Hand Peeling Hand peeling of fruits and vegetable products will in most cases provide the highest quality product and the highest yield Hand peeling is extremely labor intensive, but is currently the only option for some commodities

Abrasive Peeling Abrasive peelers are commonly used in the fresh-cut industry for such items as carrots and onions These peelers utilize abrasive surface rollers to remove the outer skin from the product The skin is washed away with a fine spray of water Yields can be variable depending upon the operator as well commodity size, shape and quality Abrasive peeling can be very damaging to commodities and may result in surface scaring which results in chalking or white blush in peeled carrots

Size Reduction / Cutting

Product Hand Prep Cores stems seeds and other unwanted plant parts must be trimmed and discarded from the bulk commodities before further size reduction is done Hand knives and stationary coring units are effectively used for this operation Knives and corers should be kept clean sanitary and sharp Any products exhibiting decay should be discarded and not cut at these stations as it will contaminate the cutting surface with microbes, and potentially allow for the

contamination of each successively trimmed fruit or vegetable This is also the primary area for sorting out decay or defects If defects and decay are not sorted out at this point, one defect will be cut into many small pieces and be dispersed in a large amount of product making it almost impossible to sort out

Cutting Equipment After preliminary trimming, size reduction is done via one of any number of cutting machines There are many manufacturers of slicers and choppers such as Urshel, Brothers, Waterfall, Hobart, and Altman, to name just a few Knife sharpness is a critical factor since dull knives can significantly reduce the shelf life of fresh-cut products Replacing and/or sharpening knives on a regular basis is highly recommended Tracking either the hours of operation on each set of blades or closely visually inspecting cut surfaces are methods which can be used to assess when blades need to be sharpened or replaced

Size and Defect Sorting

Size Sorting Size sorting is done to assure that finished product piece size is within acceptable limits to meet customer needs The most effective way to accomplish this is by the use of shaker screen sizers, which allow undersize small pieces (fines) to pass through a vibrating screen Pieces greater than the size of the aperture of the shaker screen will continue on to the next steps in processing

Defect Sorting_ Sorting after cutting is often done to remove physiological defects and/or off cut pieces Due to the number of different defects which are encountered trained people on the sorting line are the best solution to this problem Increasing the number of persons sorting when high frequencies of product defects (e g tip burn in lettuce) are expected is the only solution

Washing/Cooling

Properly washing and cooling fresh-cut products immediately after cutting is one of the most important steps in fresh-cut processing Washing in cold chlorinated water after cutting helps remove microbes, dirt and cellular juices at the cut surfaces Rinse water temperature, contact time, chlorine content and pH are all key parameters to assure that products are rinsed and cooled properly

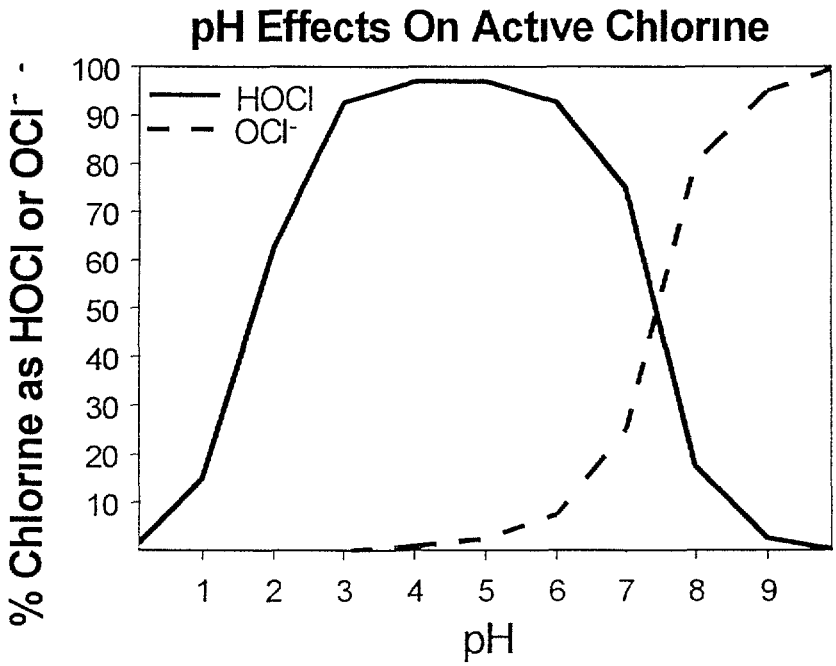
Temperature Rinse water temperature should be as cold as possible for the product being rinsed, and 0 °C is optimal for most products Rinse water temperature at the entrance and exit points from the rinse system should be monitored frequently if not continuously to assure that product is being cooled properly and to assure that the chilled water delivery system capacity has not been exceeded

Contact Time The longer the fresh-cut product is in contact with the rinse water the colder the fresh-cut product will become Fresh-cut product must be as cold as possible when exiting the rinse water system (and kept cold) since it is almost impossible to cool fresh-cut products once they are bagged boxed and palletized Product temperature at the exit of the rinse water system should be monitored to assure that proper cooling has occurred Rinse water may be sprayed on fresh-cut products from above via nozzles as it proceeds on a conveyor belt or the fresh-cut product may be submerged and flumed through the rinse system. Submerged fluming systems have the advantage of gently agitating the product pieces and more effectively removing dirt and other debris Fluming also allows for the long distance transport of product to a separate packaging area

Chlorination Total chlorine up to 200 ppm is currently allowed in food processing rinse water to assure potability 50 to 100 ppm is, however, usually sufficient Maintaining these levels of chlorine at all times is critical to reduce microbial populations on a fresh-cut produce and reduce cross contamination in the rinse water system Chlorine is injected into the rinse water system as either a gas or a liquid (Sodium or Calcium Hypochlorite) Careful monitoring and control of free

chlorine levels during processing is critical Chlorine test kits or biological oxygen demand (B O D) meters should be used to monitor and adjust chlorine levels Excessively high concentrations of chlorine will damage fresh-cut produce and reduce shelf life as well as cause off flavors and odors

pH Chlorine functions best as a bactericide at a neutral or slightly acidic pH If the pH of the rinse water increases above 7 5 chlorine is ineffective as a bactericidal agent because it is not in its active form Closely monitoring the pH of the rinse water and adjusting it with an appropriate acid (phosphoric or citric) or base (sodium hydroxide) is an often overlooked factor in fresh-cut processing operations



Effects of wash water pH on the % active (HOCl) and inactive (OCl^-) forms of chlorine

285

Dewatering Operations

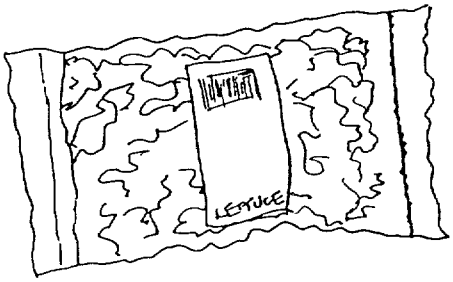
Centrifugation_ The method of choice in the fresh-cut industry to dewater product is via centrifugation (spinning to force water to the outside of a collection vessel) The time and speed of centrifugation are key parameters to adjust for each product Excessive centrifugation will result in cellular damage and cause products to leak fluids after packaging, greatly reducing quality

Forced Air Many fresh-cut products are too delicate to withstand centrifugal drying and forced air in a semi fluidized bed may be used to strip water away from products It is most effective on product pieces which have smooth surfaces allowing water to be swept away from the product Highly textured surfaces with nooks and crannies are much more difficult to dry via this method Any forced air used in such an operation must be filtered so as not to contaminate products

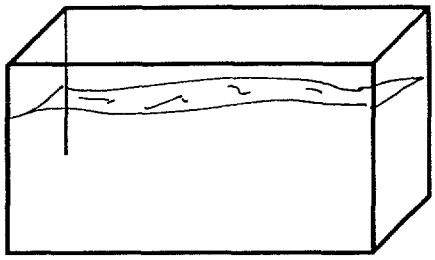
Packaging

Weighing The first step in the packaging of fresh-cut products is getting the correct amount of product, into the package This is often accomplished by manually weighing each bag of product and adding or removing product to the desired weight

Bagging and Sealing Polymeric film bags and trays for fresh-cut produce come in many sizes, shapes and formulations Bags may either be purchased already sealed on the side and bottom or formed on site from rolls or precut film Side and bottom sealing films on site requires substantial capital expenditure for equipment and is used for high volume items Pre-formed bags are slightly more expensive than rolls of film but require only small capital investment for sealing machines When fresh-cut products are packaged the atmosphere within the package may be evacuated or flushed with a mixture of gases to more rapidly establish a desirable modified atmosphere The correct combination of packaging material produce weight and gas composition within a package are critical components which must be determined for each product to maintain product quality and extend



product shelf life (See the section on MAP in Chapter 5 for details) Packaging cannot correct for unsanitary product handling, temperature abuse or poor quality raw materials Incorrect choice of packaging materials may also cause accelerated deterioration of products Some processors add a freshness indicator label to the package in order to give produce buyers and consumers additional confidence in produce quality



BAG LEAK DETECTOR Tank of clear glass (a 20 gallon fish tank works well) full of clean water allows workers to check visually for air leaks in sealed bags of fresh-cut produce

Proper sealing of bags is critical in maintaining product quality since as bags with imperfect seals will have near ambient oxygen concentrations and accelerated browning Seal bar cleanliness, temperature and dwell time must all be carefully controlled and monitored to assure good seals are being consistently produced Seal integrity as well as side and bottom seals on pre-formed bags should be checked often

Metal Detection As part of a good manufacturing practice all fresh-cut products should be screened for the presence of extraneous ferrous and non ferrous metal fragments Nails and staples from bins and boxes as well as fragments from knives and screws from equipment are all possible sources of metal fragment contamination Metal detectors must be properly calibrated to function effectively and whenever product package size changes the metal detector must be recalibrated As the net weight or volume of product going through a metal detector increases sensitivity decreases On line metal detectors should also be equipped with some sort of ejection device which removes any product which sets off the metal detector Numerous brands of metal detectors are available and allow for the continuous screening of bagged products

Boxing Fresh-cut product boxing is the last step in the processing operation Boxes should be pre-cooled to make sure that cold product is not packed into warm boxes Boxes of product should always carry a date of manufacture or use by date and production code to allow first in first out product rotation and possibility of product recall in case such an event is needed Numerous sizes and types of box forming, sealing, and labeling equipment are available

TREATMENTS FOR SHELF LIFE EXTENSION

Signs of deterioration of fresh-cut products include bruised or broken pieces, wilting, shrivelling, flacidicity, mushiness, development of off-colors presence of free liquid in the package, presence of undesirable odors, or bloated bags due to excess gas in sealed bags

> Fresh-cut products generally fail due to the following reasons
> 1) microbial spoilage,
> 2) excessive tissue softening, and/or
> 3) tissue browning at cut surfaces

One of the reasons fresh-cut products are so popular with health conscious consumers is the lack of additives and preservatives used during processing However, some acceptable treatments do exist for shelf life extension

Microbial Spoilage

The best tool to fight against microbial spoilage is implementation and monitoring of a vigorous cleaning and sanitation program (described earlier in this chapter) Cold temperatures and the chlorination rinse of fresh-cut products effectively reduce microbial growth and are key factors for attaining good product shelf-life It must be remembered that there is no one step during fresh-cut processing that kills pathogens and no amount of washing will completely remove pathogens from produce if it is contaminated

Control of Tissue Softening

Tissue softening is a very serious problem especially in fresh-cut fruit products The flesh firmness of fresh-cut fruit products can be maintained by treatments calcium salts Dipping fresh-cut products in solutions of 0 5 -1 0% (1% = 10g per liter of water) calcium chloride is very effective in maintaining product firmness However, calcium chloride may leave a bitter off-flavor on some products Calcium salts such as calcium lactate and calcium acetate may also be used Key factors which must be addressed when using such treatments are salt concentration, temperature and contact time

Control of Browning

An important issue in fresh-cut processing is the control of browning of cut surfaces Oxidative browning is caused by the enzyme polyphenoloxidase (PPO) which in the presence of oxygen converts phenolic compounds in fruits and vegetables to brown pigments Outlined below are a number of strategies which may be used to reduce PPO browning

Reduced Oxygen Because PPO requires oxygen to induce browning, reducing the amount of oxygen in a package of fresh-cut product by modified atmosphere vacuum packaging or gas flushing will significantly reduce the rate of browning Reducing the oxygen concentration in a package of fresh-cut products will only slow the rate of browning and not completely stop it Careful design of a fresh-cut package is essential to assure that the proper amount of oxygen is present Excessive amounts of oxygen in a package may accelerate browning, while too little oxygen may cause anaerobic metabolism and the production of off flavors and odors

Acidification PPO works best at promoting browning at a neutral pH of 7 Therefore browning can be slowed by dipping products in mildly acidic food grade solutions of acetic ascorbic citric tartaric fumaric or phosphoric acid The lowered product pH slows browning but acids may leave off flavors as well as tissue softening and must be used with care

Reducing Agents Ascorbic acid or erythrobate (an isomer of ascorbic acid) are two common compounds used in the food industry to prevent PPO browning Ascorbic acid or erythrobate stop

PPO browning by converting quinones (formed by PPO from phenolics) back to phenolic compounds Unfortunately, once all the ascorbic acid or erythrobate are used up, PPO browning will proceed uninhibited Ascorbic acid or erythrobate are commonly used as a 1% solution to prevent browning of cut surfaces These compounds are organic acids so they also reduce the pH of commodities and slow PPO browning

COSTS AND BENEFITS OF FRESH-CUT OPERATIONS

Costs
equipment
labor
materials
cooling (mechanical refrigeration or ice)

Benefits
higher market value

Examples
Peeled cucumber or radishes dipped in lime juice make refreshing snacks The produce costs about Rs 5/kg (Rs 0 10 to 020 per piece) and the fresh-cut produce sells for Rs 2 per piece

Fresh fruits sell for about Rs20/kg (Rs 2/100g) Peeled, cut fruits served on a plate sell for Rs 5 to Rs10 for a 100g serving

SUPPLIERS OF EQUIPMENT AND MATERIALS FOR FRESH CUT PROCESSING

bin dumpers	Brothers' Metal Products, Inc Weldfab Manufacturing Inc
citrus peeler/corers	Murotech Corporation
conveyors	Brothers' Metal Products Inc Weldfab Manufacturing Inc
custom fruit/veg fresh-cut equipment vegetable equipment	Garroutte Inc Vanmark Corporation
dicers	Urschel Laboratories
freshness labels (time-temperature indicators)	Lifeline Technology Inc
packing/sorting tables	Brothers' Metal Products, Inc

shredders	Commercial Slicers Con Inc Urschel Laboratories
slicers	Brothers' Metal Products Inc Urschel Laboratories Commercial Slicers Con Inc
spinners / spin driers	Brothers' Metal Products, Inc Sunrise Food Machinery Weldfab Manufacturing Inc
strip cutters	Urschel Laboratories
sterilization control systems (chlorine)	Stranco Inc
wash tank conveyors	Brothers' Metal Products, Inc

Supplier Addresses/Phone/FAX

Brothers' Metal Products Inc , 1270 North Grove Street Anaheim CA 92806
Phone (714) 630 1051 FAX (714) 632 5032

Commercial Slicers Company, Inc , 56A North Seneca Street Waterloo, NY 13165
Phone (315) 539 5415 FAX (315) 539 4640 e-mail commslicer@aol com

Garroutte Inc , P O Box 1747, Watsonville, CA 95077
Phone (408) 722 2487 FAX (408) 722 3409

Murotech Corporation 23820 Hawthorne Blvd Torrance CA 90505
Phone (310) 791 1776 FAX (310) 791 7252

Stranco Inc P O Box 389 595 Industrial Drive Bradley IL 60915
Phone (815) 932 8154 FAX (815) 932 0674 e-mail sales@stranco com

Sunrise Food Machinery P O Box 2106 Freedom, California 95019
Phone (408) 696 0222 FAX (408) 722 0207

Urschel Laboratories P O Box 2200 Valparaiso IN 46384-2200
Phone (219) 464 4811 FAX (219) 531 0219 e-mail marketing@urschel com

Vanmark Corporation Industrial Parkway Creston IA 50801
Phone (515) 782 6575 FAX (515) 782 9209

Weldfab Manufacturing Inc , 11045 Commercial Parkway Castroville CA 95012
Phone (408) 633 3620 FAX (408) 633 0644

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International Fresh-cut Produce Association 1997-98 *Membership Directory and Buyer's Guide*

Kader A A and Mitcham E 1995 Standardization of Quality *Perishables Handling Newsletter* Special Issue on Fresh-Cut Products 80 7-9

Luh, B S and Woodroof, J G 1975 *Commercial Vegetable Processing* AVI Publishing Co Westport CT

Wiley R C 1994 *Minimally Processed Refrigerated Fruits and Vegetables* New York Chapman and Hall

Woodroof J G and Luh B S 1986 *Commercial Fruit Processing* AVI Publishing Co Westport, CT

CHAPTER 13

PRODUCE DRYING

Dehydration or drying of fruits and vegetables can be accomplished with little capital and produces plenty of high quality, less perishable food products Drying is the simplest and most natural of all food processing technologies, and preserves fresh produce by removing most of its free water The lower water content slows the rate of respiration, enzymatic action and overall deterioration rate, makes products less susceptible to decay and much easier and less expensive to store and transport While all horticultural produce can be dried, not all commodities become high quality, good tasting dried products

You can dry produce naturally in the sun (direct solar drying), via solar assisted methods (indirect solar drying), or with added ventilation and heat to speed the process (electric, gas or diesel powered driers) Drying in the sun is the least expensive method, and quite viable if your climate is hot and dry during harvest time, but also the slowest method and often results in products of a lower overall quality Pre-treatments such as blanching and ascorbic acid dips used before drying can assist you to reduce losses of flavor, color and nutritional quality that can occur when drying produce Value can be added to dried products by enhancing flavor during drying (for example by adding spices to vegetables, or sweetening fruits with sugar or honey dips)

This chapter will provide information on 1) produce types and cultivars known to result in high quality dried products 2) a variety of pre-treatments used to reduce quality deterioration, 3) details on methods of direct solar indirect solar and power-assisted drying, 4) dehydration equipment you can build or buy and 5) packaging options for dried produce The chapter concludes with a simplified example to help you to work out the costs and benefits related to producing and drying fresh produce and packaging, storing and marketing dried products

GENERAL DOs AND DON'Ts FOR PROCESSING HIGH QUALITY DRIED HORTICULTURAL PRODUCTS

Dry only those fruits and vegetables that will result in a high quality, marketable product

Start with high quality freshly harvested produce Allow fruits to ripen on the tree or vine

In general, the faster a food is dried, the better the quality of the dried product will be (better flavor, color, texture and higher nutritional value)

Wash produce thoroughly before pre-treatments and/or preparation for drying

Pre-treatments can reduce browning and loss of vitamins (blanching, sulfuring, various dips such as lemon juice, acsorbic acid solution, sodium bisulfite, pectin or honey)

Dry as quickly as possible but keep drying temperatures from getting so high that the produce flavors change and produce becomes "cooked" (maximum 53 to 57 °C or 130° to 140 °F)

Expose as much surface as possible to speed drying rate (slice shred, grate or chop)

Dos and Don'ts continued

Peel produce to expose more surface area, remove stems, seeds, pits

Produce pieces should be uniform in size and thickness

Spread produce out in a thin, single layer on slatted or screen trays

Remove surface moisture (wipe with a clean cloth or paper towel)

Air movement over and below the trays will increase drying rate

Always test produce for adequate dryness before storing (until leathery for fruits, 15 to 20% moisture, crisp-hard for vegetables, about 5% moisture Actual times for complete drying will vary widely)

If drying outdoors in the sun, take trays indoors if it threatens to rain, and at night to prevent the collection of dew on the produce

Take care to avoid dust dirt and insect contamination during drying

Consider adding value with special seasonings or sweetening produce during drying if you have a ready market for such products

Seal wooden trays with mineral oil (pine and cedar will transfer odors to produce)

Do not use galvanized screen for trays as it will contaminate foods

Store dried products in small, airtight containers and protect products from light

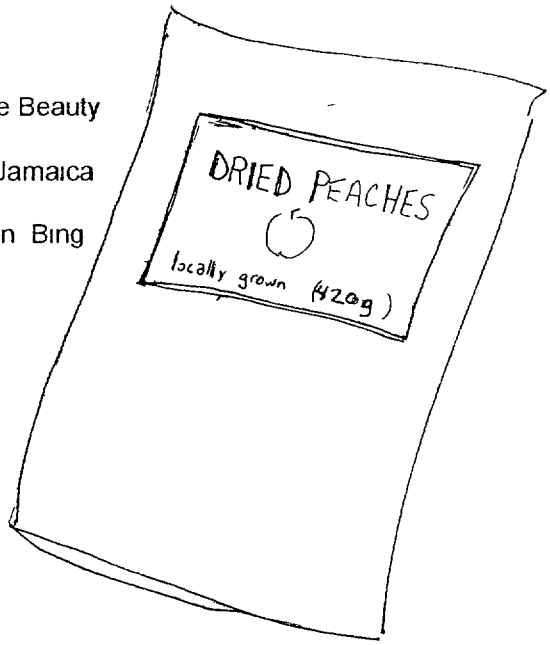
Check stored products for moisture, and dry further if any condensation is found in containers to avoid problems with fungal growth, mycotoxins or aflatoxins (found predominanatly in tree nuts)

HORTICULTURAL COMMODITIES AND CULTIVARS SUITABLE FOR DRYING

Nuts All nut crops must be dried before storage

Fruits (fully ripe)

Apples-- Gravenstein Granny Smith Jonathan Rome Beauty
Apricots-- Blenheim/Royal Tilton
Bananas-- Cavendish Gros Michel Martinique Red Jamaica
Blueberries
Cherries (sweet)-- Lambert Royal Ann Napoleon Van Bing
Currants-- black seedless varieties
Dates
Figs-- Kadota White Adriatic Black Mission
Grapes--Thompson Seedless
Kiwifruit
Mangoes
Melons-- cantaloupe Honey Dew watermelon
Nectarines
Papayas
Peaches
Pears--Bartlett Summer
Persimmons
Pineapples
Plums-- prune types D Agen French Imperials Brooks Italian Prune
Strawberries



Vegetables

Beans (green)-- Tendergreen Blue Lake
Beets--small sized Detroit Dark Red Morse Detroit Ohio Canner
Carrots-- Imperator Red Cored Chantenay
Corn (sweet)-- yellow varieties
Garlic-- use only firm cloves with no bruises
Horseradish-- use only fully mature roots
Mushrooms-- *Boletus edulis* Chantrelles Morels *Agaricus Bisporus*
Okra-- less than 4 inches (10 cm)
Onions-- Southport White Globe and Yellow Globe Red Creole White Creole Ebenezer
Parsley and herbs
Parsnips
Peas (green)-- Dark Seeded Thomas Laxton
Peppers (sweet and chilies)
Potatoes
Pumpkins
Squash (winter)
Sweetpotatoes
Tomatoes-- fully ripe Roma or paste types Red Pear Del Oro Viva Italia
Turnips --young small

PRE-TREATMENTS

Preparation for Processing

In addition to washing produce with clean, good quality water, certain produce requires special preparation before drying for best results

Removing any inedible parts Woody stems (cherries, grapes, currants, berries, mushrooms) inedible peels or pods (onions, garlic, kiwifruit, melons, bananas, mangoes, green peas) and pits or seeds (cherries, papayas, melons) should be removed

Peels can be removed from stone fruits, tomatoes, and apples to speed drying rate

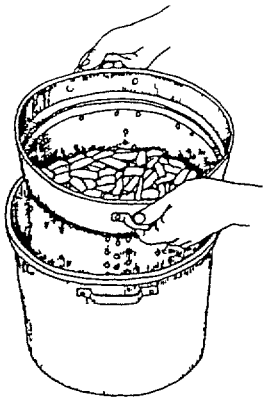
Fruits such as grapes, plums and blueberries have a waxy coating on their peels which must be "checked" by quickly dipping in boiling water or the skins must be pierced before beginning the drying process

Apricots, peaches and plums will dry faster if their backs are "popped" after being halved and pitted (pushing the peel side inward to expose more of the surface)

Large sized fruits should be cut or sliced into pieces of uniform size and thickness (1/4 inch to 1/2 inch, or 0 6 to 1 2 cm thick) Smaller sized fruits can be halved or quartered

Vegetables should be cut or sliced into smaller pieces (1/8 inch cubes, shredded or diced) to reduce drying time-- taste and texture are lost if drying takes too long (more than 14 hours)

Pre-treatments—Blanching



Some vegetable produce benefits from **blanching in boiling water or steam** before drying Blanching is quick, incomplete cooking, which ends certain enzymatic reactions in the fresh product expels tissue gases Blanching decreases the microbial population present on the surface of fresh produce and helps retain bright color, good texture and fresh flavor after processing Follow the chart below for blanching times, and always rinse blanched produce under very cold water or dip the hot produce into and ice water bath to stop the cooking process Steam blanching takes a little longer but results in less loss of vitamins B_1, B_2, niacin and C than boiling water blanching

Blanching times for vegetables

Boiling water Use one gallon of boiling water per pound (8 liters per kg) of produce
Steam blanching Use 2 inches (5cm) of water per lb or 1/2 kg of produce
Place produce in a colander on a wire rack or in a steam basket

Commodity	Blanching time (minutes)*	
	Boiling water	Steam
Beets	15 until tender	30
Carrots	5	5
Corn (whole ear cut kernels off repeat)	3	5
Green Beans	3	4
Leafy greens	2	
Mushrooms	3 to 5	4 to 5
Okra		3 to 4
Parsnips	3	4
Peas	2	3
Potatoes (new)	4 to 6 until translucent	
Pumpkin	2 to 3 until soft	
Sweetpotatoes	5 to 10 until soft	5 to 10
Tomatoes	30 seconds then cold water dip to remove skins	
Turnips	5	5 to 8

*Add 1 minute to blanching times for each 2000ft if you live at an elevation of over 4000 ft

Sources Chioffi N and Mead S 1991 *Keeping the Harvest*
and McClure S 1992 *The Harvest Gardener* Pownal VT Storey Communications Inc

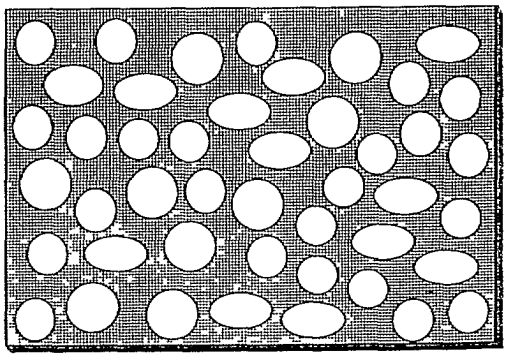
Pre-treatments--Sulfuring

Fruits such as apples and apricots are sometimes treated with sulfur before being dried Sulfuring helps prevent darkening loss of flavor and loss of vitamin C and reduces the microbial population present on produce tissues Fruits dry faster after being sulfured and insects are not as much of a problem during drying Treatments can be made by exposing prepared produce to fumes from burning sulfur powder for up to several hours or via solutions (dipping fruit in a potassium metabisulfite or sodium bisulfite solution for one minute)

Despite its technical benefits, treatment with sulfur can be a problem for several reasons Some consumers dislike the taste of sulfured produce while a small percentage may have an allergic reaction (always label your products as sulfured to provide consumers with this information so they can protect themselves from harm) Fruits treated with sulfur fumes cannot be dried indoors, since the odors are too strong

Sulfuring by dipping in bisulfite solutions Recommended for apples, green peas, available as commercial preparations such as Fruit-Fresh®

Use a solution of 1% potassium metabisulfite (1 Tbsp in 1 gallon, or 10 ml in 1 liter of water) for one minute or 2% sodium bisulfite solution (2 Tbsp in 1 gallon, or 20 ml in 1 liter of water) for up to 5 minutes Drain and pat dry before laying produce out on drying trays



DRYING TRAY
Sliced produce spread in a thin single layer on a screened tray

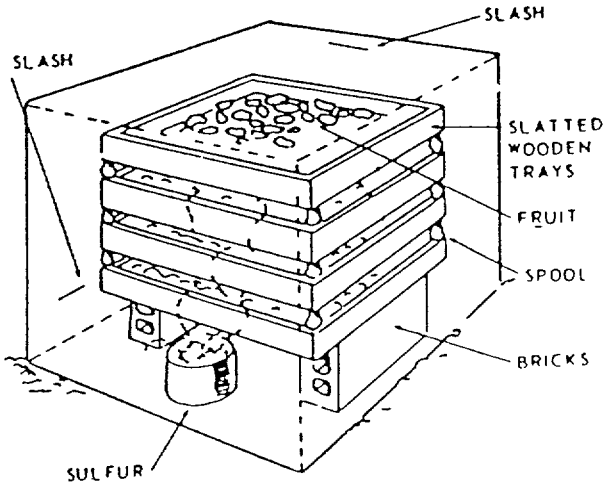
Sulfuring times via burning sulfur powder for selected fruits

(burn one tablespoon of sulfur powder per pound or 35 ml per kg of fruit)

Commodity	Sulfuring Time		
	Halves	Quarters	Slices
Apples		1 hour	45 min
Apricots	3 hours	2 hours	
Cherries	30 minutes	20 minutes	
Nectarines	3 hours	2 hours	
Peaches	2 to 3 hours	2 hours	1 hour
Pears	4 to 5 hours	2 hours	1 hour

Sources Miller M et al 1981 *Drying Foods at Home* University of California Division of Agricultural Science Leaflet 2785 and Hobson P 1994 *Making and Using Dried Foods* Pownal VT Storey Communications Inc

A low cost sulfuring box can be constructed from a large cardboard or lightweight wooden box that is vented in several places to allow adequate ventilation Trays for drying can be stacked using bricks and wooden spools as spacers The trays must be made completely of wood, since sulfur fumes will corrode metal The entire assembly must be located out of doors, preferably on bare soil Use one tablespoon of sulfur powder per pound (35 mls per kg) of fruit Place the sulfur in a container well away from the side of the box since it will become quite hot Once the powder is burning well seal the bottom edges of the box with soil



Source Miller (1981)

25.3

Pre-treatments-- Recipes for fruit dips

Some fruits can benefit from a brief dip in acid pectin sugar or salt solution Never leave fruit in the pre-treatment solution for more than a few minutes (3-4 minutes maximum)

Ascorbic acid dips Recommended for apple slices apricots, bananas peaches, nectarines, pears use 5 grams vitamin C tablets crushed in 1 L or 1 quart of lukewarm water or 30 ml (2 Tbsp) acsorbic acid powder in 1 L or 1 quart lukewarm water Slice or chop fruits directly into the solution, remove with slotted spoon drain well and pat dry

Pectin dip Recommended for berries, cherries and peaches and nectarines
1 box powdered pectin in 1 cup (250 ml) water, stir, boil 1 minute Stir in 1/2 cup (125 ml) granulated sugar, dissolve Add cold water to make two cups (500 ml) syrup Chill Cut fruit into syrup, coat thoroughly, remove with slotted spoon, drain well and place on trays

Honey dip Recommended for bananas, pears, peaches, nectarines, apricots, pineapple, strawberries Mix 1 cup (250 ml) granulated sugar in 3 cups (750 ml) hot water Stir in one cup (250 ml) honey Dip cut fruit, remove with slotted spoon, drain well and place on trays

Fruit juice dips Recommended for apples, apricots, peaches, nectarines, bananas
Pineapple Dip cut fruit in undiluted pineapple juice Drain well, place on trays
Lemon Mix 1/4 cup (63 ml) lemon juice with one quart (1 L) warm water
Dip cut fruit, remove with slotted spoon, drain well and place on trays

Salt water dip Mix 6 Tbsp (90 ml) flaked pickling salt in 1 gallon (4 L) lukewarm water Slice or chop fruit directly into solution, remove with slotted spoon, drain well and pat dry

DRYING TEMPERATURES AND TIMES FOR PRE-TREATED FRUITS AND VEGETABLES

Test produce for dryness about one half way through the recommended drying time Dried fruits will be pliable (apples, apricots, plums, strawberries) or leathery (cherries, grapes, peaches, pears) while dried vegetables will be crisp (garlic, parsnips hot peppers, potatoes, tomatoes), hard and brittle (beets, corn green beans, carrots, peas), papery (onions) or tough (sweet peppers, rhubarb)

Fruits (fully ripe, sliced)	Solar drying (days)	Power-assisted dehydration Temperature Time in hours °F	°C	(check at 1/2 way)
Apples	2-3	130	54	6-8
Apricots	2-3	130	54	12-36
Bananas	2	130	54	6-8
Blueberries	2-4	130	54	12-24
Cherries	1-2	130	54	10-12
Currants		130	54	18-24
Dates		130	54	12-24
Figs	5-6	130	54	36-48
Grapes	3-5	130	54	24-48
Kiwifruit		140	60	12-18
Mangoes		130	54	24-36
Melons		130	54	10-14
Nectarines		130	54	10-12
Papayas		130	54	24-36
Peaches	4-6	130	54	24-36
Pears	2-3	130	54	12-18
Persimmons	3-5	130	54	18-24

	Solar drying (days)	Power-assisted dehydration Temperature Time in hours °F	°C	(check at 1/2 way)
Fruits (fully ripe, sliced)				
Pineapples	3-4	130	54	24-36
Plums/prunes	4 5	140	60	18-24
Strawberries	1-2	130	54	12-18
Vegetables (diced or chopped)				
Beans (green)	4-5	130	54	48
Beets	1-3	130	54	4-8
Carrots	2-3	130	54	12-18
Corn (sweet)	1-2	130	54	8-12
Garlic		130	54	6-8
Mushrooms	1-2	130	54	8-12
Okra	1-2	130	54	8-12
Onions	2-3	130	54	12-24
Parsley and herbs		90	32	6-8
Parsnips	1-2	130	54	12-18
Peas (green)	2-3	130	54	12-18
Peppers (sweet and chilies)	1-2	130	54	8-18
Potatoes	2-3	130	54	12-18
Pumpkins	2-3	130	54	12-18
Squash (winter)	1-2	130	54	8-18
Sweetpotatoes	1-2	130	54	12-18
Tomatoes (fully ripe)	1-2	130	54	6-8
Turnips	2-3	130	54	12-18

Sources Hobson (1994) and DeLong (1979)

DRYING MFTHODS

Solar Drying

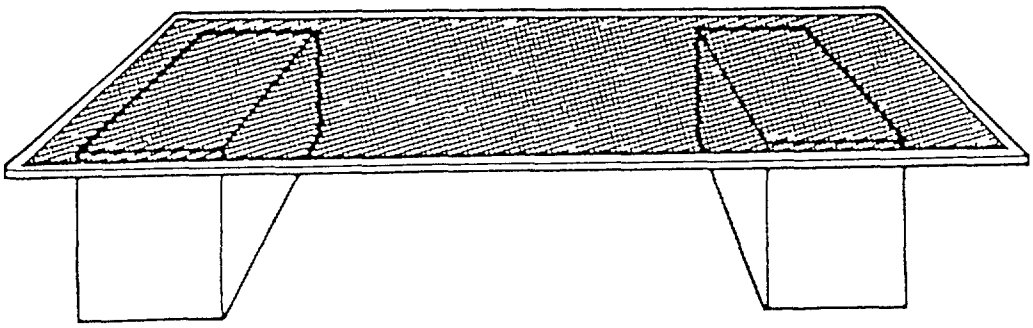
Horticultural produce can be dried using direct or indirect solar radiation The simplest method for solar drying is to lay produce directly upon a flat black surface and allow the sun and wind to dry the crop Nuts can be dried effectively in this way

Solar drying is recommended for

apples
stone fruits
pineapple
currants
grapes
figs
dates
pears

Solar drying works best in a hot, dry climate When drying produce in the sun, place the prepared produce in the sun for the first 2 or 3 days, then move it to a ventilated shady spot to complete drying If you live in a location with a high relative humidity, solar drying may take too long to produce a high quality product

Simple direct driers can be made from trays of screening material propped upon wooden or concrete blocks to allow air to circulate under the produce A layer of cheesecloth can be draped loosely over the produce, protecting it from insects and birds while drying Produce dried outdoors in India is often unsafe due to exposure to bird droppings

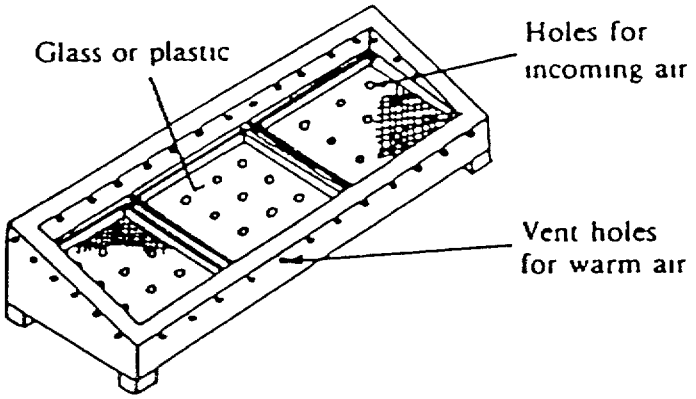


Trays should be made of food-grade materials such as stainless steel plastic or nylon **Copper, aluminum and galvanized metals (cadmium and zinc plated metals) should not be used**--copper reduces the vitamin C content in many foods aluminum will discolor some fruits and zinc and cadmium are dissolved by fruit acids and cause dried products to become toxic

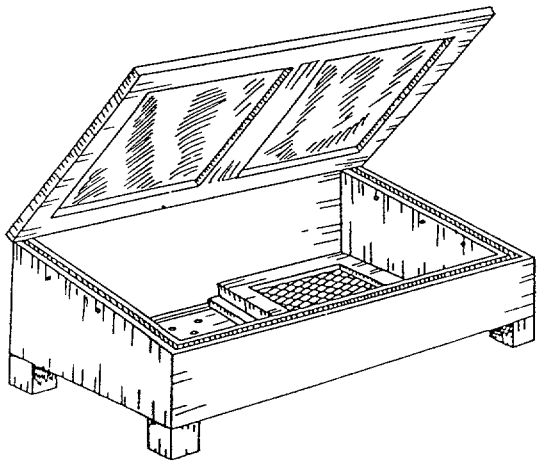
Solar driers

More complex models of solar driers have glass or clear plastic windows that cover the produce providing some protection from insects while capturing more of the heat of the sun

Direct solar drier (Source Yaciuk 1982)



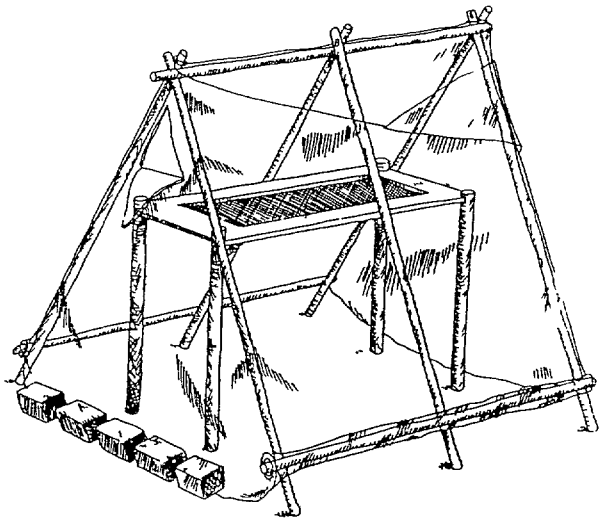
Brace or Lawand type cabinet drier
(Source Intermediate Technology Publications 1995)



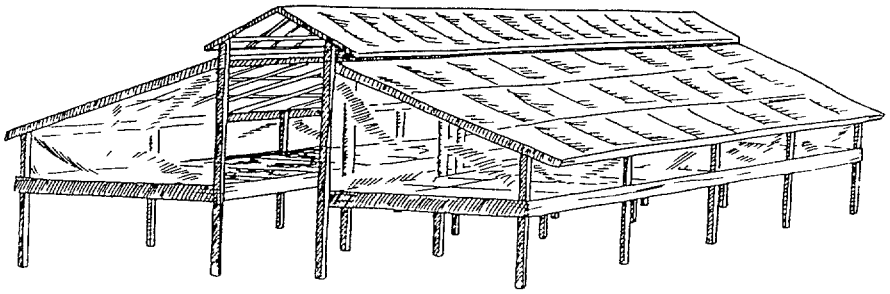
In order to improve the efficiency of sun drying, some sort of structure must be used to capture solar radiation Further improvement comes when you add a fan to move air through the trays of produce Various types of solar driers have been developed and are illustrated below

Tent drier (clear plastic cover with a black floor)
(Source Intermediate Technology Publications 1995)

PAgrExCo has set up several 40 to 50 meter long tent driers with polythene covers as demonstration projects in Punjab



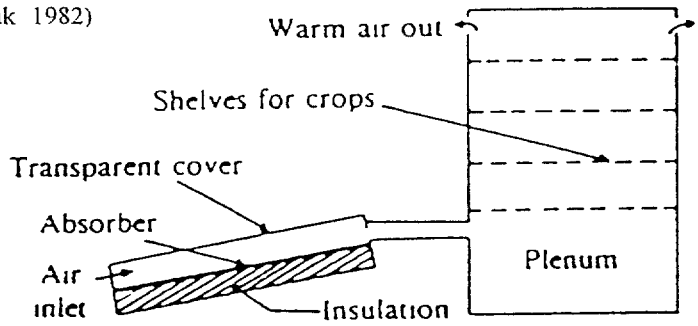
Walk-through drier
(Source Intermediate Technology Publications 1995)



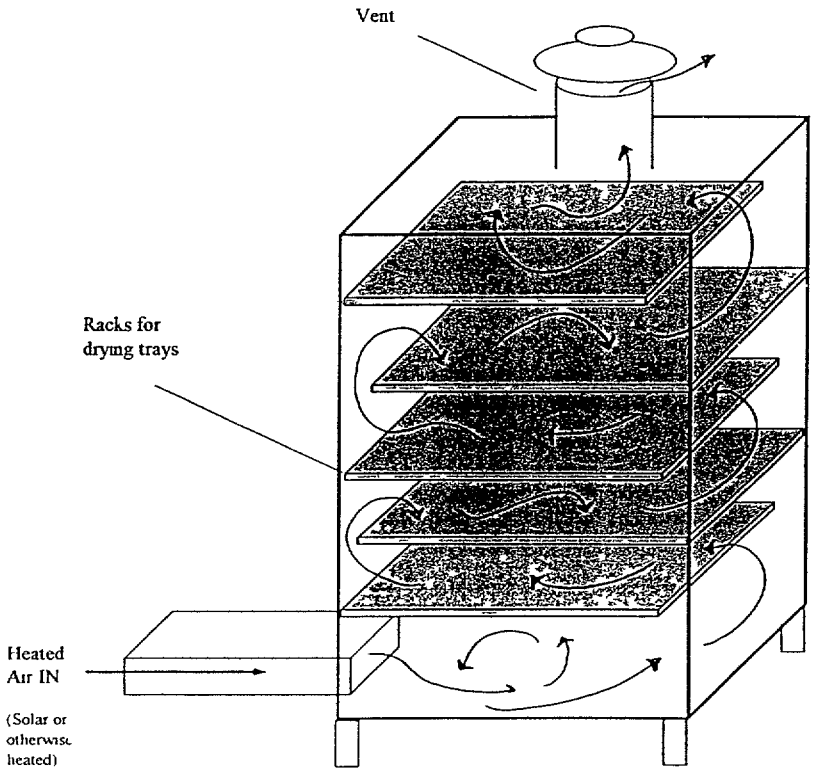
Indirect driers are constructed so the sun shines upon a solar collector (a shallow box the insides painted black topped with a pane of glass) heating air which then moves upward through a stack of four to six trays loaded with produce

Cut-away views

(Source Yaciuk 1982)

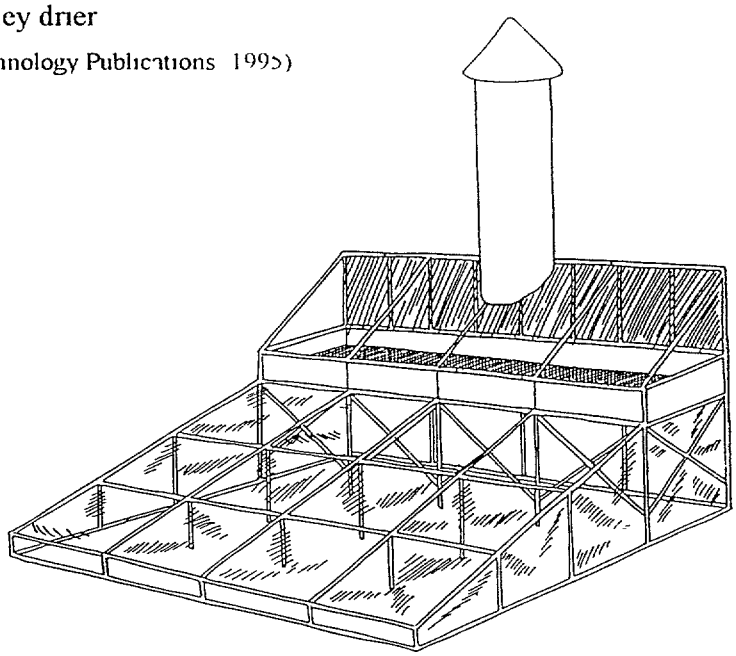


Air flow inside indirect drying cabinet



One ton indirect chimney drier

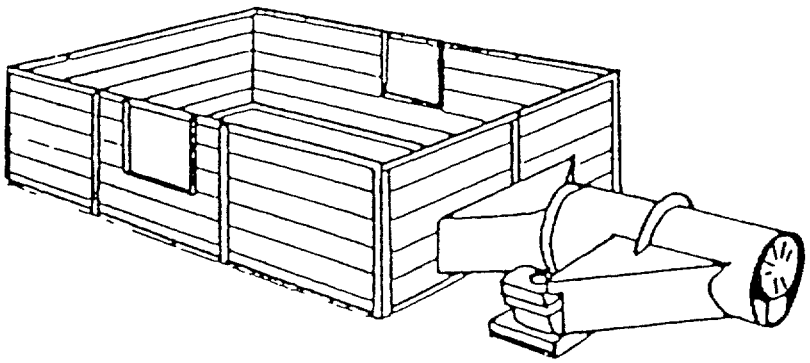
(Source Intermediate Technology Publications 1995)



Forced-Air Dehydrators (electric, oil or gas powered)

For quicker, more effective drying, or for drying during wet weather, a dehydrator can be used indoors in a dry, well ventilated room. Never dry sulfur treated produce indoors

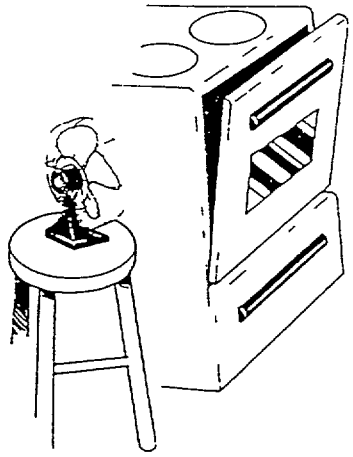
Nut crops can be dried in bulk using a dehydrator that combines a steady stream of air with an external source of heat The plenum chamber below the produce is covered with a floor of perforated sheet metal or wooden slats A fan located between the furnace and the plenum chamber moves the hot air through the drying produce The batch dryer illustrated here is constructed of wood has an axial type fan and burns kerosene or diesel oil A wide variety of dryers are available from manufacturers around the world



Source Clarke (1987)

Oven Drying

If the weather doesn't permit solar drying in your region or your normal solar drying operations are threatened by rain fruits and vegetables can be dried in a large gas or electric oven if the oven can be run at a low temperature Place the prepared produce on baking or metal screen trays set the oven temperature at 57 °C (140 °F) and leave the door ajar 5 to 10 cm (2 to 4 inches) Drying time can be reduced if ventilation is increased by using a small fan placed outside the oven Rotate the trays every 3 or 4 hours within the oven and turn foods occasionally to promote uniform drying While tending the trays requires more labor, the quality of the finshed product will be greatly improved if you pay close attention to the drying process



Source Georgia Coop Ext Service (1984)

PACKAGING AND STORAGE OF DRIED PRODUCTS

Suitable packages for dried products include air tight jars, plastic or glass bottles or plastic bags Fill containers as full as possible to remove air before sealing, and consider heat-sealing or vacuum sealing plastic bags to extend shelf life Avoid metal containers and keep packaged products in a cool, dark place during storage

Check packages a few days after dried produce has beens sealed inside-- if there is any condensation inside the container, then the product needs further drying Shelf life is typically one year when products are properly dried and sealed in air tight packages

COSTS AND BENEFITS OF DRYING PRODUCE

Costs
Produce
Pre-treatments
Trays and/or equipment
Power

The cost of dried produce depends upon the initial cost of the fresh produce, the cost of any pre-treatments, the cost of power (cost of one kilowatt hour or cost of fuel used for drying) and the time required for complete drying

$$\frac{\text{(cost per kwh x hours to dry)}}{\text{weight of dried produce}} + \frac{\text{(costs of produce + pre-treatments)}}{\text{weight of dried produce}} = \text{Cost per lb of dried produce}$$

The costs of storage, transport and marketing dried produce will be lower in comparison to handling fresh produce

Benefits
Extended shelf life
Reduced losses
Longer marketing period

Example 1 If fresh peaches are selling in California for the cost of production ($0 20/lb) at the peak of the season because of a glut on the market, fresh marketing will not provide a profit to the small-scale grower who does not have access to inexpensive cold storage facilities The cost of drying 1000 lbs of produce is $100

1000 lbs of fresh peaches yields 150 lbs of dried product with a market value of $4 00/lb

$200 of fresh produce can be processed to $600 of dried product
$600 -$100 = $500 potential profit

Example 2 If fresh tomatoes are selling in Punjab for the cost of production (Rs5/kg) at the peak of the season because of a glut on the market, fresh marketing will not provide a profit to the small-scale grower who does not have access to inexpensive cold storage facilities The cost of drying 1000 kg of produce is Rs 9200, including the non-recurring costs for trays and polythene covering

1000 kg of fresh tomatoes yields 150 kg of dried product with a market value in gourmet specialty food shops in New Delhi of Rs 200/kg

Rs 5000 of fresh produce can be processed to Rs 30,000 of dried product
(Rs 30,000-Rs 5000) -Rs 9200 = Rs 15,800 potential profit

SOURCES OF DRYING EQUIPMENT, SUPPLIES AND PACKAGING CONTAINERS

almond hulling/drying	Mid-State Manufacturing
apple parer/corer	Orchard Equipment and Supply Co
electric food drier	Garden Way Country Kitchen
glass and plastic bottles and jars	General Bottle Supply Co Inc
plastic bags	U S Plastic Corporation
mylar ® film	Dow Chemical

Refer to Appendix D for addresses and phone numbers of suppliers

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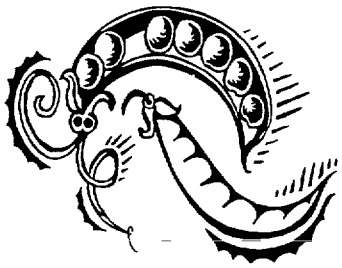
CHAPTER 14



CANNING AND BOTTLING SPECIALTY PRODUCTS

The market for specialty products is large, and includes processed foods sold through retailers in gift shops, gourmet and specialty food stores, health food stores, upscale delicatessen markets and direct to consumers at farmers' markets, on-farm shops and tourist-oriented farm stores According to *From Kitchen to Market* (Hall, 1996), condiments (sauces, dressings, seasonings, herbs and spices) make up 40% of the average sales in gourmet shops, while prepared foods, confections, meats and miscellaneous foods (including mushrooms, fruits and vegetables, soups, rice and pasta) each account for about 10% of sales Beverages, coffees/teas, and cheeses each make up about 5% of sales

Horticultural produce is processed to become part of the following categories
Condiments (salsas, pickles, chutneys, herb-vinegars, jams, jellies and preserves)
Beverages (juices, sparkling fruit-flavored waters)
Confections (fruit-based candies, cookies, cakes)
Miscellaneous (bottled herbed-mushrooms, fruit or vegetable-based snack-foods)

Start-up costs for a nationally distributed specialty food product can be enormous, and investment in production, packaging, labelling, advertising and promotion may not be repaid for years, if at all We suggest, instead, that you start with a small product line or even one product,

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and sell it directly to the people who now purchase your fresh produce All food processing must be done in a location that will pass a health department inspection Most likely this means you will need to rent an industrial kitchen (perhaps in a local restaurant during off hours) or work with a co-packer (a food processor of a similar product who has extra capacity)

The average annual growth of processed fruits and vegetables in India over the past 5 years is about 22%
(Source Ministry of Food Processing Industries/Government of India

Year	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97
lakh tonnes	3 60	4 69	5 59	6 76	8 50	9 60

This chapter will provide information on 1) produce types and cultivars known to result in high quality canned and bottled products, 2) a variety of pre-treatments used to reduce quality deterioration of processed products, 3) details on methods of boiling water bath and pressure canning, 4) packaging options for canned or bottled produce If you choose not to process produce yourself, it is usually simple to find one of the many food processors who offer co-packing services The chapter concludes with an example designed to help you to work out the costs and benefits related to producing and processing fresh produce and handling, storing and marketing canned or bottled products

GENERAL DOs AND DON'Ts FOR CANNING/BOTTLING HIGH QUALITY SPECIALTY PRODUCTS

Market test your processed products on a small scale by providing samples to your fresh produce customers

Start with only the best quality, freshest ingredients

Use only high quality containers and food grade caps/liners for a proper seal

Sort and wash produce thouroughly before chopping/slicing/pre-treating

Follow recommended procedures for pre-treatments such as blanching, peeling, seeding or coring to ensure high quality

Leave enough headspace when filling containers

Measure acidity to determine the proper processing method to use

Make sure canned/bottled products are processed at the proper temperature and/or pressure for the recommended length of time

Adjust processing times for altitude Add 5 minutes to boiling water bath times for altitudes from 3001 to 6000 ft, 10 minutes for altitudes from 6001 to 8000 ft For altitudes over 100 ft, increase the pressure for processing via pressure canners to 15 lbs pressure (weighted gauge) or 12 lbs (dial gauge)

Follow the safety practices outlined in Chapters 10 and15 to prevent food safety problems during processing

Work with a reputable co-packer to process produce if you are unwilling to make the investments necessary to ensure high quality and food safety

Store products in a cool dark place

Check containers to make sure a vacuum seal is present Signs that products have spoiled include broken seals, seepage, mold, yeast growth, gassiness, fermentation, spurting liquid when jar is opened, sliminess, cloudiness, and disagreeable odors

PREPARATION FOR PROCESSING

Some vegetable produce benefits from blanching in boiling water or steam before canning Blanching is quick incomplete cooking which ends certain enzymatic reactions in the fresh product expels tissue gases Blanching decreases the microbial population present on the surface of fresh produce and helps retain bright color, good texture and fresh flavor after processing Follow the chart below for blanching times, and always rinse blanched produce under very cold water or dip the hot produce into and ice water bath to stop the cooking process Steam blanching takes a little longer but results in less loss of vitamins B_1, B_2, niacin and C than boiling water blanching

Blanching times for selected commodities

Boiling water Use one gallon of boiling water per pound or 8 liters per kg of produce
Steam blanching Use 2 inches (5cm) of water per lb of produce
Add one minute for each 2000 ft altitude if you live at elevations over 4000 ft

Commodity	Blanching time (minutes)	
	Boiling water	Steam
Asparagus	3	5
Brocolli	3	5
Brussels sprouts	4	
Cabbage (wedges)	5	6
Carrots	5	5
Cauliflower	3 (add 4 tsp or 45 ml of salt)	
Collards	3	4 to 5
Corn (sweet)	7	
Green Beans	3	4
Eggplant	4 (add 4 oz or 125 ml lemon juice)	
Leafy greens	2	
Mushrooms	3 to 5	4 to 5
Okra		3 to 4
Parsnips	3	4
Peas	2	3
Potatoes (new)	4 to 10 until translucent	
Pumpkin	2 to 3 until soft	
Sweetpotatoes	15 to 20 until soft	
Zucchini/summer squash	3	4

Sources Chioffi N and Mead S 1991 *Keeping the Harvest*
and McClure S 1992 *The Harvest Gardener* Pownal VT Storey Communications Inc

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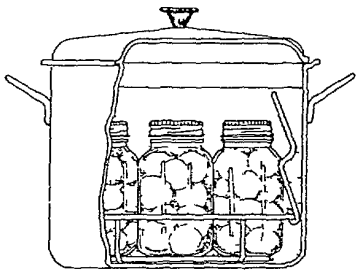
Canning and Bottling Methods

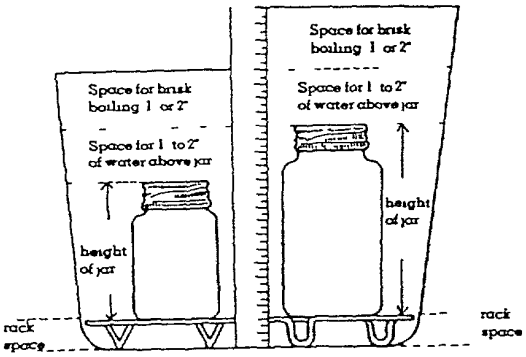
Two types of canners are commonly used to process horticultural crops These are the boiling water canner, and the pressure canner The choice of method depends on the acid content of the produce you are processsing Canners come in all sizes and can be matched to the facilities you have for cooking and heating

Boiling water bath

A water bath canner is a large pot with a loose cover and a rack to hold jars off the bottom The pot should be deep enough to cover the canning jars by one to two inches and still have another inch of space to allow brisk boiling The diameter of the pot should be no more than four inches wider than the diameter of the stove's burner to ensure even heating

Acidic foods such as fruits, tomatoes, pickles and relishes (pH < 4 5), and high sugar foods such as jams, jellies, syrups and marmalades can be safely processed using a boiling water bath

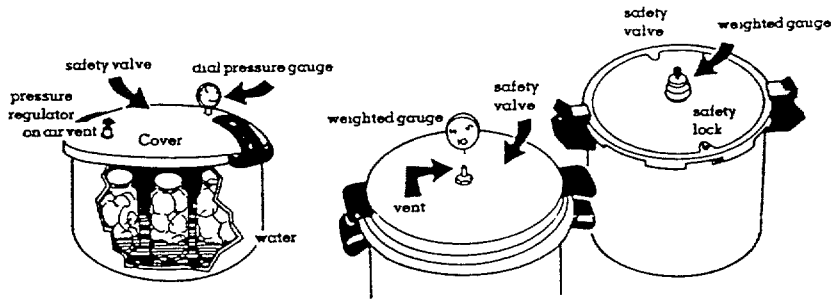




Source Georgia Cooperative Extension Service 1984

Pressure canning

A pressure canner is required for processing low acid foods such as vegetables (pH > 4 5) A pressure canner is a specially made heavy pot with a locking lid an inner rack and a steam vent in the lid The vent can be adjusted using a weight value or screw depending on the type of canner A pressure gauge registers the air pressure inside the canner A dial gauge gives a reading of the actual pressure while weighted gauges will rock gently when the canner is at the proper pressure Ten pounds of pressure at 115 °C (240 °F) is recommended for canning vegetables at 0 to 1000 ft altitude



Pressure Canners

Source Georgia Cooperative Extension Service 1984

CANNING CONTAINERS

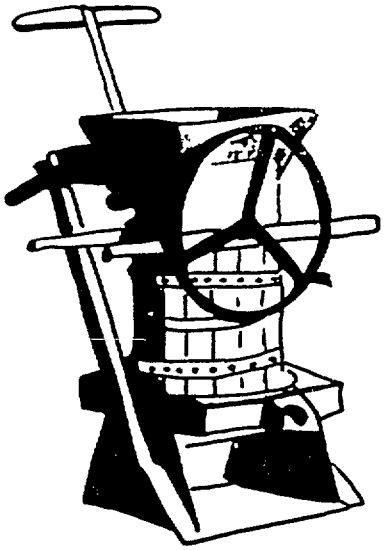
There are several types of glass canning jars used for processing horticultural crops The ball type jar and the zinc capped jar both require rubber rings as seals These can sometimes be difficult to obtain, but if locally available, make excellent containers Most people are familiar with the two-pieced lids used for home canning Currently containers (bottles or jars) with a plastisol lined lid are the most commonly used container for small-scale processing Air bubbles must be removed by gently running a non-metallic spatula around the inside of the jar between the food and the side of the jar

No matter which jar is used when filling containers it is important to leave a small amount of headspace to allow for expansion of the food while processing If a jar is filled too full it may explode If too much headspace is left the food may spoil, since all the extra air may not be driven out during processing As a rule leave 2 5 cm (1 inch) headspace for low acid foods and vegetables 1 3 cm (1/2 inch) headspace for acid foods (pH < 4 5), fruits and tomatoes, and 0 7 cm (1/4 inch) headspace for juices jellies and jams pickles and relishes (Ball 1995)

Processed Products Juices

Fruits

To process tomatoes or fruits to juices fruits are simmered in water or their own juice in a stainless steel glass or enamelware pot When tender the product is cut into pieces and pressed through a food mill colander or several layers of cheesecloth Sugar or lemon juice can be added to taste



The juices must then be either frozen or canned for storage Juices can be frozen in jars or freezer containers (leave 1 3 cm or 1/2 inch headspace) Most fruit juices can be canned in a boiling water bath for 20 minutes but apple and grape juices can be processed in hot water (82 °C or 180° F) for 30 minutes Recent problems with apple juice (Odwalla) have lead to requirements for labelling on pasteurization

Apple juice

24 lbs apples

2 liters or quarts water

Wash apples drain remove stem and blossom ends chop and place in a large pot Add water and cook until tender stirring frequently Strain through several layers of cheescloth into a second pot Heat juice just to a boil then fill hot jars leaving 0 7 cm or 1/4 inch headspace Add caps and process in a boiling water canner for 10 minutes Yield about 12half-liters or pints

Mango Squash Use ripe fruits washed with clean water and dried Squeeze each fruit rolling it between your palms to break down the pulp then remove the stem end and squeeze out the thick pulp and juice To make a 25% pulp squash combine 1 75 kg sugar 40 g citric acid and 1 25 kg water and bring to a boil Cool and filter through a muslin cloth Add 1 kg mango pulp, filter again through a muslin cloth Add 2 9 g potassium metabisulfite as a preservative (dissolved in a small quanity of juice) and mix thoroughly Fill clean dry glass bottles leaving about 1 inch headspace Source Department of Food Science and Technology PAU

Vegetables

Vegetables should be chopped or shredded, then simmered for 45 to 50 minutes until mushy The juice can then be pressed or strained from the vegetable pulp, and frozen or canned Canning vegetable juices requires processing at 10 pounds of pressure in a pressure canner Pints should be processed for 55 minutes, and quarts for 85 minutes

Processed Products Pickles and Vinegars

The high acid content of pickled vegetables allows you to use a boiling water bath rather than a pressure canner, and reduces the time required for processing The salt used for pickling is free of additives found in table salt, which will cause clouding Flavored vinegars are so highly acid that no further processing is necessary if vinegar is decanted into sterilized bottles To sterilize containers fill with hot water place in an open pot, cover with water and boil for 10 minutes

For the highest quality product, use only the freshest produce and herbs

Spicy Dill Green Beans
(Tilgner 1998)

Ingredients
green beans whole washed drained trimmed and cut to fit vertically in jars
(1 lb makes about two pint jars)

5 parts vinegar
5 parts water
0 5 parts canning salt

per pint jar
1/4 tsp crushed hot red pepper
1/2 tsp whole mustard seeds
1/2 tsp dill seed
1 clove peeled garlic
5 sprigs fresh dill

Pack beans into hot clean jars Add pepper mustard seed dill seeds garlic and fresh dill Combine vinegar water and salt heat mixture to boiling Pour liquid over beans filling to 1/2 inch below top of jar Seal jars adjust lids (not too tight) Process in a boiling water bath for five minutes Remove from boiling water complete seals (tighten lids) and let cool completely before handling

Mango Pickle (Achar)

Use sour varieties of well developed but under-ripe mangoes washed and cut lenthwise into slices

Ingredients

mango slices	1 kg
salt	250 g
fenugreek (methi)	50 g
fennel (saunf)	50 g
nigella (kalaunji	20 g
red chilli powder	25 g
tumeric powder (haldi)	20 g
black pepper	25 g
cumin (zira)	25 g
thyme (ajwain)	25 g
mustard oil	

Dip mango slices into 2% salt solution (brine) to prevent blackening of cut surfaces
Drain the brine spread slices on trays and place in the sun for 1 to 2 hours to remove surface moisture
Mix fenugreek fennel nigella black pepper cumin and thyme and fry in mustard oil unitl slightly browned Cool to room temperature and add salt tumeric and red chilli powder Add mango slices and mix thouroughly
Transfer mixture to a large glass or stone jar press well to squeeze the air out and cover content with a layer of mustard oil
Examine the pickle after 2 or 3 days and add oil if needed to ensure the pickle is covered with oil
The pickle is ready for eating in 2 to 3 weeks

Source Department of Food Science and Technology, PAU

Flavored Vinegars

Use only glass or enamel pots and glass containers since vinegar is corrosive Crush flavorings (fresh herbs of your choice, spice seeds, peeled shallots or onions, hulled berries) and place them in a glass jar Use 250 ml (1 cup) of herbs or 125 ml (1/2 cup) of berries for each 0 5 L (16 oz) of cider vinegar Slowly heat the vinegar in a glass pot until warm (not boiling) Pour the vinegar into the glass jars over the herbs/flavorings and seal tightly Place the jars in a sunny location and let vinegar mature for about two weeks Shake daily and taste periodically When vinegar has reached desired taste, filter through cheesecloth into a clean sterile bottle Add fresh herbs or spices for decoration and seal Use only cork, plastic or glass lids Store in a cool, dark place

Herbs in cider vinegar
tarragon, dill, marjoram, sage, thyme, chile peppers

Use white vinegar
for red basil or chive blossoms

Processed Products Preservation in Oil or Salt

One of the simplest methods of preservation is to cover peeled or dried produce with edible oil and seal it in a clean container In India the most popular products are preserved in mustard oil Use high quality olive oil for the best flavor and highest market price in the U S and Europe Salt cured products are becoming less popular as people change their food habits and eat less salty foods An exception is olives for which there are many recipes and well-guarded secret processing methods The example provided here comes from Morocco

Products in oil
Dried tomatoes
Dried chili peppers

Moroccan black olives

10 kg black olives very mature defect free
2 kg unrefined canning salt
1/2 liter olive oil

Mix olives and salt and put the mixture into deep baskets Cover with something heavy that will press the liquid out of the olives (during 2 to 3 weeks) and leave in a shady place After 3 weeks wash olives thouroughly with clean water dry in sunlight for 1 to 2 days Mix with 1/2 liter olive oil and ladle into jars close firmly

Processed Products Specialty Sauces Salsas Chutneys

A few inexpensive ingredients that you produce on your farm can be combined into specialty products that yield high prices at the market Recipes are from Ball (1995) and Chioffi and Mead (1991)

Spicy tomato ketchup

Ingredients
35 to 45 medium tomatoes very ripe peeled quartered cored
2 sweet red peppers seeded and cut into pieces
2 sweet green peppers seeded and cut into pieces
2 hot red peppers diced
4 large onions diced
3 cups cider vinegar
2 cups sugar or honey (use less if desire less sweetness)
3 Tbsp salt

Tie into a cheescloth bag
1 tsp whole allspice 1 tsp whole cloves 1 tsp broken cinnamon stick

Combine vegetables in a large pot cook until tender (15 to 30 minutes) Remove from heat and run through a food mill Add all remaining ingredients except vinegar and simmer uncovered until thick while stirring frequently Add vinegar and cook an additional 15 minutes Remove bag of spices ladle into hot clean jars Add lids and process for 15 minutes in a boiling water canner Yield 8 to 10 cups

Hot Salsa

6 lbs tomatoes ripe peeled seeded cored chopped
2 lbs green peppers seeded and chopped
1 5 lbs onions chopped
1 lb hot peppers chopped (remove seeds if you desire a milder version)
1 1/4 cups cider vinegar
3 cloves garlic minced
2 Tbsp cilantro minced
3 Tbsp salt

Combine all ingredients in a large pot bring mixture to a boil Reduce heat and simmer 10 minutes Ladle hot salsa into hot jars leaving 1/4 inch headspace Add lids process 15 minutes in a boiling water canner Yield 12 cups

Peach chutney

Ingredients
20 medium peaches peeled pitted and chopped
1 cup raisins (250 ml)
1 medium chopped onions
2 cups brown sugar (500 ml)
1/4 cup mustard seed (125 ml)
2 Tbsp ginger (40 ml)
2 tsp salt (15 ml)
1 clove garlic minced
1 hot red pepper finely chopped
5 cups vinegar (1 25 L)

Combine all ingredients in a large pot Cook slowly until thick (about 40 minutes) while stirring frequently Ladle hot chutney into hot ja s leaving 0 7 cm (1/4 inch) headspace Add lids and process 10 minutes in a boiling water canner Yield 14 jars (250 ml each)

REGULATIONS AFFECTING FOOD PROCESSING

Food safety and sanitation requirements

Contact the Food and Drug Administration and ask for a current copy of their publications on how to start a food business and *Current Good Manufacturing Processes* The FDA has an office in Washington, DC and in each US state

Food and Drug Administration
Center for Applied Nutrition FDA (HFS-585)
200 C Street, SW
Washington, DC 20204

The Government Printing Office can provide you with a copy (for a fee) of the current Code of Federal Regulations Chapters 1 through 3 of the Code cover the regulations affecting food processing operations, including use of additives, color, good manufacturing practices and food standards

Superintendent of Documents
GPO
Washington, DC 20402

Labeling

Products shipped interstate which do not conform to the FDA labeling regulations will be removed from store shelves Some key elements include a list of ingredients and a net weight statement (in metric measurements) on the lower third of the label

THE NUTRITIONAL LABELING AND EDUCATION ACT (1990)

Exceptions to the law that all products carry nutritional information include coffee, tea and spices, containers too small to carry a nutritional label, and producers whose total annual revenues are less than $500,000

Packaging

If you are aiming for the gourmet market, your processed product better look beautiful! Visit *http //www packstrat com* for information on all sorts of packaging materials Here are some sources of labels, design services, marketing materials and containers

Labels Plus
2407 106th St SW
Everett Washington 98204
(206) 745-4592
FAX (206) 523-1973

Packagemasters Inc
P O Box
118352 Sindle Ave
Little Falls, New Jersey 07424
(201) 890-7511
FAX (201) 890-0470

Presentation Packaging
870 Louisiana Ave South
Minneappolis, Minnesota 55426
(800) 326-2698 or (612) 540-9544
FAX (612) 540-9522 or -9628

Southern Atlantic Label
1300 Cavalier Blvd
Chesapeake, Virginia 23323
(804) 487-2525
FAX (804) 487- 9712

Sources of containers (metal, plastic, PET, and glass)

Agri-Pack
870 Louisiana Ave South
Mineappolis Minnesota 55426
(800) 328-1784

Fruit and vegetable containers
Fruit and jam gift containers

Berlin Packaging
111 North Canal St , Suite 300
Chicago Illinois 60606
(800) 4-BERLIN
FAX (800) 423-7545

Largest U S distributor of glass plastic and metal containers

Essentials 'N Such 3999 N Chestnut Ave Suite 368 Fresno, California 93726	Bottles, jars vials
General Bottle Supply Co Inc P O Box 58734 1930 East 51st Street Los Angeles, California 90058 (213) 581-2001	Glass and plastic bottles, vials and jars Metal caps with plastisol liners Wide range of PET containers
Southland Container Inc 8620 Dorsey Run Road Jessup, Maryland 20794 (410) 792-2088 FAX (410) 792-7453	Manufacture and distribution of packaging materials
Sunburst Bottle Co 7001 Sunburst Citrus Heights California 95621	Vinegar bottles, vials, canning jars
Western Specialty Container 17955 East Ajax Circle Industry, California 91748 (818) 912-8600 FAX (818) 913-5337	Decorative containers tamper-evidence bands

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CO-PACKERS

Working with a local co-packer can reduce many of the costs associated with food processing and packaging Some co-packers can even provide product distribution services through their marketing networks According to Hall (1996), benefits and cost savings of co-packing include

- elimination of capital costs of facilities and processing equipment
- access to experts in food processing
- compliance with the complex process of meeting federal state and local regulations
- product uniformity and quality control
- purchasing power (containers labels etc)
- networking
- low cost technical services
- marketing assistance
- distribution

Some co-packers specialize in processing either dry or liquid products, while others provide only packaging or only labeling services Contact co-packers in you area to identify which companies can provide the services you need A few examples of California based companies are provided here, and many more can be found in telephone directories and in the Appendix on co-packers provided in Hall, 1996

California Style Gourmet Products
6161 El Cajon Blvd , #200
San Diego, CA 92115
(800) 243 5226
Fax (619) 265 0893

Lodi Nut Co Inc
1230 S Fairmont Ave
Lodi CA 95240
(209) 334 2081
FAX (209) 369 6815

Radich Bor-do-lay, Inc
8130 Berry Ave , Suite 100
Sacramento, CA 95828
(916) 387 2107
FAX (800) 795 8349

Spectrum Naturals Inc
(specializes in organic products)
133 Copeland Street
Petaluma CA 95476
(707) 778 8900
FAX (707) 765 1026

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COSTS AND BENEFITS OF CANNING AND BOTTLING SPECIALTY PRODUCTS

Costs
fiesh produce
materials
containers, labels
equipment
powei foi processing
laboi

Benefits
longei shelf life
added value
reduced postharvest losses

Example 1 Preparation, packaging and marketing of a low sugar kiwi-strawberry jam. Approximately $100 worth of fresh produce grown in California is processed to yield $1350 of processed pioduct

Costs	
equipment (pots, ladles, cooling rack)	$50
kiwifruit (100 lbs, trimmed, peeled)	$50
strawberries (100 lbs of very ripe berries)	$50
bottles and lids(300 each)	$150
labels-- custom printed (300)	$75
sugar (50 lbs)	$5
pectin (5 lbs)	$10
feul for cooking	$5
total costs	$395

Benefits	
Market value	
300 (10 oz) jars of specialty jam @ $4 50 /jar	$1350

Example 2 Preparation, packaging and marketing of mango pickle Approximately Rs 500 worth of fresh produce is processed to yield Rs 6000 of processed product

Costs	
equipment (drying trays, stone jar)	Rs500
labor (1 day @ Rs 80/day)	Rs 80
mangoes (100 kgs, trimmed, peeled)	Rs 500
salt	Rs 100
spices and mustard oil	Rs1000
bottles and lids(400 @ Rs3)	Rs1200
labels-- custom printed (400 @ Rs0 10)	Rs 40
total costs	Rs 3420

Benefits	
Market value	
400 (0 5 kg) jars of specialty pickles @ Rs 30/kg	Rs 6000

SOURCES OF PROCESSING AND CANNING/BOTTLING EQUIPMENT AND SUPPLIES

bottle capper	Countryside General Store
bottling equipment	Orchard Equipment and Supply Co
can sealer	Countryside General Store
cider jugs, plastic	Rockford Package Supply Co
hand-press	Michigan Orchard Supply Orchard Equipment and Supply Co Garden Way Country Kitchen
juice presses /non-citrus	Goodnature Products, Inc Michigan Orchard Supply Orchard Equipment and Supply Co

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Ball Corporation 1995 *The Ball Blue Book Guide to home canning, freezing and dehydration* Muncie Indiana Alltrista Corp

Chioffi, N and Mead, G 1991 *Keeping the Harvest Preserving your fruits, vegetables and herbs* Pownal VT Storey Communications Inc

Georgia Cooperative Extension Service 1984 *So Easy to Preserve* University of Georgia Athens, Georgia

Hall, S F 1996 *From Kitchen to Market Selling your Gourmet Food Specialty* (2nd edition) Chicago Upstart Publishing Co

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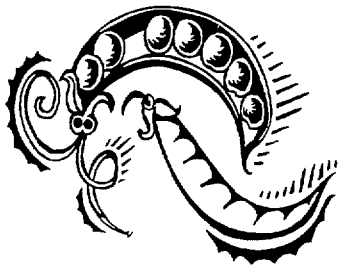
Stoner C H (Ed) 1977 *Stocking Up* Emmaus Penn Rodale Press

CHAPTER 15



FOOD SAFETY DURING PROCESSING

Consumers expect that food processors will manufacture wholesome and nutritious foods To do this, food processors must have systems in place to assure that products which are being manufactured do not have physical, chemical or microbial contaminants introduced during processing and packaging Common some sources of potential contamination include animal waste fertilizers, contaminated irrigation water, human handling practices, contaminated containers, inadequate postharvest washing, improper packaging, poor temperature management and contamination in the food preparation area

If food safety systems are not in place during processing, hundreds if not thousands of consumers are at risk A single incident of personal injury traced back to a specific food processor may put that company out business and result in criminal prosecution of the owners and management Systems which assure the safety and wholesomeness during food processing fall into three categories 1) Good Manufacturing Practices (GMP's), 2) Sanitation Procedures and 3) Hazard Analysis Critical Control Points (HACCP) These systems will be discussed in detail and may be applied to fresh-cut processing, or traditional processing operations Assuring that food products are manufactured in a safe and wholesome manner does add cost to the final product However, your long term success as a food processor depends on your ability to consistently produce safe products Food safety should not be confused with food quality Food safety programs simply

assure that food products are safe to consume and prevent injury to consumers This chapter will cover food safety issues during processing Food safety begins during production, so the production and postharvest handling of raw ingredients should be carefully monitored (see Chapter 10)

GENERAL DO'S AND DONT'S TO ASSURE FOOD SAFETY DURING PROCESSING

Follow state regulations regarding the type of licenced facility you may use for food processing (for example, no home or farm kitchens)

Educate and train employee's in proper food handling practices and personal hygiene

Strictly adhere to Good Manufacturing Practices (GMP's)

Design food processing and storage areas to allow for easy cleaning and sanitation

Monitor raw material suppliers for adherence to Good Agricultural Practices

Keep processing facility grounds clean and free from clutter

Processing facilities should be completely enclosed from the outside environment by walls

Windows or other glass should not be present in the food processing area

Processing facility floors walls and ceilings must be cleanable and in good repair

Adequate lighting should be present and be protected in case of breakage

Pipes, ducts and fixtures should not be suspended over processing areas

Use only potable (safe to drink) water

Monitor water quality regularly

Plumbing should be of adequate size and design for sanitary food processing (floor drains, separate sanitary sewers, etc)

Dos and Don'ts continued

Adequate numbers of toilets and hand wash stations should be provided for employees

Toilets facilities should be segregated from the processing area

Written sanitation schedules and procedures should be established and monitored on a regular basis

Cleaning and toxic chemicals should be stored in a secured locked area

Effective rodent and insect control programs should be in place and monitored

GOOD MANUFACTURING PRACTICES (GMP's)

GMP's are guidelines to assure that food for human consumption is safe and has been prepared, packed and held under sanitary conditions These guidelines deal with personnel involved in food processing, physical plant and grounds as well as facility construction and design

Personnel GMP's Personnel working in food processing can be a significant source of food contamination This includes production employees, maintenance employees, supervisors and management It is the responsibility of processing facility management to educate and train all food handlers about sanitary handling of food Employees experiencing diarrhea, vomiting, open skin sores, boils, fever, or disease must report these symptoms to their supervisor and must NOT be allowed to work with edible food products All food handlers should have clean outer garments or aprons and thoroughly wash their hands before entering a food processing area, especially after using toilets No jewelry (earrings, pendants, rings etc) or wrist watches are allowed in the food processing areas as these items may fall into food products unnoticed Clean, intact gloves as well hair restraints should be used by all personnel in the food processing area

Physical Plant and Grounds Food processing facilities should be constructed to segregate food processing activities from the outside environment The physical building itself should have no gaps which could allow infestation by rodents, insects or birds Surrounding grounds should be

free of clutter such as equipment, litter, waste, refuse or animal feces No unpaved or dusty roads should be adjacent to the processing facility and surrounding areas should be adequately drained so that no standing or pooled water is present Vegetation surrounding the processing plant should be keep down to prevent the formation of breeding grounds for rodents Rodent traps should be placed on the outside perimeter of the grounds and be inspected and serviced regularly

Construction and Design The most important aspect of food processing design is sufficient space for sanitary operation Processing areas should be designed for easy cleaning and sanitation Floors, walls and ceilings should be made of a cleanable, noncorrosive, non-absorbent material and be in good repair Floors should have a rounded corner joints where they meet the wall so as to allow for easy cleaning Processing facility floors should be constructed of sealed concrete or tile to withstand physical and chemical abuses from machinery and cleaning chemicals Equipment should be constructed of stainless steel to prevent corrosion Overhead pipes, ducts and fixtures should not be suspended over work areas and horizontal surfaces of these items should be minimized to reduce the accumulation of dust and water condensation Adequate lighting should be provided and all light bulbs should be protected to insure that broken glass cannot contaminate food products All water (rinse, flume, cleaning, ice, etc) used in food processing must be potable Plumbing should be of adequate size and design to handle the amount of product being processed Food processing environments are usually wet, therefore sloping floors with drains should be present of remove excess water from the processing area Sanitary sewer lines should be separate from floor drains to assure that cross contamination of the processing area from sewage back flow does not occur An adequate number of toilets and hand washing stations should be available to accommodate all employees Rest room facilities should not open into processing areas The restroom is the only room in the processing facility that should have negative air pressure and it should be exhausted continually from the restrooms Hot running potable water, soap and hand towels should be available at all times Signs should be posted to instruct employees to wash their hands after using the restroom Employee aprons, gloves and knives should never be taken into the restroom and adequate storage space should be available for temporary storage of these items directly outside the restroom door Heating, ventilation and air conditioning systems (HVAC) should feature filtered

positive air pressure in processing plants because of the potential airborne pathogen contamination HVAC units should blow air along the ceiling and down the walls to keep them dry and free of condensation

SANITATION PROCEDURES

Cleaning and sanitation are some of the most important programs in any food processing plant Regular and scheduled equipment cleaning and sanitizing assures that food products are being processed under hygienic conditions Adequate time must be given to the sanitation crew to allow for a thorough job Cleaning and sanitation is best done by a specially trained sanitation and cleaning crew NOT by production personnel A sanitation program in a food processing plant consists of two elements

A Master Sanitation Schedule

Monitoring Program

Master Sanitation Schedule A written master sanitation schedule should be in place to assure that all areas of a food processing facility are cleaned on a regular basis The master sanitation schedule should detail the area to be cleaned, the sanitation method, tool, cleaning materials and frequency of cleaning An example of a portion of a master sanitation schedule is shown below

Area	*Sanitation Method*	*Tool*	*Cleaning Materials*	*Frequency*
Walls	Foam, Brush, Rinse	Soft Nylon Brush	Chlorine-quat based cleaner	Once / Month
Floor	Wash, Rinse	Hard Bristle Broom, Hose	Chlorine-quat based cleaner	Daily

Cleaning and sanitizing involves five basic steps

- Physical Debris Removal
- Rinse
- Detergent / Mild Abrasion
- Post Rinse
- Sanitizing

It is critical that cleaning (i e the removal of debris and food particles) is done prior to any sanitation steps, since many sanitizers are inactivated by organic materials Once large pieces of food are removed equipment should be rinsed with potable water to remove smaller particles Then soaps and detergents should be applied Mild abrasion should be used to scrub equipment clean and remove caked on food particles as well as biofilms (layers of bacteria) It is recommended that warm water (NOT steam) be used for cleaning since steam may actually promote the formation of biofilms All soaps and detergents used should be approved for use on food contact surfaces After cleaning soaps and detergents should be removed by rinsing equipment with potable water After rinsing equipment should be sanitized to kill microbes which reduce product shelf-life and may cause food borne illness Sanitizing consists of rinsing all food contact surfaces with bactericidal compounds such as chlorine, iodine or quaternary ammonia followed by a potable water rinse Sanitizer and cleaning chemical manufacturer product directions should be strictly followed

Specific pieces of equipment which are cleaned on a regular basis should have written standard operating procedures (SOP's) for cleaning and sanitation This assures that equipment is cleaned properly regardless of who does the job

SOP's identify the following

What	Identifies task
Why	Purpose of task
Who	Responsible Person
How	Steps for completing the task

Cleaners and Sanitizers There are numerous cleaning and sanitizing compounds available for use in food processing plants These compounds fall into 5 categories

Chelators Tie up cations or salts (e g EDTA)

Alkalines Detergents (e g Soaps and Sodium Hydroxide)

Acids Remove Mineral Deposits (e g Phosphoric Acid)

Wetting Agents Emulsify and Penetrate Soil (e g , Alkyl Sulfates)

Sanitizers Kill Microbes (e g Sodium Hypochlorite)

Sanitizers are important to reduce microbial populations on all food contact surfaces after cleaning The most common sanitizers are chlorine, iodine and quaternary ammonia compounds Each of these compound classes have advantages and disadvantages to their use It is advisable to rotate or not use any one sanitizer for long periods of time since bacteria can become resistant to chemical sanitizers Also some sanitizers such as quaternary ammonia compounds are more effective against certain food borne pathogens such as *Listeria monocytogenes* Listed below are some of the advantages and disadvantages of using each sanitizer

Chlorine Compounds Low Cost, Good Germicide, Corrosive to Equipment, Irritating aroma

Iodine Compounds Heat Stable, Non Irritating, Non Corrosive, Stains equipment

Quaternary Ammonia Compounds
Non Corrosive, Heat Stable, Expensive

Chlorine by far is the most commonly used sanitizer Liquid household bleach may be used as a source of chlorine as it typically contains 5 25% by volume sodium hypochlorite Chlorine is used as a sanitizer at concentrations of between 100 and 200 parts per million It is important that the water containing chlorine be free from organic matter and have a pH between 6 0 and 7 0 If either of these conditions are not meet then the chlorine is ineffective as a sanitizer

MONITORING

The processing facility should be evaluated on a daily basis to assure that conditions are hygienic before processing begins Visual inspection should assure that no food particles or foreign matter are present on processing equipment In particular, hard to clean spots should be inspected such as the underside of conveyors and peeling equipment Unfortunately, visual inspection is not enough to assure that equipment has been sanitized properly The number of microbes present on processing equipment after sanitation operations should be determined on a

regular basis to evaluate sanitation crew performance via the one of the following methods

Petri Contact Plates

Surface Swabbing

Biolumenesce

Petri Contact Plates

Plastic petri plates or films contain sterile agar with growth media for microbes The type of microbes that will grow on these plates is determined by the type of media used In this method numerous petri plates or films are take to the processing area and pressed up against a food contact surface and this information is noted The plates are then placed at room temperature in the laboratory and if microbes where present they will grow on the petri films or plates After a day or two the microbes on each plate can be counted. The number of microbes present should be noted and charted for comparison over time A low bacteria count per square centimeter means that the sanitation crew is doing a good job at cleaning and sanitizing If the number microbes dramatically increases an evaluation of sanitation procedures is in order

Surface Swabbing

A variation of the petri plate method is to use sterile swabs in water to collect samples of food contact surfaces Wet sterile swabs are used to brush an area of a food contact surface The swab is then placed back in the sterile water container Bacteria are washed off into the sterile water and this water is then plated on to petri plates of films and counted after incubation as above

Both of these methods are fairly simple sterilizing (20 min at 250 °C) agar swabs water and media may be done in a pressure cooker Petri films from 3M corporation offer convenience of not having to prepare media or petri plates Water may be rendered sterile by boiling it vigorously for 20 min and allowing it to cool in a container sealed with aluminum foil Processing plants are never completely sterile even after the best sanitation efforts Below are listed microbial counts on food processing equipment which can routinely be achieved by a good sanitation program in a food processing plant

Microbial Counts After Effective Sanitation		
Total Plate Count	<	200 cfu / 25 cm^2
Yeast and Molds	<	50 cfu / 25 cm^2
Coliforms	<	10 cfu / 25 cm^2

Bioluminescence

Both the contact petri plate or swab methods are good for monitoring sanitation crew performance but results are not available immediately Another microbe detection method called bioluminescence is capable of detecting the presence of microbes immediately This method relies on measuring the amount ATP that is present on food contact surfaces as it is a good indicator of the number of microbes present This test is similar to the swab testing method except that the cleanliness of equipment is determined within minutes after the swab is taken In this test, equipment is swabbed with a sterile swab and then the amount of ATP present is determined by a chemical test kit These test kits are available from a number of suppliers that are listed below Bioluminescence is slightly more expensive than other methods but because test results are immediate it provides a new level of security since it can determine immediately if cleaning and sanitation procedures must be repeated before processing begins

Microbiological Test Suppliers

3M Microbiological Products 3M Center Building 275-5W-05 St Paul MN 55144-1000 USA Tel 612-733-9558	Rapid Micro Testing Films
IDEXX One Idexx Drive Westbrook ME 04092-2040 USA Tel 207-856-0496	Microbiology Media and Bioluminescence Testing Systems

Biotrace Inc 666 Plainsboro Rd Suite 1116 Plainsboro NJ 08356 USA Tel 609-897-0282	Bioluminescence Testing Systems
GEM Biomedical Inc 925 Sherman Ave Hamden, CT 06514 USA Tel 203-248-4008	Bioluminescence Testing Systems
HACH Company P O Box 608 Loveland CO 80539 Tel (970) 669 3050 FAX (970) 669 2932	Quick reference guide MEL portable labs presence/absence testing

HACCP

The seven HACCP principles outlined in chapter 10 should also be applied for processing of produce The prevention of physical, chemical and microbial contamination of produce during processing is essential to assuring the production of a safe product A HACCP program is only effective if sanitation and good manufacturing processes are implemented and verified It is recommended that each food processor identify one person in their operation to have formal HACCP training and be in charge of a team that is responsible for implementing the HACCP program. HACCP programs should be a simple as possible, without an excessive number of critical control points Each HACCP program is unique and must be tailored to your specific operations needs A model for dried apples has been provided as an example of a HACCP program which can be used as a starting point for you to develop a HACCP program for your food processing operation

Model HACCP Plan for Dried Apple Slices

Description Apple slices packed in food grade plastic bags 200 g to 1 kg units with an optimal shelf-life of 6 months, product is distributed to foodservice and retail markets Bag and/or box contains a "processed on" or "use by" date to be used in case of product recall or lot traceability

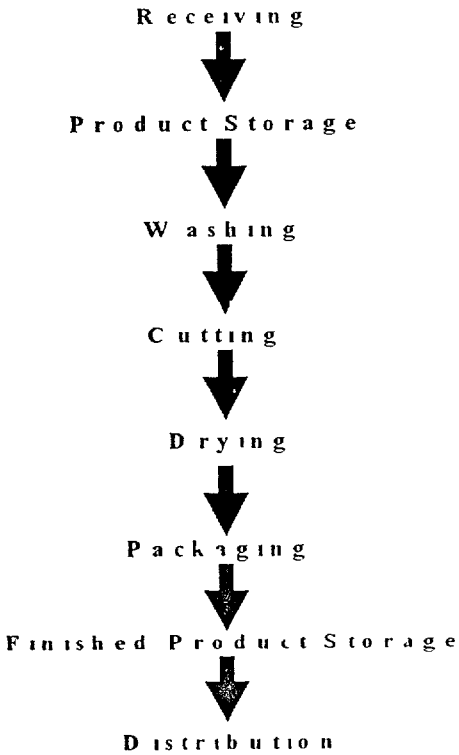
Ingredients Apple

Potential Microbiological Hazards to be Monitored

Potential Human Pathogens Pathogenic *E coli*
Salmonella Shigella, and foodborne viruses
Sanitation Monitoring Organisms
E coli aerobic plate count

Critical Control Points

7 CCPs were identified, critical limits established, monitoring methods established and corrective action identified (see table on the next page)



Flow Diagram for a fruit or vegetable drying operation

Model HACCP Plan for Dried Apple Slices

Flow Process	Hazard Catagory	Critical Control Point	Critical Limit	Monitoring	Frequency	Corrective Action	Record Keeping	Verification
Raw Product Storage	Microbial	#1 Room Temperature	0 to 5°C	Thermometer or continuous strip chart	Hourly	Inform maintenance Repair equipment Evaluate product Reject/Release	Temperature record Thermometer calibration record	Random sampling QA audit
Washing	Microbial	#2 Chlorination water pH	Free Chlorine 2 to 7 ppm free residual after contact. Total chlorine maximum of 100 to 150 ppm pH = 6 0 to 7 0	Test Kit or continuous strip chart	Three times per shift	Manually adjust water chemistry Repair system Hold product from last correct reading Rewash product	Chlorine/pH records	Random sampling QA audit Microbe counts
Cutting	Physical	#3 Employee Handling and visual inspection	No foreign objects	Visual	Continuous	Remove foreign object	Incident Foreign Object Report	Random sampling QA audit
Drying	Microbial	#4 Water content of finished product	Product water activity is low enough to prevent bacteria growth	Determine product water activity	Once per hour	Dry product	Water activity records	Random sampling QA audit
	Microbial	#5 Dryer tray cleanliness	Trays are clean and functional	Visual	Each time product is loaded	Repair system Discard product	Inspection Record	
Packaging	Chemical	#6 Food Contact Packaging	Food Grade	Certification letter	Annually or with new product	Resolve the problem or withdraw supplier certification	Certification Letter	Random sampling QA audit
	Physical	#7 Metal Detector	No metal	Calibrate machine with metal sample	Hourly	Inform maintenance Repair equipment. Hold product from last correct reading Rerun product.	Metal detector record	

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WORKSHEETS

PART II COSTS AND BENEFITS of SMALL-SCALE PROCESSING

Comparison of estimated costs and expected benefits related to adopting postharvest technology for small-scale processing and marketing

If you need more facts to fill out any worksheet, it is recommended that you select one specific commodity that you produce, and actually use the new processing practice on one row of vegetables or on a small group of trees for one season or any suitable period of time During this time collect information on yields, losses, grades of produce harvested, costs of labor, materials and equipment for handling and processing, and power requirements or fuel costs for the new processing operation in comparison to your current practice Some of your expenses will not be affected at all, while others will be added or no longer be necessary when you change practices

INSTRUCTIONS

Make copies of these blank worksheets and use a complete set for each commodity you process and market If you want to compare various postharvest technologies you may need to use several copies of the worksheets for each commodity

Overhead costs should be reported by month, by season or by year, depending upon how you generally allocate costs of operation The idea is to be able to determine how much of your overhead costs can be assigned to the commodity of interest For example, if you produce handle and process only one commodity, it will take on 100% of your overhead If you process and market equal amounts of 3 commodities, each can be assigned 1/3 of the total overhead

Most of the costs for the topics listed in Worksheet 6 will have several components including capital costs (equipment or facilities), and recurring costs (supplies, labor and purchased power or fuel for running equipment) If you purchase produce for processing from other growers, use the actual cost of produce , plus any costs associated with handling, processing, packaging and marketing processed product (from Worksheet 6) when completing Worksheet 8

Worksheet 5 Collect some basic information

Commodity _____
Variety _____

1 Overhead Costs

Salaries (managers, office staff, etc)	Rs_____
Office expenses and supplies	Rs_____
Maintenance, parts and repairs	Rs_____
Utilities (gas electric)	Rs_____
Communications (Telephone, FAX, e-mail)	Rs_____
Rent	Rs_____
Other	Rs_____
Total =	Rs_____

Overhead costs affiliated with this commodity
(base on percent of your total processed product)

_____% Rs_____*

2 General information related to each practice

Base upon previous experience with the commodity, your CSAM results (see Appendix A) or estimates provided by other producers/shippers, buyers, published literature on postharvest technology, cost/benefit examples provided in each chapter of this workbook or information available from your local Extension Service Many recommended PHTs will reduce losses by minimizing decay, mechanical damage and weight loss during fresh handling, and optimizing product quality during processing

Current Practice (describe)_____

New Practice (describe)_____

	Current practice	New practice
Expected yields	_____kg	_____kg
Estimated physical losses		
amount of culls during pre-sorting	_____%	_____%
losses due to pests	_____%	_____%
losses due to mechanical damage	_____%	_____%
weight loss during handling/storage	_____%	_____%
Sum of losses	_____kg	_____kg
Expected grades		
highest	_____kg	_____kg
second	_____kg	_____kg
lowest	_____kg	_____kg

How much fresh produce will you have available for processing?
(lowest grade is usually not acceptable quality for processing)

(Expected yields - Estimated sum of losses)	_____kg	_____kg
How much processed product will you have to sell?	_____units	_____units

3 Market Prices (obtain from your buyers or past history) Units may be by weight (lbs, kgs, etc), by volume (pints, quarts, liters, etc) or both

Expected prices per unit (wholesale)

highest category_____ Rs_____/ _____(unit?)

second category_____ Rs_____/ _____

Expected prices per unit (retail)

highest category_____ Rs_____/ _____

second category_____ Rs_____/ _____

Worksheet 2 Comparison of Direct Costs

Does one practice cost more than the other for production, preparation for processing, postharvest handling (temporary storage or transport), materials, power, equipment for processing, marketing, etc ? Calculations should be based on expected yield, postharvest and processing losses, hourly labor costs, and expected volumes to be handled Specific details for recommended practices are included in the examples found at the end of each chapter of the book with those costs that are expected to change listed individually under each category If you find there are additional costs associated with your operation, please add these to the list

Current Practice _____

New Practice _____

	Current practice	New practice
Pre-Harvest		
seeds or planting materials	Rs_____	Rs_____
land preparation/planting	Rs_____	Rs_____
cultivation (pruning, thinning, mulching, etc)	Rs_____	Rs_____
preharvest treatments (pesticides, etc)	Rs_____	Rs_____
irrigation	Rs_____	Rs_____

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	Current practice	New practice
fertilization	Rs_____	Rs_____
other_____	Rs_____	Rs_____
Harvest and Market Preparation		
labor and equipment for harvesting	Rs_____	Rs_____
other_____	Rs_____	Rs_____
cost of any purchased produce	Rs_____	Rs_____
Packinghouse Operations		
pre-sorting	Rs_____	Rs_____
washing/cleaning	Rs_____	Rs_____
sizing/grading	Rs_____	Rs_____
sanitation	Rs_____	Rs_____
bulk packing	Rs_____	Rs_____
other_____	Rs_____	Rs_____
Temperature/RH Management		
pre-cooling	Rs_____	Rs_____
cooling	Rs_____	Rs_____
storage	Rs_____	Rs_____
other_____	Rs_____	Rs_____
Transportation		
vehicles	Rs_____	Rs_____
fuel	Rs_____	Rs_____
cooling	Rs_____	Rs_____
other_____	Rs_____	Rs_____

	Current practice	New practice
Processing		
ripening	Rs_____	Rs_____
sorting/grading	Rs_____	Rs_____
pre-treatments	Rs_____	Rs_____
processing equipment	Rs_____	Rs_____
materials/supplies for processing	Rs_____	Rs_____
labor	Rs_____	Rs_____
fuel/power costs	Rs_____	Rs_____
packaging	Rs_____	Rs_____
other_____	Rs_____	Rs_____
Other Costs		
marketing (fees, sales labor)	Rs_____	Rs_____
display	Rs_____	Rs_____
promotional activities	Rs_____	Rs_____
food safety program	Rs_____	Rs_____
other_____	Rs_____	Rs_____
Total Direct Costs	Rs_____	Rs_____
*Overhead Costs for this commodity	Rs_____	Rs_____
Total Costs	Rs_____	Rs_____
Total costs per unit of product for sale	Rs_____	Rs_____

Worksheet 7 Comparison of Benefits

Base upon expected yields and quality, amount of product available for sale in various prices categories, and expected prices per unit collected in Worksheet 5 (units of product at each price x price/unit = expected sales at each price category) Do the calculations for either wholesale or retail prices or a combination if you will sell both ways

Current Practice _____

New Practice _____

	Current practice	New practice
1 Expected sales (wholesale)		
highest category	Rs_____	Rs_____
second category	Rs_____	Rs_____
Subtotal Sales (wholesale)	Rs_____	Rs_____
2 Expected sales (retail)		
highest category	Rs_____	Rs_____
second category	Rs_____	Rs_____
Subtotal Sales (retail)	Rs_____	Rs_____
3 Total Expected Sales	Rs_____	Rs_____

4 Comparative Advantage
(Total Expected Sales - Total Costs = Comparative Advantage)
refer to the total costs calculated for each practice in Worksheet 6

Current practice Rs_____ **- Rs**_____ **= Rs**_____ (a)

New practice Rs_____ **- Rs**_____ **= Rs**_____ (b)

	Current practice	New practice
Which practice is most profitable, and can provide the best economic opportunity?	Rs_____ (a)	Rs_____ (b)

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Worksheet 8 Recovery of Invested Capital (ROIC)

If the new processing technology costs more than your current practice, how long will it take to pay for your investment in the new practice? An excellent return on investment would be a recovery time of less than one month, while a slower return may require an entire season (3 to 5 months) Any longer recovery period usually would not be considered a good return on investment

Current Practice _____

New Practice _____

1 Difference in total direct costs for new practice = Rs_____
(Actual capital outlay for new equipment and facilities, plus power costs, supplies and labor requirements when compared to costs for the current practice over the entire season see Worksheet 6) If you purchase produce for processing, use your actual cost plus any handling, processing, packaging and marketing costs

2 Interest rate (if capital is borrowed) = _____% per annum, or _____% per month
Cost of capital at three months = Rs _____
Cost of capital at six months = Rs _____

3 Difference in sales using the new practice = Rs_____per month
(Subtract total expected sales using the current practice from total expected sales using the new practice see Worksheet 7, divide the difference by number of months of sales)

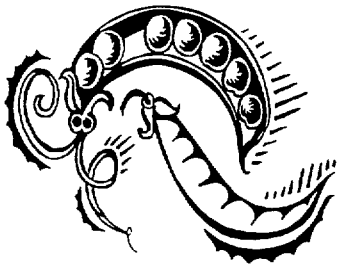
4 Calculate ROIC in months to recover invested capital

(Difference in total direct costs + any interest paid)
_____ = Months to pay for investment

Difference in Sales per month

(Rs_____ + Rs_____)
_____ = _____ Months
Rs _____ per month

CHAPTER 16



INTRODUCTION TO PART III
SMALL-SCALE MARKETING STRATEGIES

There are wide variety of wholesale and retail marketing strategies available to the small-scale producer or processor of horticultural products When producers sell through traditional wholesale terminal markets in the US, only about 30% of the consumer price goes to the grower The majority of the purchase price goes to pay those who pack, ship and retail produce to consumers In comparison, with direct marketing strategies, much more of the consumer price winds up in the hands of the grower because you take on these postharvest teasks If you think of customers as groups of people who have varying needs and wants, and develop a plan to produce crops that will meet their needs, you can provide products they truly value (based upon superior flavor, nutritional value, convenience, etc) Ideally you will communicate with potential customers and develop relationships with your buyers that allows you to plan well ahead for each season, and generates repeat business at prices that reflect the perceived high value of your products Depending on how many of the postharvest steps you decide to take upon yourself, it is possible that 100% of the final produce price can be yours to spend on appropriate produce production, postharvest handling, storage practices, etc and to take as the profits associated with these handling operations

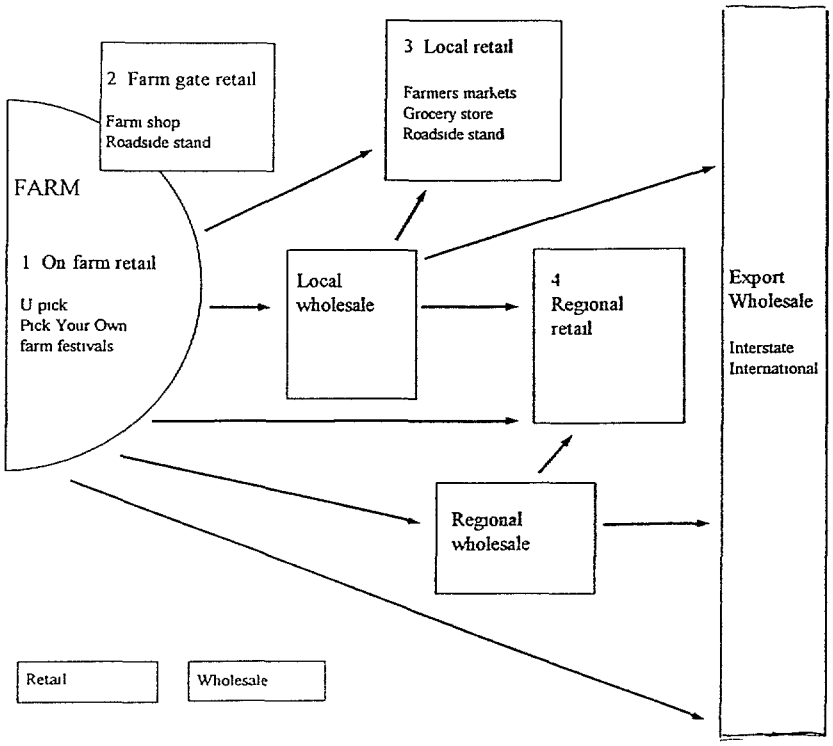
The third part of this book will assist you to identify and utilize scale-appropriate, cost-effective postharvest technologies for horticultural produce and value-added products to

Reduce postharvest losses due to water and weight loss, decay and physical damage during marketing

- Maintain produce quality and economic value during marketing
- Increase shelf life with proper temperature and relative humidity management
- Assure food safety of fresh produce and processed products during marketing
- Increase income by adopting postharvest technologies that are profitable when marketing produce or processed products on a small-scale

EXPANDING YOUR MARKETING OPTIONS

Fresh and processed produce can be marketed on the farm, at the farm gate, locally or regionally via wholesale or retail operations or through exports to other states or countries When deciding how you will market your fresh and processed produce each postharvest handling step that you take on provides another opportunity to make additional profits



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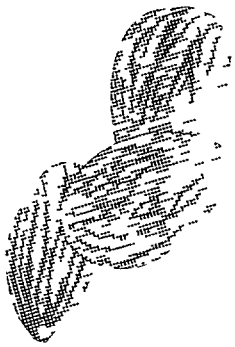
"Intermediaries are important in India because they are a substitute for infrastructure they perform the distribution function that in other countries would be carried out by transport companies, commodities processors and cooperatives '

Source *FoodTalk* March 1998

TYPICAL MARKETING MARGINS FOR FRESH PRODUCE

	U S and Developed countries	India
wholesale	2 to 3%	15%
retail	4 to 5%	15-20%
farmer receives	40 to 70%	25%
postharvest losses	4 to 6%	to 50%

Source McKinsey & Co 1997



We recommend that you use more than one marketing strategy and develop different markets for your produce For example, you could market your highest grade peaches at a very high price, tree ripened, and packed in new beautifully designed cartons, to specialty shops, take the medium grade to the local farmer's market in reusable crates and sell the peaches directly to consumers at a moderate price and use your seconds very ripe, handled in bulk for processing to a value added product such as fruit jam Finding your own ways to market your produce is the key to generating the highest profits

Marketing Options for Horticultural Producers

	WHOLESALE BUYERS							RETAIL OUTLETS					
Postharvest Requirements (Your responsibilities)	Terminal wholesale markets	Produce markets /grocers	Processor	Food service	Grower Coops	Specialty shops	Restaurants/ Hotels	On farm shops	Roadside stands	PYO / U Pick	Farmers Markets	CSA	Retail Marketing Coops
Pre harvest quality	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Harvesting tools and technique	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sorting	✓	✓	*	✓	✓	✓	✓	✓	✓		✓	✓	✓
Washing/Sanitation	✓	✓		✓	*	✓	✓	✓	✓		✓	✓	✓
Sizing/Grading	✓	✓		✓	*	✓	✓	*	*		*		*
PH Pest Mgmt	✓	✓		✓	*	✓	✓	✓	✓		✓	✓	✓
Packing	✓	✓		✓	*	✓	✓				*	✓	*
Special packaging	✓	✓		*	*	✓	*						*
Temp/RH mgmt (cooling)	✓	✓		✓	*	✓	✓	✓	✓		✓	✓	✓
Storage	*	*		*	*	*	*	*	*		*	*	*
Transport	*	✓		✓	*	✓	✓		*		✓		*
Destination handling		*				*	*	✓	✓		✓		*
Display/ Sales								✓	✓	✓	✓		*
Promotion								✓	✓	✓	✓	✓	*
Customer Service								✓	✓	✓	✓	✓	*
* = sometimes Notes	Need large quantities Must meet grade standards	Establish personal contact with buyers	Usually pay lower prices	Need to provide regular supply	Share costs and returns	Need highest quality produce	Need highest quality produce work directly with chefs	Need a good location parking and building	Need a good location parking and building	Location is critical Supply training for harvesting	Limited times of operation	Need to sign up members who will pay ahead	Share costs of ads promotional activities

The table on the previous page outlines the responsibilities associated with the many direct marketing options available to produce growers Many of you will currently be using one or more of these approaches to market your produce, and may have some interest in learning about others If you are new to direct marketing, you will have to attempt many of the postharvest tasks described in Part I of this book For example if you want to wholesale your fresh or fresh-cut produce directly to users in restaurants hospitals, hotels or food service providers at a minimum you must take on the costs of packing, cooling and shipping to market If you want to retail market your fresh or fresh-cut produce directly to consumers, you must take on these postharvest tasks plus the costs of storage, destination handling (ripening, display) and sales There are trade-offs in costs and benefits to make whenever direct marketing, but having direct control of these postharvest operations allows you to protect produce quality and food safety and maintain the highest economic value during the period you wish to sell produce As the examples provided in this book have shown, investments in postharvest technologies often pay off quickly by reducing weight loss and decay, and protecting produce quality and value while increasing your marketing options and economic opportunities

MARKETING VERSUS SELLING

Producers can choose to sell horticultural crops to a variety of customers using a wide range of marketing strategies Marketing requires an attitude quite different than does selling Selling produce ends with finding someone who will take what you have to sell off your hands and pay you for it Selling usually involves advertising products, and somehow being clever enough to get a price high enough to allow the seller to make a profit Some growers speak of "throwing", dumping" or "getting rid of" their produce, as though it is some kind of waste product rather than a carefully cultivated high-value commodity Most fruit growers in India sell their produce even before the crop is harvested, and allow a harvest contractor to decide when to harvest and reap the profits associated with postharvest handling and marketing If you are uncomfortable with meeting and selling to the people who will eat your produce, or have no particular interest in postharvest handling, packing, storage or processing and retailing, you can simply sell your produce directly to a trader or reseller for a minimal wholesale price and be done with it

Marketing, on the other hand requires that you determine and meet the needs of your customers before harvesting and packing the product If you want to earn more of the potential profits associated with horticultural handling and marketing, and have some interest in applying some of the postharvest technologies described in this book, you may want to think of learning more about direct produce marketing Each chapter has provided examples of postharvest technologies that can help you increase your profits during produce handling and marketing Marketing is quite different than selling, in that you first try to find out what potential buyers want, then supply the produce people would most like to buy, at prices they will willingly pay when they want it and at places where they want to shop

Marketing produce involves everything from planning exactly what to grow, harvesting at the right time for high quality, proper maturity and food safety, packing and cooling to protect produce quality, storage under proper conditions until prices are higher, and transport to a variety of market outlets, to direct sales to customers Marketing requires you to be knowledgeable about the produce (its characteristics, nutritional value, uses in cooking, etc), packaging (providing protection, information and visual appeal), pricing strategies (offering bulk produce, specialties, value-added products) and promotion (including sales displays, advertising, deliveries and customer service) There are many excellent reference books on marketing, and we refer you to those listed in the Reference section at the end of the chapter for more detailed information

Part III of the book describes marketing practices including destination handling technologies such as re-sorting/re-packing, temporary storage, ripening and de-greening practices, display methods, and a wide range of direct wholesale and retail marketing options

The marketing options described include the following

Wholesale marketing direct to local produce markets/supermarkets, food service providers/schools restaurants/hotels, specialty retail shops and through trade shows and wholesale marketing cooperatives (Chapter 18)

Retail marketing direct through farm shops, roadside stands, pick-your-own operations, farm trails, farmer's markets, and retail marketing cooperatives (Chapter 19)

Alternative (non-marketing) options community supported agriculture (CSA), subscription or membership farming (Chapter 20)

If you review the options and complete the worksheets on marketing strategies provided in Chapters 18 and 19, you should be able to make some clear decisions about which marketing options make the most sense for you, your customers and the crops you would like to produce, handle, process and/or market Your choices will depend upon your individual interests, desired level of involvement in various postharvest handling tasks and marketing operations, and the profit potential associated with the specific crops you handle and the customers to which you target your marketing efforts

How do I get my food product noticed?
- Packaging upscale
- Labeling refined
- Ingredients only the best quality
- Size appropriate (no "giant economy" size)
- Price on the high side
- Shape upscale but practical

Source Hall, 1996

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CHAPTER 17

DESTINATION HANDLING

When handling fresh produce at its market destination, again it is important to avoid rough handling, minimize the number of handling steps, and maintain temperature and RH management If produce is to be stored on site for any period of time before sale, wholesale and retail markets need clean, well insulated storage rooms Since a wide variety of commodities are usually being handled simultaneously at this point it is important to remember not to mix those with different temperature requirements or store ethylene sensitive commodities near ethylene generating commodities Stacking of non-uniform containers should be done with care to prevent collapse of weaker packages, and heavier cartons should always be placed at the bottom of a stack

Before produce is sold to the consumer, you may wish to sort any ungraded produce into various quality categories, and then charge a higher price for the better quality produce At the minimum, you should discard any damaged or decayed produce in order to give the product more market appeal If ripeness or maturity is non-uniform, sorting at destination can help you to ensure that consumers are buying produce that is ready to eat, while you hold the remainder for sales the next day or week

If the produce handled is a climacteric fruit crop that was harvested when mature-green (pears, bananas, tomatoes, avocadoes mangoes), or at less than full ripe (stone fruits, muskmelons) you may want to ripen the produce at the destination market before it is sold to the public

You can help reduce losses in the future by maintaining good records of the sources of losses suffered at the wholesale or retail level Identifying whether losses were due to mechanical damage, decay/disease immaturity or overripeness allows the you to provide better quality feedback to produce harvesters and packers

GENERAL DOs AND DON'Ts FOR HANDLING PRODUCE AT THE DESTINATION MARKET

Protect unloaded produce from the sun, and move containers quickly from the vehicle to the storage area

Load and unload produce from vehicles as gently as possible

Stack containers (not too high) in cool, well-ventilated storage areas

Mark containers with date of arrival

Entrances of cold rooms should have plastic strip curtains to reduce temperature variations during produce movement when doors are open

Storage rooms must be cleaned periodically to reduce decay organisms and odors

Use activated carbon filters in storage rooms to absorb odors generated by mixed lots of produce

Use a pad containing potassium permanganate to reduce ethylene levels, especially if storage temperature is greater than 5 °C (41 °F)

Resort, trim , wash or ripen produce before marketing to increase its value, then create displays of ripened or ready-to-eat produce (include a sign promoting these features)

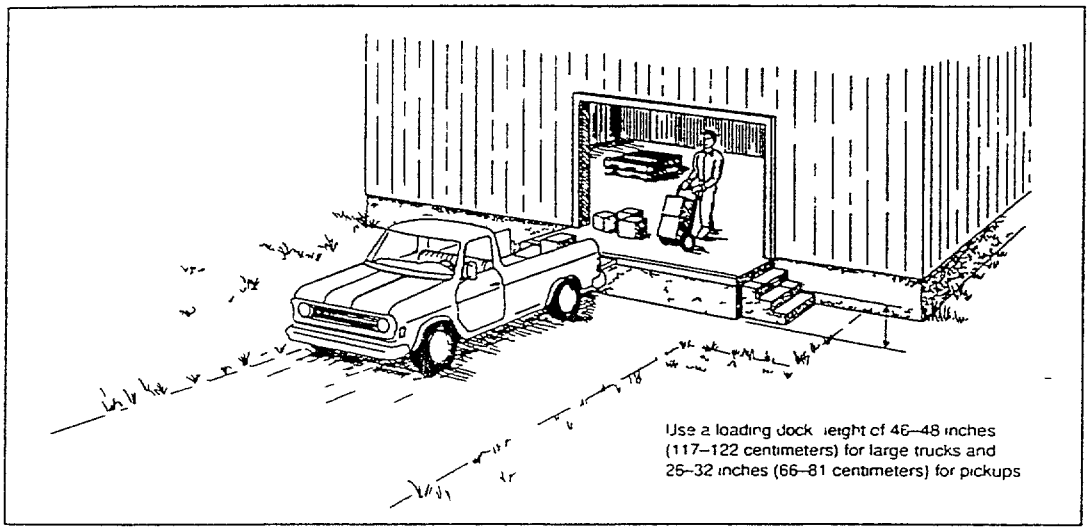
Create unusual or convenient combinations of produce for displays (mixed greens, "mesclun" salad mix, salsa ingredients)

Display produce in shallow layers to minimize consumer handling and reduce mechanical damage

LOADING AND UNLOADING

- Bays or platforms for unloading should be of same height as bed of delivery trucks
- Turn off the engine of delivery trucks to reduce heat generation and production of ethylene gas
- Handle produce as gently as possible
- Use push carts or hand-trolleys for moving commodities

A loading dock can ease the work associated with handling horticultural produce at destination Containers can be transfered more rapidly and with less bending and lifting
For large trucks, a loading dock 117 to 122 cm high (46 to 48 inches) functions well, while for small trucks or pickups a height of 66 to 81 cm (26 to 32 inches) is recommended Measure your vehicles to determine the appropriate height for safe and easy unloading if you have the opportunity to construct a loading dock



POSTHARVEST HANDLING AT DESTINATION MARKETS

Resorting

- Provide adequate space, appropriate sorting tables
- Facilities should be equipped with good lighting
- Culls should be properly disposed of

Trimming/re-cutting/bundling

- Provide adequate space, equipment
- Use clean, sharp knives and cutters
- Provide scales if bundling by weight
- Dispose of trimmed wastes properly

Washing, cleaning and drying

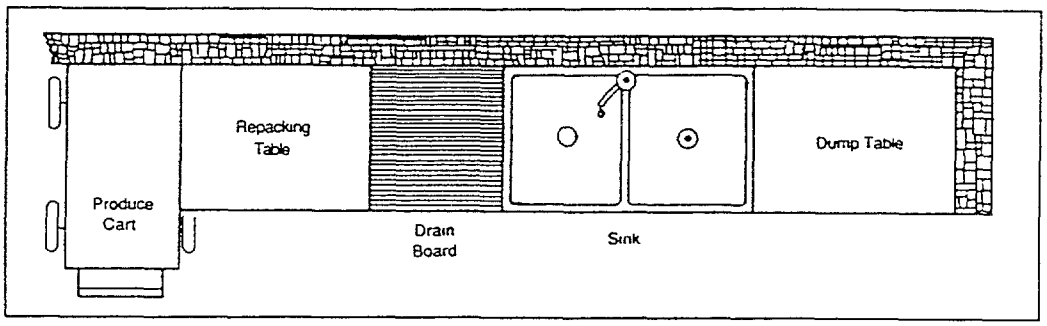
- Provide potable, clean water
- Use clean rags or sponges
- Provide racks for air drying produce

Inspection and re-packing

- Provide adequate space
- Provide good lighting
- Use color charts or samples for visual comparisons

Some produce may require washing, trimming, bunching or sorting at the wholesale or retail market level You will want to inspect incoming produce to check on initial quality The layout of the work station used for handling produce at destination should be organized to minimize non-productive movement In the illustration here, a dump table is located next to a sink for washing produce and the drain board is positioned directly next to the sink Once produce has dried cartons can be packed and placed onto a cart located right next to the repacking table With this layout, a single operator could easily perform all the handling steps or several handlers could work side by side

.12



Source Selders A W et al 1992

TEMPORARY STORAGE

- Provide adequate ventilation
- Avoid chilling injury
- Avoid water loss (use film wraps, wet the floor of the storage area)
- Avoid mixing ethylene generating commodities with those sensitive to ethylene
- Use flaps on cold room doors to reduce temperature fluctuations
- Use storage racks and stackable boxes to minimize product damage
- Check air and product temperature with a thermometer
- Store the most cold-demanding produce directly in front of the cold air outlet
- Use paper wraps or covers to protect chilling-sensitive commodities
- Provide adequate air movement for all storage
- Designate the storages as non-smoking areas
- Keep storage areas clean
- Use FIFO (first-in, first-out) rotation of produce placed into storage

Avoid chilling injury!
The minimum safe temperature is 10 °C (50 °F) for most chilling sensitive commodities

Temporary Storage Temperatures

When produce is held at the destination market for a short time before marketing the handler can help maintain quality and reduce losses by storing commodities under their most suitable temperature/RH conditions as described in Chapter 7 and listed in Appendix C However, if the storage period is five days or less relative humidity is maintained between 85 and 95%, and the ethylene level is kept below 1 ppm by ventilating or using a scrubber, most commodities can be grouped into the following **three categories** for temporary storage

32-36°F, 0-2°C			45-50°F, 7-10°C	60-65°F, 16-18°C
Vegetables and Melons				
anise	collard*	parsnip	basil	casaba melon
artichoke	cut vegetables	raddichio	beans snap etc	cassava
arugula*	daikon*	radish	cactus leaves	crenshaw melon
asparagus*	endive*	rutabaga	cucumber*	dry onions
bean sprouts	escarole*	rhubarb	eggplant*	ginger
beet	garlic	salsify	Juan Canary melon	honeydew melon
Belgian endive*	green onion*	shallot	kiwano	jicama
bok choy	herbs(not basil)	spinach*	okra*	potato
broccoli*	horseradish	snow pea*	pepper bell	Persian melon
broccoflower*	Jerusalem artichoke	sweet corn	chili	pumpkin
brussel sprouts*	kale	sweet pea*	squash summer soft rind*	squash winter hard rind
cabbage*	kohlrabi	Swiss chard	tomatillo	sweet potato*
cantaloupe	leek*	turnip	watermelon*	taro
carrot*	lettuce*	turnip greens*		tomato ripe mature green
cauliflower*	mint	waterchestnut		yam*
celeriac	mushroom	watercress*		
celery*	mustard greens*			
chard*	parsley*			
chicory*				
Fruits				
apple	quince		avocado unripe	atemoya
apricot	raspberry		cactus pear tuna	banana
avocado ripe	strawberry		carambola	breadfruit
blackberry			chayote	cherimoya
blueberry			cranberry	coconut
cherry			feijoa	grapefruit*
currant			guava	lemon*
cut fruits			kumquat	lime*
date			longan	mango
fig			lychee	mangosteen
gooseberry			mandarin	papaya
grape			olive	plantain
kiwifruit*			orange	pummelo
nectarine			passion fruit	rambutan
peach			pepino	sapote
pear Asian European			pineapple	soursop
persimmon*			pomegranate	
plum			tamarillo	
prune			tangelo	
			tangerine	

Products marked with an asterisk are sensitive to ethylene damage

Source Thompson J F and Kader A A 1995 Postharvest Outreach Program

RIPENING, CONDITIONING OR DEGREENING

- Use the proper temperature/amount of ethylene /timing for sufficient ripening/conditioning or de-greening of mature commodities
- Seal rooms tightly
- Provide adequate ventilation

Market studies have demonstrated that consumers are more likely to purchase fruits if they are ripe and ready to eat Sometimes commodities such as bananas are left at ambient temperatures and allowed to ripen naturally Covering the bananas with a plastic sheet will help ripening be more uniform throughout the lot (PHTRC, 1984) Placing a simple air vent (a pipe or a tube of some sort) into the center of the pile of ripening fruit can help reduce overheating during ripening and increase subsequent shelf life Small-scale wholesalers and retailers can also ripen fruits in bins or large cartons by placing a small quantity of ethylene-generating produce such as ripe bananas in with the produce to be ripened Cover the bin or carton with a plastic sheet for 24 hours, then remove the plastic cover

Too high temperatures can actually slow the rate of ripening and softening Stone fruits can become dry and mealy Aim for a temperature of 68 °F (20 °C) for the best quality ripening

Number of days to soften to ready-to-eat firmness (about 2 lbf)

Temperature		Peaches	Nectarines	Plums
(°F)	(°C)			
86	30	3 3	4 2	2 8
77	25	2 7	3 2	2 7
68	20	3 8	4 3	3 7
59	15	5 6	6 9	5 6

Source *California Summer Fruits Do the Ripe Thing* (CA Tree Fruit Agreement)

Ripening, conditioning and de-greening recommendations

The introduction of ethylene gas or ethylene-releasing compounds into a special storage environment (known as a ripening room or cabinet, depending upon size) is a more effective way to ensure uniform ripening

Ripening and conditioning temperatures in the table refer to pulp temperature, and should be measured with a calibrated temperature probe Relative humidity during ripening should be maintained between 85 to 95% Fans should be used to ensure that ethylene gas is uniformly distributed within the room. After ripening, produce should be moved into recommended storage conditions at lower temperature to maintain quality during marketing Exposure to ethylene for ripening, conditioning and degreening purposes will always decrease shelf life, so you should carefully evaluate the market requirements before you use these postharvest techologies

RIPENING will increase sales and increase value of avocadoes, tomatoes, melons, mangoes, stone fruits, bananas and kiwifruit

Indigenous ripening practices in India include the use of Calcium Carbide and water or ice, and using fires to create smoke and ethylene gas

It has been shown, however, that

1) mangoes ripened slowly at a temperature as low as 20 °C (68 °F) develop better eating quality and color

2) bananas ripen much better in cold storage They can be stored at a temperature slightly above 12 °C (55 °F) and an RH of 85-95% for about 3 weeks, and ripened in a week or two at 17-21 °C (62-70 °F) Fruit ripened at this temperature has a uniform, attractive yellow color and does not have the black spots that are found on fruit ripened at higher temperatures

Source Singh 1998

Ripening conditions of some commonly ripened fruits

Commodity	Ethylene conc (ppm)	Ethylene exposure (hr)	Temperature °F	°C
avocadoes	10-100	12-48	59-65	15-18
bananas	100-150	24	59-65	15-18
kiwifruit	10-100	12-24	32-68	0-20
mango	100-150	12-24	68-72	20-22
melon (honey dew)	100-150	18-24	68-77	20-25
stone fruits	10-100	12-72	55-77	13-25
tomatoes (mature-green)	100-150	24-48	68-77	20-25

Sources Thompson 1994 Cantwell 1994

Conditioning refers to a variety of postharvest treatments that enhance quality For pears, storage at low temperature (2 weeks for 'Bartlett' and 6 to 8 weeks at 0 °C or 32 °F for 'Anjou') followed by exposure to ethylene gas results in the most uniform ripening and best eating quality Some cultivars of pears do not change color as they ripen-- consumers should be educated as to what to expect when purchasing these varieties ('Anjou', 'Bosc', 'Comice', 'Seckel') Canteloupe melons require only warmer temperatures (2 to 3 days at 15 to 20 °C or 59-68 °F) to soften and develop their characteristic aroma Most apples will not require conditioning, but sometimes 'Granny Smith' apples are treated with ethylene when harvested early in the season to get a jump on the market

Conditioning recommendations for some fruits (enhancing softening, color and/or aroma development)

Commodity	Ethylene conc (ppm)	Ethylene exposure (hr)	Temperature °F	°C
apples ('Granny Smith')	10	144	77	25
pears (after cold storage)	10-100	24-48	68-77	20-25

Sources Cantwell 1994 Mitcham 1994

De-greening of citrus is sometimes practiced when the local climate does not provide the cold nights/warm days necessary for natural de-greening of the peel during ripening The conditions required for de-greening using ethylene gas will always decrease the postharvest life of the citrus fruit, so it is a good idea to assess the market before doing any unnecessary de-greening For example, if consumers will be making juice or using the fruit peeled and cut into sections, they may desire longer shelf life as a trade for de-greened peel

De-greening conditions of some commonly de-greened fruits (at RH= 90%)

Commodity	Ethylene conc (ppm)	Ethylene exposure (days)	Temperature °F	°C
grapefruit	5	2-3	68-70	20-21
lemons (CA coast)	5	5-14	60-65	15-18
lemons (AZ/CA desert)	5	2-8	68-70	20-21
oranges	1-10	1-3	68-72	20-22

Source Thompson 1994 Arpaia 1994

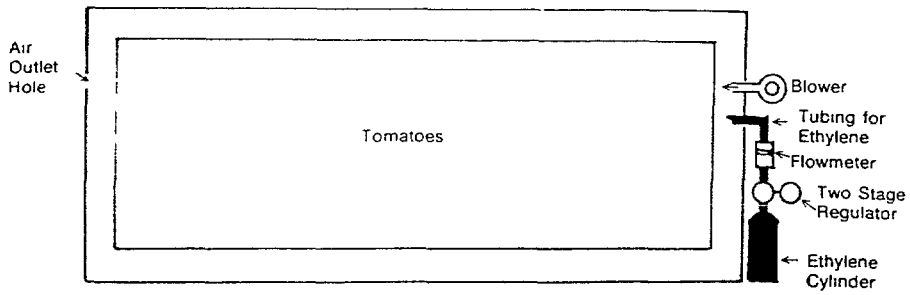
Ripening (or de-greening) rooms are often used for tomatoes, citrus fruits and bananas The use of diluted ethylene gas mixtures is safer than using pure ethylene which is explosive and flammable at concentrations of 3% or higher

De-greening does NOT improve internal quality -- only the external color of citrus fruits is changed, and shelf life is reduced

For tomatoes, technical grade ethylene gas is introduced into the room at a concentration of about 100 ppm for about 48 hours Approximately 025 cubic feet/hr of ethylene gas is required for each 1000 cubic feet of ripening room volume A small fan can be used to ensure a uniform continuous flow of ethylene into and through the

room Forced-air ripening is increasingly being used to provide more uniform temperatures and ethylene concentrations throughout the ripening room

Continuous flow gassing



Source Kasmire 1981

Remember

- **Concentrations above 150 ppm do not speed up the ripening process**
- **Buildup of CO_2 will reduce effectiveness of ethylene (use adequate air exchanges to prevent buildup)**
- **Ethtlene gas is explosive in air at concentrations between 2 8% and 29 %**
- **Never use an open flame near rooms containing ethylene gas, or near a gas cylinder**
- **Ground all piping to eliminate the danger of electrostatic discharge**
- **Instruments that detect the concentration of ethylene in air should be set to sound an alarm is the concentration approaches explosive levels (2 to 30 percent)**

Ripening can also be initiated by using ethylene generated by passing ethanol over a bed of activated alumina This method is safer than using pure ethylene gas Ethylene-releasing compounds such as ethephon {(2-chloroethyl) phosphonic acid} are sometimes used to ripen tomatoes destined for processing When using ethephon as a spray, the amount of ethylene released will increase as pH and/or relative humidity increase

DISPLAY INDOORS/OUTDOORS

- Provide racks and shelves
- Provide shade
- Protect produce from injury (don't stack too high)
- Use crushed ice as a bed foi ice-tolerant crops
- Use watei (sprinkling, misting) to reduce wilting of leafy vegetables
- Use colorful signs with prices and other useful information

High levels of postharvest losses in India are due to poor retailing conditions, where dispays are in piles or baskets open to the elements

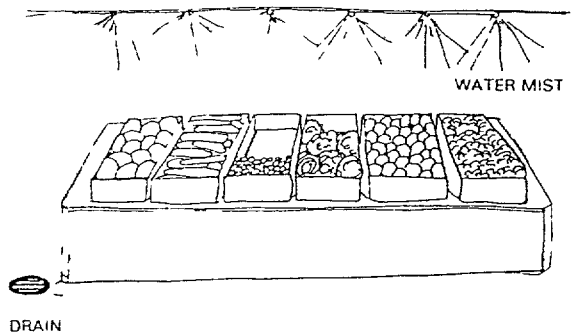
Source McKinsey & Co 1997

When displaying horticultural crops, single of produce are most likely to protect the commodities from compression damage and overhandling by the consumers Temperatures of the display tables or refrigerated supermarket displays should be suited to the commodities on sale Most likely you will need more than one display, since crops need different handling for quality maintenance For example, while peppers and tomatoes look pleasing when displayed with lettuce, peppers and tomatoes are chilling sensitive, while lettuce is will have a shortened postharvest life at 10 °C (50 °F)

You'll want to display produce in an attractive way, using a variety of methods, arrangements and backgrounds Pyramid displays tend to allow produce to roll down and become damaged, while bins of produce result in the bottom layer becoming squashed as people handle the produce while shopping Try to present produce in a single layer or at most two layers deep, and restock regularly as customers buy from the display

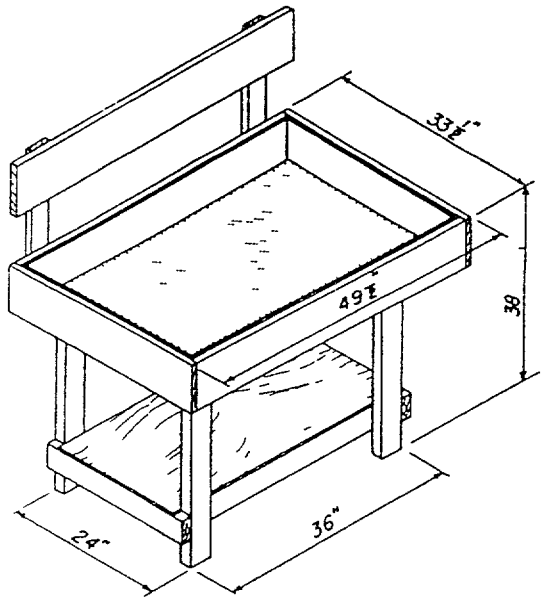
Outdoor marketplaces make temperature control difficult and the high rate of air circulation outdoors can lead to speedy dessication of crops, which will be seen as shriveling and wilting These marketplaces can often benefit by the increased use of shading and protection from prevailing winds Misting commodities that can tolerate surface water (lettuce broccoli green onions) with cool, clean water can help maintain a high relative humidity around the product

A simple sprinkler device can be constructed by perforating a pipe with tiny holes and connecting it to a hose If this display is used outdoors shade should be provided



This wooden display table is designed to be used for commodities such as cruciferous crops or leafy green vegetables that tolerate cooling with ice The table can be used in the horizontal position or as a tilted display For more complete design specifications, contact the Cornell University Extension Service, 304 Riley-Robb Hall, Ithaca, New York, 14853

About 15 kg of crushed ice per square meter (4 to 5 lbs per square foot) of display space are required for cooling per day A catch pail should be provided for melt water To minimize ice needs, the display tray should be insulated and kept out of the direct sun



Source Bartsch J A et al No date

COSTS AND BENEFITS OF RIPENING FRESH PRODUCE BEFORE MARKETING

Costs
Facilities (ripening room or cabinet)
Ethylene generator
Power
Labor

Benefits
Increase market value
Increased sales (reduced losses)

Example 1

20 cartons (30 lb/carton) of avocadoes are harvested, packed, cooled and transported to the destination market in California At the roadside stand, a display of 10 cartons of avocadoes is immediately set up at ambient temperature (shaded) while the other 10 cartons are placed into the ripening room for 2 days before being put on display for sale

	Mature-green	Ripe fruit
Marketing period	7 days	4 days
Cost of ripening		$20
Market value	$0 69/lb	$0 99/lb
Sales	450 lbs	500 lbs
Losses	150 lbs	100 lbs
Net returns	$310	$475

Note

Signs informing customers of the ready-to-eat state of the fruits will help increase sales Some vendors have found that creating separate displays of both ripe and un-ripe fruits can improve sales even further since customers will purchase a few of each type, one for immediate use and the other for use in a few days

Example 2

1000 kg of bananas are harvested packed cooled and transported to the destination market in Punjab At the roadside stand, a display of 500 kgs is immediately set up at ambient temperature (shaded) while the other 500 kgs are placed into the ripening room for 2 days before being put on display for sale

	Mature-green	Ripe fruit
Marketing period	7 days	4 days
Cost of ripening		Rs 1000
Market value	Rs 5/kg	Rs 15/kg
Losses	10%	10%
Sales	450 kg	450 kg
	Rs 2250	Rs 6750
Net returns	Rs 2250	Rs 5750

SOURCES OF EQUIPMENT AND SUPPLIES FOR DESTINATION MARKETING

bags (plastic, cotton, paper)	Action Bag Co Adelman-Fisher Packaging Polybags Plus
canopies and market umbrellas	Northern
ethylene generators	American Ripener Co Catalytic Generators Inc International Ripening Corp Precision Generators Co Inc
market containers	Rockford Package Supply Co
marketing materials for produce marketing	JAMarketing
refrigerated forced-air ripening facilities	Cool Care Consulting Inc
ripening cabinet	Catalytic Generators Inc

ripening room	American Ripener Co Dade Service Corp
ripening room supplies	American Ripener Co Catalytic Generators Inc International Ripening Corp

For addresses and phone/FAX numbers of suppliers please refer to Appendix D

REFERENCES

Arpaia, M L 1994 Degreening citrus fruits *Perishables Handling Newsletter* Nov 1994 Special Issue No 80 26-27

Bartsch, J A et al No date Construction and management of an iced produce display Cornell University, Agricultural Engineering Extension Bull 438

California Tree Fruit Agreement No date *California Summer Fruits Do the Ripe Thing*

Cantwell, M 1994 Optimum procedures for ripening melons *Perishables Handling Newsletter* Nov 1994 Special Issue No 80 17-18

Kasmire, R F 1981 Continuous flow ethylene gassing of tomatoes *California Tomatorama* Fresh Market Tomato Advisory Board Information Bulletin No 29

Kays, S J and Beaudry, R M 1987 Techniques for inducing ethylene effects *Acta Horticulturae* 201 77-115

Mitcham, B 1994 Optimum procedures for ripening apples *Perishables Handling Newsletter* Nov 1994 Special Issue No 80 9-10

Mitcham B 1994 Optimum procedures for ripening pears *Perishables Handling Newsletter* Nov 1994 Special Issue No 80 19-20

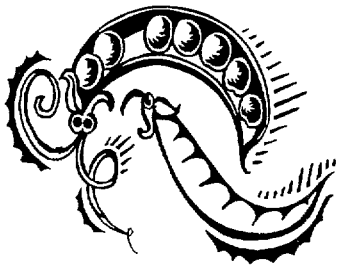
Oregon Washington California Pear Bureau No date *Know Your USA Pears* 813 SW Alder #601 Portland Oregon 97205-3182

Selders A W et al 1992 Facilities for Roadside Markets Northeast Regional Agricultural Engineering Service/ Cornell University Cooperative Extension

Singh R 1998 *Fruits India—the Food and the People* New Delhi National Book Trust, India

Thompson J F 1994 Ripening facilities *Perishables Handling Newsletter* Nov 1994 Special Issue No 80 5-8

CHAPTER 18



WHOLESALE PRODUCE MARKETING

Wholesale produce marketing is a highly competitive business, involving brokers, commision agents, shippers auctioneers, receivers, mixers, distributors, purveyors and producers If you sell through a traditional terminal market, you will find that there are many more produce growers than produce buyers, creating a "buyer's market" where the buyers generally set the daily wholesale prices Whenever the supply of a specific type of produce is higher than projected demand, prices can fall to very low levels, and producers will find it more difficult to make a profit It is important to find ways to differentiate your products and marketing options and to take advantage of the postharvest tools you have at hand to maximize your profits

Some of the practices and technologies we have presented in Part I and Part II and Chapter 17 can be utilized directly to assist your wholesale marketing efforts

- avoid seasonal gluts by producing earlier or later than other growers
- produce cultivars with specialty characteristics (flavor, appearance, storage potential)
- use maturity indices to assure highest quality at harvest
- sort by quality/maturity to maximize marketing options
- field pack or ranch pack to minimize mechanical damage and protect quality
- use packaging that will protect produce during handling and extend shelf life
- cool produce properly (avoid delays in cooling, avoid chilling injury, provide the proper RH environment) to extend shelf life

- store produce on the farm to avoid selling during glut supply periods
- process produce to more stable forms to extend shelf life and increase marketing options

One way to increase potential profits is to market directly to local wholesale customers such as food markets (produce departments, independent retailers, supermarkets), industrial food service operators (schools, hospitals, prison cafeterias), restaurants and hotels, or specialty retail food shops (health food stores, gourmet shops) rather than selling produce only through regional terminal markets Another option is to reduce your total costs by selling to food processors (requiring fewer handling steps) or by joining a cooperative (and share production, handling and marketing costs with others)

"The marketing of fruits in India is the most sorry aspect of the fruit industry Whereas in countries like Japan, the small growers are assured of an adequate price for their produce through cooperative marketing, the grower in India is at the mercy of the middlemen, who make more profit than the grower"

Source Singh 1998

Finding a niche market will greatly increase potential profits Market niches are unpredictable, but often are related to something new or unusual Providing safe food (chemical free, organically grown produce) may be a niche market in your community Doing something better then it is currently done can fill a niche-- for example, providing organically grown leafy greens that are free of aphids, a common problem found in the organic produce section of health food stores Truly unusual products can sell well if you market them to innovative people, such as a chef known for his unique cuisine Sometimes ethnic cooking using 'new' ingredients or a nutritious vegetable will be highlighted in the media and will suddenly become popular Be warned that if you identify a new product that sells well at a high profit, new growers will join you during the next season and your prices may have to come down as competitors flood the market Consider niche markets to be temporary, and always be on the lookout for a new idea

If you process fresh produce to add value, additional markets will be available to you You'll need to follow standard processing procedures to ensure food safety and may need to provide a safe, cool place for storage of processed products Quality and the perceived value of processed products will be judged by a wide range of standards related to appearance, flavor, packaging materials labels and whether you provide a written product guarantee Rather than processing produce because simply because the method suits the produce and provides a profit, process to meet a need or want of your customers You may want to provide some samples for taste-testing in order to get a good idea of the potential market before you invest in any produce processing for wholesale or retail sales

Exporting produce has its own long list of rules and regulations to be followed Sea-Land Service, Inc has compiled a list of 40 typical steps that must be carried out by 11 separate parties, including the shipper (you), freight forwarders, inland carriers, commercial banks terminal operators, ocean carriers, customs inspectors, customs brokers, cargo inspectors, port authorities and insurance surveyors If you are interested in learning about produce exports, identifying export markets, meeting phyto-sanitary restrictions and food safety requirements visit the California Agricultural Export Program website

California Department of Food and Agriculture 1220 N Street, Room 280-A
Sacramento, CA 95814 Phone (916) 654 0389 http //www cdfa gov/exports

For more information contact your state Department of Agriculture and refer to USDA Handbook 700 (Welby and McGregor 1997)

GENERAL DOs AND DON'Ts FOR WHOLESALE PRODUCE MARKETING

Meet customers to inquire about their produce needs (what they want to purchase, how much and when)

Assess your marketing options to determine which will be profitable (Worksheet 9)

Pack produce in standardized, new containers, by standardized grade (usually by size)

Check products before shipping to ensure they will meet all the buyer's specifications for quality, grade, packaging, volumes or weight

Diversify your markets and reduce risks by using more than one marketing strategy and selling to more than one buyer

Provide only high quality products, consistent over the season

Offer samples of new produce or processed products to prospective buyers

Ship the amount agreed upon on the date agreed upon Do NOT miss shipments or make late deliveries

Provide buyers with information on the proper conditons for wholesale level storage of produce (see Appendix B for specifics)

- Refrigerated and moist for leafy greens
- Refrigerated and dry for most produce items
- Cool, dry for chilling sensitive commodities
- Cool, dry for onions and garlic--separate from all fruits

Consider attending specialty or professional trade shows to meet potential wholesale buyers

Mandated Marketing Orders and Commissions

In California, marketing orders and commissions have been set up to aid marketing of specific horticultural commodities and establish standards for grades by size or/and maturity Although affected by marketing orders and commissions, most stone fruits and melons, citrus, pears, dates, kiwifruit and walnuts are exempt from if direct marketed If you plan to produce and sell large volumes of regulated produce contact the CDFA Marketing Branch for the manager of the appropriate commission at (916) 445-5141

Marketing Orders in California that may affect direct marketers(as of 1997)

almonds
apples
apricots
artichoke
asparagus
avocado
carrot
cherry
figs
grapes
olives
peppers
pistachio
potatoes
prunes
raisins
strawberry
tomatoes

TERMINAL PRODUCE MARKETS

When marketing wholesale through US terminal markets, you must package produce in new containers of the type specified for each commodity, sized to meet US or state grades, and meet certain minimum quality standards Grades are usually referred to as either *Extra Fancy, Fancy* and *Good* or *U S No 1* and *U S No 2* Most growers will find they have 30 to 40% "out of grade" due to cosmetic appearance alone (size, shape or maturity), and will need to find alternative outlets for this produce

Most buyers will require pre-cooled produce, since it will have a much longer shelf life compared to produce that is handled without cooling If there is any disagreement over grade, the USDA or your state Department of Agriculture can provide inspection services (at a fee) that follow USDA or market order guidelines

You can gather information in the US on current commodity market prices, average trucking rates between major shipping and destination points, current supply and demand for your products by calling the Federal-State Market News Service at (900) 555 7500 Many states have local information gathered for the use of growers and marketers available

through their state Department of Agriculture, and in some countries information is provided through governmental marketing boards If you are on-line you can find links to current market information on the Internet at a variety of websites, including http //postharvest ucdavis edu, www todaymarket com and www producenet com

If you are looking for wholesale produce buyers in your area or for a broker who deals in produce sales in the nearest regional terminal market, the telephone book is a good source of current information Local libraries have phone directories for most major cities available for reference use Other information sources, available to members and subscribers, include the trade directories of the United Fresh Fruit and Vegetable Association (UFFVA) and the Produce Marketing Association (PMA), credit references listed in *The Red Book* and *The Blue Book*, U S and Canadian terminal markets described in *The Green Book* and advertisements in the weekly newspaper *The Packer*

The Blue Book
Produce Reporter Co
Wheaton, Illinois 60187

The Red Book
7950 College Blvd
Overland Park, Kansas 66210-1821

The Packer
P O Box 2939
Shawnee Mission, Kansas 66201

Produce News
2185 Lemoine Ave
Fort Lee New Jersey 07024

LOCAL RETAIL PRODUCE MARKETS

The produce vendors in the supermarkets independent grocers and roadside stands in the towns near your farm most likely purchase most of their fresh produce from a traditional terminal market Produce buyers travel to visit the regional terminal market to select the produce they need and either transport it to their shops in their own vehicles or have it delivered by the shipper or by independent trucker The savings in the cost of transportation alone, when produce is sold near where it is grown, makes it possible for you to offer competitive prices when you market directly to these buyers

Produce buyers from these retail outlets may not have time to go out and look for local produce, but most will be willing to sample your fresh produce and buy if you can provide high quality produce that meets their needs As with all marketing, it pays to meet potential buyers and discuss their needs and your production possibilities before spending time and money producing crops And once an agreement is made, it is important to deliver the volumes you have promised on the expected dates If you have production problems that force you to make changes, buyers can usually make adjustments if you let them know as soon as possible that deliveries must be rescheduled

Raley's Supermarket offers Nutri-Clean® certified lab tested produce with no detected pesticide residues (tolerance 0 05 ppm) Growers interested in selling to Raley's must agree to work with NutriClean field inspectors and agricultural scientists to produce a product that will pass these very tough food safety standards

WHOLESALE TO PROCESSORS

While this marketing option is one of the least complicated for growers, the price you will receive for produce sold to processors is usually very low compared to the price for fresh produce sold directly to retailers There is a tendency for producers to believe they can get rid of sub-standard "out-of-grade" produce by selling it for processing, but this is not likely, unless a predictable volume of produce at the packinghouse is regularly out-of-grade due to extreme ripeness Certain melons and stone fruits can be processed (frozen or dried) when they are too ripe for successful fresh handling and shipping to wholesale buyers

If you want to sell to local processors, make sure that the cultivars you produce are the types they require for their products Generally a legal contract is made between the grower and the processor, and planting is done on a pre-arranged schedule so that a certain amount of produce is supplied over a certain period of time at a specified price Some processors provide production and harvesting assistance such as seeds, cultivation advice, harvest labor and/or transport to the processing facility

INDUSTRIAL FOOD SERVICE CUSTOMERS

Produce buyers for these operations often need large quantities of fresh produce, delivered consistently over the season They will generally not be interested in purchasing specialty, high priced produce

If you become a supplier for a local school, hospital, camp, nursing home or prison you will need to plan production to extend the season to maximize sales With a combination of multiple planting dates, multiple cultivars, production practices to assist early and/or later harvests, and storage methods you can supply fresh produce over a long period

Produce can usually be delivered in large sized packages If you make arrangements for the return of empty crates you can reuse the same containers after cleaning them or changing the liners

SPECIALTY FOOD SHOPS

Your highest quality, creatively packaged produce can be marketed in specialty food shops These shops sell the most expensive and exclusive products to customers who want the best For specialty shops, health food stores and gourmet food stores, brand name produce and processed products are often preferred by produce buyers and their customers Designing a simple label with your farm's name or logo is a useful way to distinguish your products from those of your competitors For example, for specialty shops you can use a small sticker on individual fruits, larger labels on bottled products or consumer packs of produce, or have cartons designed and printed to establish and identify your brand It goes without saying that once you have established

a brand name the produce given that label must be of the highest quality One bad experience will not only lose you that customer but possibly many others since they will be sure to tell others of the problem with your brand

RESTAURANTS AND HOTELS

Since restaurants and hotels have to plan menus well ahead of the produce season, they need a consistent supply at a stable price Most buyers for these operations want produce fresh, clean and on time Chefs and sous-chefs can give you direct feedback on flavor varieties, size, packaging and the other characteristics of the produce you offer for sale Find out what they want, and make plans with them to provide it over the next season Consider working with your neighboring growers to increase the variety and volume of the produce you can supply

Some chefs are willing to try exotic produce or processed products that they can use in their restaurants Often they are willing to pay more for produce that has been washed, trimmed or fresh-cut If the cold storage facilities at the restaurant or hotel are small, you may need to make frequent deliveries Avoid rush times (meal preparation and serving times) when making deliveries and place produce in the cooler yourself to ensure it is stored properly

Offer triple washed mixed salad greens for 25% more per lb

COSTS AND BENEFITS OF DIRECT WHOLESALE MARKETING OPTIONS

Costs

Preparation for market

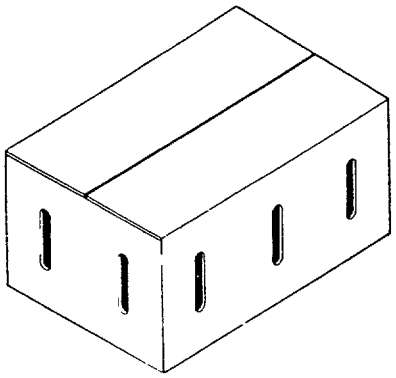
Special packaging requirements

Transport (vehicles fuel or shipping fees)

Promotion

Labor (delivery, customer service)

Insurance



Benefits

No broker fees

Higher market prices

Potential for matching market requirements (lower losses)

WORKSHEET 9 WHOLESALE MARKETING OPTIONS

Make copies of this blank worksheet and use one for each commodity you are marketing If you do not know the actual market prices of the produce you will be marketing, work backwards to calculate your costs, then determine the minimum market price you need to make the profit you desire

Commodity (varieties)_____

1 Do some market research
What types of wholesale markets are available to you?

_____ Terminal markets
_____ Local produce retailers
_____ Processors
_____ Food service
_____ Specialty shops
_____ Restaurants/Hotels
_____ Other

Gather information on potential local wholesale buyers

Buyers (names, addresses, telephone, FAX, e-mail)	What do they want to buy? (commodity varieties)	How much?	When? Price?

Estimate the volume of produce or processed product you expect to have to sell this season (Refer to Worksheets 1 and 2 and/or Worksheets 5 and 6)

Commodity (variety) or Product	Volume (lbs or units)	Market window (when)

Find out what your competitors are charging local buyers for their similar produce or processed product

Competition	Commodity (variety) or Product	Market window	Selling prices

2 Compare the Costs associated with Marketing Options

What are the specific handling and marketing costs for each type of wholesale marketing you will use? (For the first topics on the list, complete Worksheets 2 and/or 5 for specific commodities and calculate the subtotals under each topic heading) Major differences will come from the distance to various markets, specific market requirements for quality/grade, whether you must provide transportation, and which postharvest steps you are willing to undertake Make all comparisons on a per lb or per unit basis (divide the costs by the amount you have to sell)

Fill in the types of markets you want to investigate on the top row, then enter the associated costs

Market Type				
Pre-harvest				
Harvest				
Packinghouse				
Temperature management				
Storage				
Transportation				
Destination handling				
Processing				
Food safety				
Marketing fees				
Commissions				
Sales labor				
Recordkeeping				
Promotion				
Insurance				
Overhead				
Other				
Total cost/lb or cost/unit				

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3 Profitablility

Compare the costs/lb or /unit to the expected market prices to determine which marketing strategies have the potential to provide the most profits Avoid any markets or buyers that will not provide a good return on investment

Market Type	Cost/lb or /unit	Buyer	Expected price	Price-Total Cost

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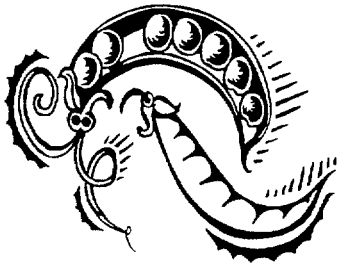
CHAPTER 19



DIRECT RETAIL PRODUCE MARKETING

Farmers' markets, roadside stands and pick-your-own operations are well known forms of direct marketing for vendors of horticultural produce These outlets are perfect for selling delicate vegetables and ready to eat ripe fruits that would not ship well The California Department of Food and Agriculture (CDFA) and other states exempt these types of operations from sizing, standard pack and certain container and labeling requirements

Some of the benefits of direct retail marketing include

- Cash sales (immediate payment)
- More control over market prices (higher prices)
- Low volume is not a problem
- Flexible working hours
- Packing, grading, labeling exemptions
- Opportunity to test new products
- Immediate feedback from customers

One of the best reasons to direct market is to provide the freshest produce possible by reducing the number of times produce is handled and minimizing the distance between the farm and the market While everyone knows how wonderful a freshly picked, vine-ripened tomato tastes, few people have the opportunity to eat fresh tomatoes unless they grow them in their own backyard

garden Direct marketing through a farmers' market is a way to bring ripe tomatoes or tree-ripened fruits to city-dwellers who are willing to pay a high price for the pleasure of buying and eating them immediately

Some of the practices and technologies we have presented in Part I and Part II and Chapter 17 can be utilized directly to assist your retail marketing efforts

- avoid seasonal gluts by producing earlier or later than other growers
- produce cultivars with specialty characteristics (flavor appearance, storage potential)
- use maturity indices to assure highest quality at harvest
- sort by quality/maturity to maximize marketing options
- field pack or ranch pack to minimize mechanical damage and protect quality
- use containers that will protect produce during handling and extend shelf life
- cool produce properly (avoid delays in cooling, avoid chilling injury, provide the proper RH environment) to extend shelf life
- store produce on the farm to avoid selling during glut supply periods
- ripen produce before marketing to increase sales
- create displays of ready-to-eat produce (washed fruits, mixed salad greens)
- process produce to more stable forms to extend shelf life and increase marketing options

GENERAL DOs AND DON'Ts FOR RETAIL PRODUCE MARKETING

Meet customers to inquire about their produce needs (what they want to purchase, how much and when)

Assess your marketing options to determine which will be profitable (Worksheet 10)

Diversify your markets and reduce risks by using more than one marketing strategy and selling to more than one buyer

Provide only high quality products, consistent over the season

Create attractive displays and keep the produce section clean

Offer samples of new produce or processed products to prospective buyers

GENERAL INFORMATION ON RETAIL MARKETING

Promotional Activities

Direct marketing requires that you spend a good portion of your time promoting and selling your produce and/or processed products One promotional activity that works for many types of retail endeavors is to personally meet and greet the people who will buy your produce For example you can ask your fresh apple buyers how they intend to use the produce and whether they would like to purchase a processed version of the fruits such as dried apple slices jellies applesauce cider or apple butter Some marketers prepare newsletters to keep their customers informed of up-coming availability of produce (Mann Packing Company, Inc in Salinas, CA), while others have moved onto the Internet to provide information on produce and market directly to consumers by mail (examples of informative websites include www friedas com and www melissas com)

Promotion of produce can be simplified if you ask customers what they want to buy, then consistently provide high quality products Ideally you will plant and grow exactly what your buyers ask you to grow, then offer fresh produce and/or processed products when they need it and in the amounts they require Advertising is sometimes helpful to attract new customers, but it is easy to waste money on unprofitable ads Try to find out which media your potential customers read, watch and/or listen to, and find a professional to help you design a successful advertisement before you spend any money on paid ads Providing educational or informational materials such as recipes can assist you to build a market for your products Some marketers add value and promote their products by providing a toll-free phone number for questions/problems

Farmer's Market On-line
helps farmers and consumers throughout the world meet on-line and negotiate direct sales
P O Box 277 Shoshone
Idaho 83352
e-mail farm@aol com

Insurance, Health and other Regulations

Many direct retail marketing options require you to have some sort of liability insurance to cover possible injuries caused by the produce or processed products you sell and accidents that might

occur on your property Liability insurance is available to cover a wide range of problems, such as if one of your employees drives the forklift into the parked car of a customer, or one of your customers slips and breaks his leg while shopping Many direct marketing operations in the US are corporations in the legal sense, in order to limit personal responsibility for any claim filed against them In any case, you must try to make your property as safe as possible to limit the possibilities of accidents Eric Gibson (1994) describes how to take 'every reasonable action' to remove hazards or warn people of potential hazards in his book entitled *Sell What You Sow!* He recommends establishing safe parking patterns in parking areas and good visibility for entries and exits smoothing out any holes, ruts and mounds which could cause a fall, making sure strong, smooth handrails are in place on steps and ramps, posting warning signs and guard rails on any potentially dangerous area (ponds, creeks, farm equipment, barns, etc), eliminating tripping hazards such as empty crates in walkways, or ruts in paths, and not allowing customers to climb trees or use ladders to pick fruit in Pick-Your-Own operations Training employees in safe working practices and following the HACCP program steps described in Chapters 10 and 15 will ensure that you have adequate records to provide evidence you have taken the appropriate steps to prevent food safety problems should any case ever be filed against you

Make sure you follow any federal, state or local laws or regulations affecting direct marketing in your area Regulations may affect signage, parking, insurance needs, zoning and licences for retail sales sales taxes employee benefits, building permits, required restroom facilities or sewer systems as well as many other factors When direct marketing, containers can often be reused if kept clean, reducing the costs of doing business Although many commodities are covered by marketing orders and commissions in California, some crops are allowed a direct marketing exemption in certain circumstances (contact the CDFA Marketing Branch at 916-445-5141) There are however certain government health regulations that must be followed

1) All produce must be stored at least 18 inches off the floor Food stored in a walk-in refrigeration unit must be at least 5 inches off the floor

2) Food preparation is prohibited (packaging, processing, assembling, portioning or **any operation which changes the form, flavor or consistency of the food)** unless you have a food processing licence Trimming of outer leaves, stems, stalks, tops and roots is permitted

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In California marketing orders and commissions have been set up to aid marketing of specific horticultural commodities and establish standards for grades by size or/and maturity Although affected by commissions most stone fruits and melons citrus pears dates kiwifruit and walnuts are exempt from if direct marketed If you plan to produce and sell large volumes of regulated produce, contact the CDFA Marketing Branch for the manager of the appropriate commission at (916) 445-5141

Marketing Orders in California that may affect direct marketers (as of 1997)

almonds
apples
apricots
artichoke
asparagus
avocado
carrot
cherry
figs
grapes
olives
peppers
pistachio
potatoes
prunes
raisins
strawberry
tomatoes

FARMERS' MARKETS

The number of farmer's markets in the US is increasing, and open air marketing is generally the most common form of marketing in developing countries The best locations are usually near urban centers Farmers' markets are known to offer consumers a wide selection of locally grown fresh produce, as well as a chance to talk with the growers and ask questions about the produce they buy As with other forms of direct marketing, the vendor must be willing to interact with customers, or be ready to hire someone who is suited to this type of work Most farmers' markets advertise market days and some provide other related activities to attract shoppers, such as prepared foods, baked goods or live music

If you are interested in selling at an existing farmer's market, start with a visit to the market yourself as a shopper Look at the whole market though the eyes of a customer, and evaluate it for the hours of operation, parking, prices, selection, cleanliness, etc Talk to the market manager about fees, rules, taxes or commissions, insurance requirements and what types of promotional activities are done to advertise the market

The most popular produce

tomatoes
peppers
onions
cucumbers
beans
lettuce
carrots
sweet corn
radishes
cabbage
peas

The most profitable

tomatoes
peas
carrots

Less profitable

sweet corn
onions
potatoes

Since most produce harvests are seasonal, sales will tend to peak and decline, leaving the vendor alternately buried in produce or without a source of income for extended periods Sometimes it is possible to extend the marketing period by producing several different varieties of major crops Some growers in California supplement their fruit and vegetable sales with fresh and potted herbs, container plants, and even nursery stock and Christmas trees

There are now an estimated 35,000 farmers taking part in Punjab's Apni Mandis (1997-98)

Source Punjab Mandi Board

The stated objectives of the Apni Mandi Scheme in Punjab

1) Better marketing of agricultural produce especially fruits and vegetables
2) to diversify agricultural production and improve the profitability of these crops for the producers
3) to ensure the availability of farm fresh produce at reasonable rates and discipline margins of profit in the market
4) to remove social inhibition among the farmers for retail sale of their produce themselves
5) to ensure direct contact between the producer and the consumer
6) to help self employment of producers and thus help in rural development and economic growth
7) to promote national integration by inviting the farmers of other States to sell the produce grown by them at their fields direct to consumers in APNI MANDIS "

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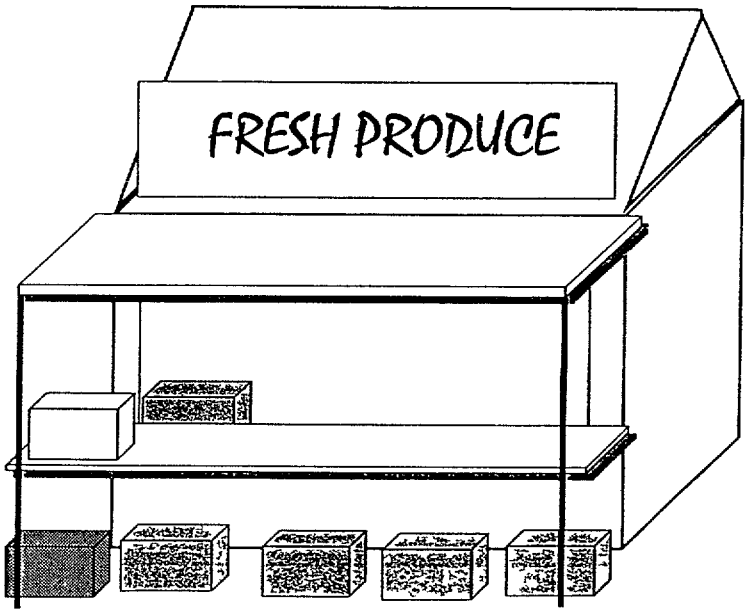
POST PRODUCE PRICES
Some shoppers are too hurried or too shy to ask you for the price

Provide shade
Attractively display produce
Keep the stand or shop clean
Provide good lighting

ROADSIDE STANDS and FARM SHOPS

The primary consideration for a produce stand or shop is location Roadside stands and farm shops require a location that is appealing, near a major city or popular road, with good signage and a place to park for consumers who have to come out of their way to buy In the US, the general rule is that nearly all your customers will live within 18 km (30 miles) of your farm, and most will come from within 12 km (20 miles) Other roadside stands located nearby could either be competition or complementary, depending on their selection and prices

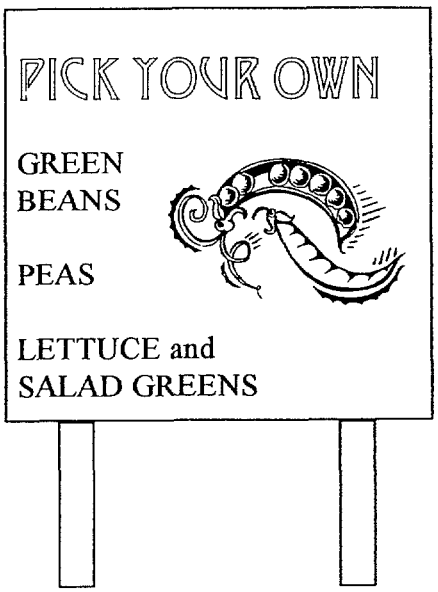
ROADSIDE STAND display produce in the shade provided by awnings tables or canopies provides space inside for short term storage and a chair and desk for worker comfort



These shops can be the most profitable of all marketing options if you have a good location Profits are higher since the costs of packing and transport are greatly reduced and market prices can be set relatively high The better the quality and the fresher your produce (fresh picked) and fruits (ready-to-eat) the higher your sales will be Sales can be difficult to predict on a daily basis and losses can be high if too much produce is harvested at once Gibson (1994) recommends that you start out small and see what kind of traffic you get One option is to have a worker standing by to go out and harvest produce as it is needed to fill displays Another possibility is to offer farm tours or hold an annual farm festival to attract buyers when you have a seasonal glut

PICK-YOUR-OWN

Location is the most important factor in whether it is possible to develop a profitable pick-your-own operation Some variations on this theme include "rent-a-tree", "rent-a-row", "rent-a-garden" or "U-pick" operations Since customers harvest the produce themselves, the field or orchard must near an urban center, easily accessible by major road or located along a tourist route You can offer lower prices since so many of your costs are lower (no harvest labor to pay or packinghouse operations to run, minimal packaging and cooling, no transport or storage) There are some new costs, similar to those of other direct marketing operations (insurance, promotional activities developing parking areas and providing harvest supervisors and sales personnel to work with customers)



The crops especially profitable for Pick-your-own operations are those that require a lot of labor for harvesting, packinghouse operations and packaging for wholesale or retail sale Examples include peas, green beans okra and berries Other crops well suited to these operations are those that taste better harvested full ripe (when it is very difficult to handle them without causing mechanical damage) Examples include strawberries raspberries blueberries peaches and

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apricots You can extend the harvest season by producing several varieties of the commodities you produce and market

Commodities well suited for PICK-YOUR-OWN operations

tree fruits
berries
green beans
tomatoes
sweet corn
okra
peas
asparagus
herbs

The "shoppers" who are harvesting your carefully cultivated crops will need close supervision to protect themselves, your plants or trees and your property from damage You can provide unobtrusive supervision and reduce losses by

- planting easy to pick varieties of crops ('Novella' peas, 'E-Z Pick' or 'Purple teepee' beans)
- providing a quick training session upon arrival of customer groups (show them how to pick)
- offering to carry filled containers to a check-out area (label them with the customer's name and keep them in a cooler if possible)
- assigning people to a specific row or tree
- providing transport to the field or orchard (a wagon or motorized cart with a driver)
- keep a few pre-packed containers of high quality produce in the cold room for those customers who don't want to do the harvesting themselves

MARKETING COOPERATIVES (CO-OPS)

Cooperatives, or user-owned and controlled businesses, can provide many benefits to small-scale producers By working with other produce growers, many of your marketing costs can be reduced Co-ops make it possible to share expenses for packinghouse operations (such as grading or packing), transportation, packaging materials, storage facilities, processing equipment, advertising (brands and promotional activities) and other inputs that contribute to the marketing of a quality product

When marketing cooperatives combine the produce of their grower-members, each small-scale producer gains an opportunity to sell to lucrative large domestic and foreign markets that were out of their reach Incentives for forming co-ops tend to be higher for perennial crops than for annuals, since growers have a long-term investment in tree crops Specialty commodities can benefit from mutual marketing efforts as for members of the Cooperative of Certified Organic Growers Similarly incentives are higher for growers of processed commodities than for fresh, since a large investment in a processing facility is usually required

Cooperative of Certified Organic Growers
5115 5th Street
Rainbow, CA 92028

PlacerGROWN Farm Trails puts out an annual "Harvest Calendar and Local Buying Guide" and provides free maps and information on farms and roadside stands in Placer County, CA

Examples of successful marketing co-ops abound Many of California's Certified Farmers Markets are cooperatives Apple Hill Farmers based in Camino draws urban consumers from the Bay Area and Sacramento to shop at its member farms in the foothills of the Sierras in El Dorado County A map of the co-op's members listing the produce each offers for sale, and a shuttle bus service combine to help buyers find the varieties of apples, pears and other produce they want to sample

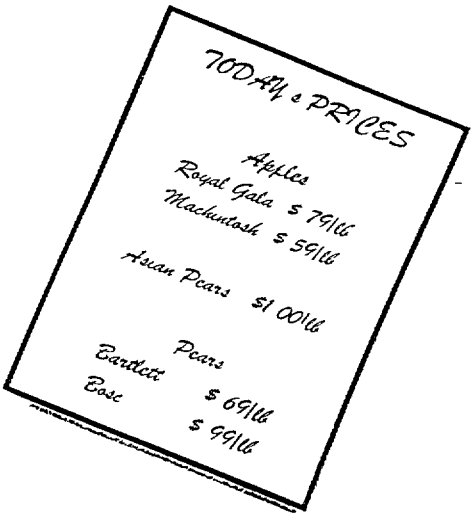
On the grander scale, Sun-Diamond Growers of California acts as a marketing agency for its five member cooperatives (Diamond Walnut Growers Inc Sun-Maid Growers of California Sunsweet Growers Inc Valley Fig Growers and Hazelnut Growers of Oregon) Diamond Walnut Growers Inc has 2300 members and handles 47% of California's walnut tonnage in its Stockton processing facility Sun-Maid Growers of California (Kingsburg) runs the largest raisin processing plant in the world and currently handles almost 30% of California's raisins for their 1600 members

If there is no cooperative in your local area that fits your needs it is always possible to form one There must be sufficient high quality produce grown by farmers in the area and expected benefits must justify the investment required For detailed information and assistance with establishing a marketing co-op start with the University of California Center for Cooperatives

UC Center for Cooperatives
One Shields Avenue, UC Davis, Davis CA 95616
(530) 752 2408

COSTS AND BENEFITS OF DIRECT RETAIL MARKETING OPTIONS

Costs
Preparation for market
Facilities (shop, farm stand or market booth)
Utilities
Cold storage (equipment and power)
Transport (vehicles fuel)
Promotion (signs, advertisements etc)
Labor (sales customer service)
Insurance (liability)
Licences permits



Benefits

No broker fees

Higher market prices (retail price)

Immediate payment (cash)

Lower costs for packing (pick-your-owns) and/or transport (farm stands)

Potential for matching market requirements (lower losses)

Shared costs (marketing cooperatives)

WORKSHEET 10 RETAIL DIRECT MARKETING OPTIONS

Make copies of this blank worksheet and use one for each commodity you are marketing If you do not know the actual market prices of the produce you will be marketing, work backwards to calculate your costs, then determine the minimum market prices you need to make the profits you desire

Commodity (varieties)_____

1 Do some market research What types of retail markets are available to you?

_____ On-farm shop
_____ Roadside stand
_____ Pick-your -own
_____ Farmer's market
_____ Community Supported Agriculture
_____ Marketing Cooperative
_____ Other

Gather information on potential local produce customers

Customers	What do they want to buy? (commodity, varieties)	How much?	When?	Price?

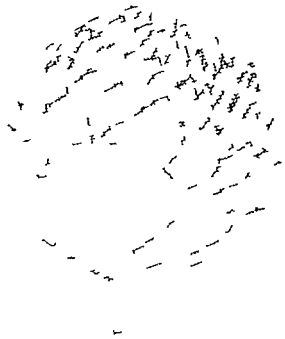
Estimate the volume of produce or processed product you expect to have to sell this season (Refer to Worksheets 1 and 2 and/or Worksheets 5 and 6)

Commodity (variety) or Product	Volume (lbs or units)	Market window (when)

Find out what your competitors are charging local buyers for their similar produce or processed products Can you offer produce at a different time or lower price?

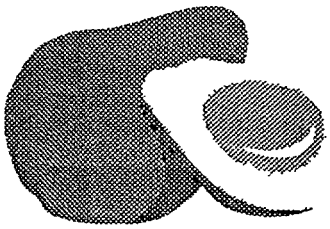
Competition

Commodity (variety) or Product	Market window	Selling prices



2 Compare the Costs associated with Marketing Options

What are the specific handling and marketing costs for each type of wholesale marketing you will use? (For the first topics on the list, complete Worksheets 2 and/or 5 and calculate the subtotals under each topic heading) Major differences will come from the distance to various markets specific market requirements for quality/grade, what the costs of marketing are (rental space, booth fees or commissions) whether you must provide transportation, which postharvest steps you undertake, and whether you share any of the costs Make all comparisons on a per lb or per unit basis (divide the costs by the amount you have to sell)



Write the names or locations of the types of retail markets you wish to investigate on the top row then enter the associated costs for each

Market Type				
Pre-harvest				
Harvest				
Packinghouse				
Temperature management				
Storage				
Transportation				
Destination handling				
Processing				
Food safety				
Marketing fees				
Commissions				
Sales labor				
Display				
Retail outlet facilities				
Recordkeeping				
Promotion				
Insurance				
Overhead				
Other				
Total cost/lb or cost/unit				

3 Profitablility

Compare the costs/lb or costs/unit to the expected market prices to determine which retail marketing strategies have the potential to provide the most profits Avoid any markets or buyers that will not provide a good return on investment

Market Type	Cost/lb or /unit	Location/buyer	Expected price	Price - Total Cost

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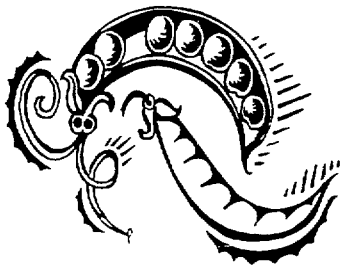
CHAPTER 20



ALTERNATIVE MARKETING STRATEGIES

COMMUNITY SUPPORTED AGRICULTURE

In recent years the Community Supported Agriculture movement, originating in Europe in the 1980's, has arrived in the U S , and is spreading rapidly as local consumers decide to take a more active interest in the production and handling of the food they eat According to Groh and McFadden (1997) the first CSAs were started in America in 1986, and in 1997 there were about 1000 farms involved with nearly 100,000 households

In the classic case, a CSA farm sells shares in its farm produce to consumers, based upon the actual cost of production Throughout the growing season, shareholders then receive a weekly allotment of mixed fresh produce (the volume is based on the number of shares purchased and the total amount harvested) Shareholders either pick their produce up at the farm or have it delivered to a central location in their neighborhood The CSA organization is comprised of farmers (who are responsible for growing the produce), a steering committee (active in planning and managing daily operations) and shareholders (who agree to pay up front to support the farm by purchasing shares) For example, 100 shares might be sold, each priced at 1% of the projected cost of production, harvest and distribution Included in the costs are a basic salary and benefits for the farmers who produce the crops, and a budget for those who work together to sell shares, plan production to meet the needs of shareholders, and manage farm activities (harvest, washing,

packing, delivery, etc) People who participate in CSA tend to be risk-takers who provide the capital for production, and may also provide labor during production and postharvest handling

Benefits of CSA.

- grower receives payment for produce during production
- very low postharvest losses, deliver exactly what you harvest and pack
- less time and money spent on handling and marketing
- shared risk of financial failure
- customer gets fresh, just-picked produce

"Get some local folks together, find out what they want you to grow and in what volume, figure out how much it will cost you to grow and distribute (including your time) Divide the costs by the number of shareholders you have recruited to determine the cost per share "

Source Lee, 1993

Example of a CSA marketing brochure

COMMUNITY SUPPORTED AGRICULTURE

Valley Farms of the Highlands

Throughout the harvest season from April to October, your weekly share of vegetables and fruits will be the freshest and best quality we can provide The actual variety and amount of each in your share will depend on the weather and our success in avoiding production problems Heres a example of one weeks share during two different months from last year

June

2 heads of lettuce
2 dozen radishes
2 lbs spinach
1 head chinese cabbage
2 lbs mixed greens
1 bunch green onions
1 lb tomatoes from our greenhouse
1 lb snap peas
1 lb shelling peas
1 lb green beans
2 quarts strawberries

September

2 heads lettuce
4 lbs mixed greens
1 bunch of celery
2 lbs broccoli
2 lbs eggplant
5 lbs tomatoes
2 lbs zucchini
4 lbs winter squash
2 lbs beets
5 lbs potatoes
1 lb onions

MEMBERSHIP FARMS AND SUBSCRIPTION AGRICULTURE

In California, CSA has taken a slightly different path, and is more or less incorporated into the many marketing options being used by small-scale growers Rather than depend upon local consumers to provide the entire budget of the farm up front, subcriptions for a set amount of produce or memberships are sold to individuals at the start of each season This is referred to in some places as subscription farming or subscription agriculture, and in others as membership farming

These alternatives are similar to CSA, in that they allow consumers to sign up for produce to be delivered for a set price throughout the harvesting season The price of a subscription is not neccesarily tied exactly to the cost of production, and subscribers are not locked in for the entire growing season Subscribers like these marketing arrangements because of the convenience, the wide variety of fruits and vegetables provided forces them to be more creative when cooking, and because they seem to enjoy the idea of knowing who grows their food

Some variations practiced by CSA and membership farms to increase sales and profits include

- providing home deliveries of produce to members for an additional fee
- supplementing produce with additional items purchased from another grower or wholesaler (tropical fruits out-of-season produce)
- adding processed products (purchased dried fruits, specialty canned or bottled products)

DO'S AND DON'TS FOR HIGH QUALITY PRODUCE VIA CSA OR SUBSCRIPTION FARMING

Plan ahead, with your shareholders or subscribers, to determine which crops to plant in what quantity

Consider setting up Pick-Your-Own operations for commodities requiring a lot of labor to harvest (for example raspberries, strawberries, peas green beans)

Provide training when shareholders or members offers to take on farm labors, harvesting or postharvest handling tasks Emphasize harvesting at proper maturity for desired use, gentle handling throughout and cooling as soon as possible after harvest

Don't worry about uniformity in size or shape, but sort produce to ensure high quality (remove immature, over-mature, diseased or badly damaged produce before cooling and packing)

Use appropriate cleaning, packing and cooling practices for the commodities handled (see Chapters 4 through 6) to increase shelf life and protect nutritional value and food safety

Store produce at recommended temperatures and relative humidity to avoid chilling injury, water loss and protect produce quality (see Chapter 7)

Avoid mixing ethylene sensitive produce (vegetables, leafy greens) with those that give off ethylene (ripe fruit) during packing, storage and transport

RESOURCES PERIODICALS, BOOKS AND ASSOCIATIONS

Many references and information sources are available for those interested in implementing CSA or subscription farming approaches

Community Alliance with Family Farmers — annual directory of direct marketers
P O Box 363, Davis, California 95617
(530) 756 8518

Small Farm Center — *Small Farm News*
One Shields Ave, UCDavis, Davis, California 95616

Growing for Market — magazine for small-scale farmers
P O Box 3747, Lawrence, Kansas 66046 (913) 841-2559

The CSA Food Book — handbook providing crop descriptions,
Elizabeth Henderson — recipes, storage tips
Rose Valley Farm, P O Box 149, Rose Valley, New York 14542

CSA Handbook — worksheets legal issues
Cooperative Extension — postharvest handling
11477 E Avenue, Auburn, California 95603 (530) 889-7385

CSA of North America — not-for-profit educational network,
Indian Line Farm — information and technical assistance
57 Jugend Road, Great Barrington
Massachussetts 01230, (413) 528-4374

REFERENCES

Ableman M 1993 *From the Good Earth A Celebration of Growing Food Around the World* New York Harry N Abrams

CAFF 1995 *California Farm Fresh Directory* Davis CA CAFF (updated annually)

Gibson E 1994 *Sell What You Sow! The Grower's Guide to Sucessful Produce Marketing* Carmichael CA New World Publishing

Groh T and McFadden S 1997 *Farms of Tomorrow Revisited Community Supported Farms--Farm Supported Communities* Kimberton PA Biodynamic Farming and Gardening Association

Lee A W 1993 *Backyard Market Gardening the Entrepreneurs' Guide to Selling what you Grow* Burlington, VT Good Earth Publications

Steiner R 1993 *Agriculture* Kimberton PA Biodynamic Farming and Gardening Association

APPENDIX A

COMMODITY SYSTEMS ASSESSMENT METHODOLOGY

The primary source for materials found in this appendix is the manual LaGra J 1990 ***A Commodity System Assessment Methodology for Problem and Project Identification*** **Moscow, Idaho Postharvest Institute for Perishables**

The following information will help you look at your operation within the context of your local, regional or national commodity system to determine whether any of the practices you are now using to produce, handle or market your horticultural crops are the cause or source of postharvest losses, quality problems or loss of economic value or nutritional quality

Step 1 Assessing Postharvest Losses in Your Operation --CSAM

A postharvest loss assessment method known as Commodity Systems Assessment Methodology (CSAM) was originally developed by Jerry LaGra (1990), and modified during its implementation over the course of many years The commodity system is made up of 27 components that together account for all the steps associated with the production, postharvest handling and marketing of any given commodity Ideally teams of 4 or 5 people work together while investigating a commodity system For example, a horticultural producer and a trader might be teamed up with a marketing specialist and an extension agent If you would like to conduct a simplified survey of losses for your operation using CSAM, you can form a "team" made up of yourself and at least one other person, preferably someone with skills in areas of horticulture complementary to your own

CSAM Sample Questions

The following is a list of system components and sample questions for investigating the commodity system within your operation Begin by considering these questions in relation to one commodity of interest, and feel free to add any other questions about information you feel is pertinent to your own situation Some of the questions can be answered directly by you or your managers, extension personnel or others who are knowledgable about the commodity Often, information can be found in the printed literature in agricultural libraries, journals or trade magazines Many questions, however, require the team to visit, observe and ask questions of those who harvest, handle and market the product Do not assume that you know what is actually happening until you observe the situation-- for example, workers can misunderstand instructions and mishandle produce, or unanticipated delays during shipping can cause temperature management problems

CSAM can assist a loss assessment team to determine 1) the sources of postharvest losses (who within the marketing chain is responsible) 2) the causes of those losses (what handling or marketing practices are responsible) and 3) the economic value of the losses compared to the costs of current and proposed postharvest practices Many times weight loss via water loss (wilting, shriveling, loss of volume) will be directly related to loss of income and quality changes (over-ripeness, browning, decay) will also be determined to reduce profits when produce must be culled during handling These losses must be assessed in terms of the costs associated with adopting new postharvest practices Fill out the worksheet at the end of Appendix A after reviewing the chapters of the book related to the postharvest losses and quality problems you have uncovered in your assessment Once you have collected this kind of information the handlers responsible for losses can be targeted with appropriate information on the most cost effective improved postharvest technologies

CSAM Components 1 - 7 Pre-Production
These components help you to put the commodity into perspective within the horticultural market and gain some understanding of how much competition you may face whether there are any political economic or environmental constraints or incentives and if there is any technical or marketing assistance available

1- **Importance of the crop** What is the relative importance of the crop (number of producers amount produced area of production (local regional national) economic value)? What crops compete with this one for shelf space?

2- **Governmental policies** Are there any laws regulations incentives or disincentives related to producing or marketing the crop? (example existing price supports or controls)

3- **Relevant institutions** Are there any organizations involved in projects related to production or marketing the crop? What are the goals of the projects? How many people are participating?

4- **Facilitating services** What services are available to producers and marketers (for example credit inputs technical advice extension services subsidies)?

5- **Producer/shipper organizations** Are there any producer or marketer organizations involved with the crop? What benefits or services do they provide to participants? At what cost?

6- **Environmental conditions** Does the local climate soils or other factors limit the quality of production?

7- **Availability of planting materials** Are seeds or planting materials of adequate quality? Can adequate supplies be obtained when needed?

CSAM Components 8 - 11 Production
Many of the choices you make during production will later affect postharvest quality food safety produce losses and economic value The first step in identifying possible improvements is to determine whether any of these production components are contributing to postharvest problems As you collect information on each component compare current practices to known recommendations for producing the commodity Calculating production costs at this point will help you to make useful comparisons between current practices and any new practice that you may be interested in adopting

8- **Farmers' general cultural practices** What is the average area planted? Do any farming practices have an effect on produce quality (planting density planting pattern irrigation weed control fertilization practices field sanitation)? What are the grower's sources of labor?

9- **Pests and diseases** Are there any insects fungi bacteria weeds or other pests that affect the quality of produce?

10- **Preharvest treatments** What kinds of physical or chemical preharvest treatments might affect postharvest quality (such as use of pesticides pruning practices thinning)?

11- **Production costs** Estimate the total cost of production (inputs labor rent etc) What are the costs of any proposed alternative methods?

CSAM Components 12 - 21 Postharvest
Postharvest handling practices will have an enormous impact on produce quality losses and safety Postharvest handling maintains the quality of produce but cannot improve it Understanding each step of the postharvest chain will enable you to determine whether any of your current practices are causing problems Sometimes it is possible to measure losses at each step and determine whether making a simple change can have a major impact

12- **Harvest** When and how is produce harvested? by whom? at what time of day? Why? What sort of tools and containers are used? How do harvesters determine the proper maturity for harvest ? How should harvest maturity be determined?

13- **Grading and inspection** How is produce sorted? by whom? Does value (price) change as quality/size grades change? Do local regional or national standards (voluntary or mandatory) exist for inspection? What happens to culled produce?

14-**Postharvest treatments** What kinds of postharvest treatments are used? (Describe any curing practices cleaning trimming waxes chemical treatments hot water dips etc)

15- **Packaging** How is produced packed for transport and storage? What kind or packages are used? Are packages reused or recycled?

16- **Cooling** When and how is produce cooled? To what temperature? Using which method(s)? How do current practices compare to recommendations for the commodity?

17- **Storage** Where and for how long is produce stored? In what type of storage facility? Under what conditions (packaging temperature RH physical setting hygiene inspections etc)? How do these compare to recommendations for optimum storage life?

18- **Transport** How and for what distance is produce transported? In what type of vehicle? How many times is produce transported? How is produce loaded and unloaded? What are the conditions of the roads?

19- **Delays/ waiting** Are there any delays during handling? How long and under what conditions (temperature RH physical setting) does produce wait between steps? Who is responisible for delays and who suffers financially?

20- **Other handling** What other types of handling does the produce undergo? Is there sufficient labor available? Is the labor force well trained for proper handling from harvest through transport? Would alternative handling methods reduce losses? Would these methods require new workers or displace current workers?

21- **Agro-processing** How is produce processed (methods processing steps) and to what kinds of products? How much value is added? Are sufficient facilities equipment fuel packaging materials and labor available for processing?

CSAM Components 22 - 27 Marketing
Marketing is not simply the last step of handling fresh produce but must be part of the overall plan to provide produce that best meets the needs of the consumer Consumer preferences play a large role in determining the economic value of the produce you sell

22- **Market intermediaries** If you do not handle the commodity yourself who are the handlers of the crop between producers and consumers? How long do they have control of produce and how do they handle it? Who is responsible for losses /who suffers financially?

23- **Market information** Do you have access to current prices and volumes in order to plan your marketing strategies? Who does the recordkeeping? Is information accurate reliable timely useful to you as a decision maker?

24- **Consumer demand and preferences** Do consumers have specific preferences for produce sizes flavors colors maturities quality grades packages types package sizes or other characteristics? Will they pay more for the characteristics they desire? Is there any sign of unmet demand and/or over-supply? How do consumers react to the use of postharvest treatments (pesticides irradiation coatings etc) or certain packaging methods (plastic styrofoam recyclables)?

25- **Exports** Do you produce this commodity for export? What are the specific requirements for export (regulations of importing country with respect to grades packaging pest control—etc)?

26- **Marketing costs** Estimate the total marketing costs for the crop (inputs and labor for harvest packaging grading transport storage processing marketing etc) What are the costs for any alternative methods proposed? Do you have access to credit? Are prevailing market interest rates at a level that allows you to repay the loan and still make a profit?

27- **Supporting infrastruture** Is supporting infrastructure adequate (roads marketing facilities management skills of staff communication systems such as telephone FAX e-mail services)?

Step 2 Review and Evaluate Recommended Practices

You may notice that many of the questions posed during a commodity system assessment are directly related to the common practices that lead to high produce losses, quality and food safety problems and loss of value Others relate to the market value of the produce, and may depend upon the season of production, packaging materials or consumer demand By comparing the facts you have gathered using CSAM with the recommended practices and small-scale technologies for postharvest handling and marketing of the commodity which are presented in this book, you can make beneficial changes to reduce fresh produce losses, maintain quality and nutritional value and ensure food safety If you uncover problems with no known technical solution you can pass this information on to the university researchers and postharvest extension specialists in your state or region

On the following 4 pages are example questionnaires from LaGra J 1990 *A Commodity System Assessment Methodology for Problem and Project Identification* **Moscow, Idaho Postharvest Institute for Perishables** You should develop suitable questionnaires for each component when you do your own Commodity Systems Assessment

COMPONENT 12 Crop Harvest

NAME OF DATA COLLECTOR _____ TEL. _____

TITLE _____ INSTITUTION _____

1 Who harvests the crop? _____

2 Describe in detail the harvest operation _____

3 Why is the crop harvested in this particular manner? _____

4 When is the harvest undertaken? Time of day _____

5 Under what conditions? Temperature _____ Relative humidity _____

6 Does the present method of harvest appear to affect quantity of produce available for market( ), quality of produce available for market( ) value of produce available for market( )? Explain _____

7 Does the volume of produce unsuitable for market appear to be high( ) medium( ) low( )? Describe the causes e g size of product, weather damage pest damage disease damage, lack of soil nutrients sun damage, harvest damage others _____

8 Estimate percentage of crop suitable for market _____%

9 Identify and describe the harvesting tools _____

10 Is all of the crop harvested at one time? yes( ) no( ) If no why not and how is selection made for that part which is harvested? _____

11 Identify harvest seasons for each cultivar or variety of crop (if more than one)

Cultivar	Months of harvest	No months in crop cycle

12 Which if any cultivar produces off season?_____

13 Optimum harvesting parameters
Moisture content_____
Color/appearance_____
Tenderness/texture_____

14 Maturity index known yes( ) no( ) If yes describe _____
_____

15 What criteria are used by the pickers in selecting the product for harvest?
_____

16 For the principal cultivar(s)
What is a good yield per hectare under good growing conditions?_____tons
What is a good yield per hectare under average conditions?_____tons

17 Sensitivity to mechanical damage during harvest high( ), medium( ) low( )

18 Sensitivity to dehydration high( ) medium( ) low( )

19 Summarize the problems occuring at harvest which may affect the processing postharvest handling, or marketing of the product
1
2
3
4
5

20 Observations

Source LaGra J 1990 *A Commodity System Assessment Methodology for Problem and Project Identification* Moscow, Idaho Postharvest Institute for Perishables

COMPONENT 24 Consumer Demand

NAME OF DATA COLLECTOR _____ TEL _____

TITLE _____ INSTITUTION _____

1 What percent of total national production of this product is sold on the domestic market? _____% export market? _____%

2 What percent of the production in the geographical area under study goes to the domestic market?_____% export market_____%

3 Which consumers purchase the product in domestic and export markets

	Domestic market	Export market
-low income consumers	_____%	_____%
-medium income consumers	_____%	_____%
-high income consumer	_____%	_____%
Total(%)	100	100

4 Indicate ethnic group consumption of this product

Ethnic group	Domestic market	Export market
_____	_____%	_____%
_____	_____%	_____%
_____	_____%	_____%
Total(%)	100	100

5 For each important consumer group identified above provide the following information for the applicable questions

a Preferred cultivar?_____

b Preferred size?_____

c Preferred color?_____

d Desired flavor?_____

e Desired texture?_____

f Preferred degree of maturity?_____

g Preferred type of package?_____

h Desired number of units/products per package?_____

i Consumer willingness to accept pest or disease blemishes?
will accept( ) will not accept( )

j Which of the following is most important to this consumer group quality( ) or price( )?

k How sensitive is this consumer group to fluctuations in product prices?
( ) very sensitive (small price increase decreases comsumer purchases)
( ) moderately sensitive
( ) slightly sensitive
( ) not very sensitive (large price increase won t decrease amount purchased)

l Desired product characteristics for religious cultural, and medicinal uses
religious _____
cultural _____
medicinal uses _____
other _____

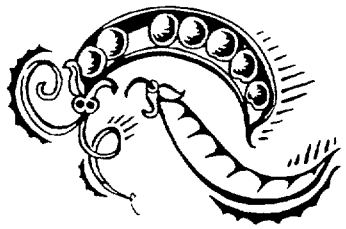
6 Summarize the characteristics of consumer demand which are most likely to affect the marketability of the product in question
1
2
3
4
5

7 Observations

Feasibility of reducing postharvest losses due to pre-harvest factors and postharvest handling practices causing problems in both technical and economic terms

		Reducible in Technological terms?		Economic terms?	
PHT STEPS	Source of postharvest loss or quality problem	yes	no	yes	no
land prep					
seeds/planting materials					
fertilization					
irrigation					
pests/diseases					
pruning/ thinning					
harvest					
sorting/ grading					
postharvest treatments					
packing/ packaging					
delays					
cooling/ RH mgmt					
loading/ unloading					
transport					
storage					
loading/ unloading					
transport					
delays					
wholesale					
loading/ unloading					
transport					
delays					
retail					
other					

APPENDIX B



RECOMMENDED CONDITIONS TEMPERATURE and RELATIVE HUMIDITY

The information found in this table was compiled by Marita Cantwell, Department of Vegetable Crops, University of California, Davis (April 1996) For future updates visit http //postharvest ucdavis edu

Common Name in English	Scientific Name	Temperature °C	°F	R.H. %	Approximate Shelf-life
African horned melon	*Cucumis anguria*	13-15	50-60	90	6 months
Amaranth, Pigweed	*Amaranthus spp*	0-2	32-36	95-100	10-14 days
Apple	*Malus pumila*	-1-4	30-40	90-95	1-12 months
Apricot	*Prunus armeniaca*	-0 5-0	31-32	90-95	1-3 weeks
Artichoke	*Cynara acolymus*	0	32	95 100	2-3 weeks
Asian Pear, Nashi	*Pyrus serotina P pyrifolia*	1	34	90-95	5-6 months
Asparagus, green, white	*Asparagus officinalis*	1-2	34-36	95-100	2-3 weeks
Atemoya	*Annona squamosa x cherimola*	13	55	85-90	4-6 weeks
Avocado	*Persea americana*				
cv Fuerte, Hass		7	45	85-90	- 2-4 weeks
cv Fuchs, Pollock		13	55	85-90	2 weeks
cv Lula, Booth-1		4	40	90-95	4-8 weeks
Babaco Mt. papaya	*Carica candamarcensis*	7	45	85-90	1-3 weeks
Banana	*Musa paradisiaca var sapientum*	13-15	56-59	90-95	1-4 weeks
Barbados cherry	*Malpighia glabra*	0	32	85-90	7-8 weeks
Basil	*Ocimum basilicum*	7 5-10	45-50	90	7 days
Beans					
Snapbean, Green Beans	*Phaseolus vulgaris*	4-7	40-45	95	7-10 days
Faba beans		4-7?	40-45	90-95	7-10 days
Lima beans	*Phaseolus lunatus*	5-6	41-43	95	5 days
Beet	*Beta vulgaris*				
bunched		0	32	98-100	10-14 days
topped		0	32	98-100	4 months
Belgian endive Witloof chicory	*Cichorium intybus*	2-3	36-38	95-98	2-4 weeks

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Common Name in English	Scientific Name	Temperature °C	°F	R.H %	Approximate Shelf-life
Bittermelon, Bitter gourd	*Momordica charantia*	10-12	50-54	85-90	2-3 weeks
Black salsify Scorzonera	*Scorzonera hispanica*	0-1	32-34	95-98	6 months
Black sapote	*Diospyros ebenaster*	13-15	55-59	85-90	2-3 weeks
Blackberries	*Rubus spp*	-0 5-0	31-32	90-95	3-6 days
Blueberries	*Vaccinium corymbosum*	-0 5-0	31-32	90-95	2 weeks
Bok choy	*Brassica chinensis*	0	32	95-100	3 weeks
Breadfruit	*Artocarpus altilis*	13-15	55-60	85-90	2-6 weeks
Broad bean, Faba bean	*Vicia faba*	4-5?	40-41?	90-95	1 semana?
Broccoli	*Brassica oleracea* var *Italica*	0	32	95-100	10-14 days
Brussel Sprouts	*B oleracea var Gemmifera*	0	32	95-100	3-5 weeks
Cabbage	*B oleracea* var *Capitata*				
Early crop		0	32	98-100	3-6 weeks
Late cabbage		0	32	95-100	5-6 months
Cactus leaves Nopalitos	*Opuntia spp*	5-10	41-50	90-95	2-3 weeks
Cactus pear Prickly pear fruit	*Opuntia spp*	5	41	85-90	3 weeks
Caimito, star apple	*Chrysophyllum caimito*	3	38	90	3 weeks
Calamondin orange	*Citrus reticulta x Fortunella spp*	9-10	48-50	90	2 weeks
Canistel, Eggfruit	*Pouteria campechiana*	13-15	55-60	85-90	3 weeks
Carambola, Starfruit	*Averrhoa carambola*	9-10	48-50	85-90	3-4 weeks
Carrots	*Daucus carota*				
bunched, immature		0	32	98-100	10-14 days
topped		0	32	98-100	6-8 months
Cashew apple	*Anacardium occidentale*	0-2	32-36	85-90	5 weeks
Cassava, Yucca root	*Manihot esculenta*	0-5	32-41	85-90	1-2 months
Cauliflower	*B oleracea* var *Botrytis*	0	32	95-98	3-4 weeks
Celeriac	*Apium graveolens var Rapaceum*	0	32	98-100	6-8 months
Celery	*Apium graveolens* var *Dulce*	0	32	98-100	1-2 months
Chard	*Beta vulgaris* var *Cicla*	0	32	95-100	10-14 days
Chayote	*Sechium edule*	7	45	85-90	4-6 weeks
Cherimoya, Custard apple	*Annona cherimola*	13	55	90-95	2-4 weeks
Chinese broccoli gailan	*Brassica alboglabra*	0	32	95-100	10-14 days
Chinese cabbage Napa cabbage	*Brassica campestris* var *Pekinensis*	0	32	95-100	2-3 months
Chinese Long bean	*Vigna sesquipedalis*	4-7	40-45	90-95	7-10 days
Chives	*Allium schoenoprasum*	0	32	95-100	2-3 weeks
Cilantro Chinese parsley	*Coriandrum sativum*	0-2	32-34	95-100	2 weeks
Coconut	*Cocos nucifera*	0-2	32-36	89-85	1-2 months
Collards Kale	*B oleracea* var *Acephala*	0	32	95-100	10-14 days
Cool season Leafy Greens	*various genera*	0	32	95-100	10-14 days
Cranberry	*Vaccinium macrocarpon*	2-4	36-40	90-95	2-4 months
Cucumber	*Cucumis sativus*	10	50	85-90	10-14 days
Currants	*Ribes sativum R. nigrum R. rubrum*	-0 5-0	31-32	90-95	1-4 weeks
Daikon, Oriental radish	*Raphanus sativus*	0-1	32-34	95-100	4 months
Date	*Phoenix dactylifera*	-18-0	0-32	75	6-12 months

Common Name in English	Scientific Name	Temperature °C	°F	R.H %	Approximate Shelf-life
Dill	*Anethum graveolens*	0	32	95-100	1-2 weeks
Durian	*Durio zibethinus*	4-6	39-42	85-90	6-8 weeks
Eggplant	*Solanum melongena*	10-12	50-54	90-95	1-2 weeks
Endive and Escarole	*Cichorium endivia*	0	32	95-100	2-3 weeks
Epazote	*Chenopodium ambrosioides*	0-5	32-41	90-95	1-2 weeks
Feijoa, Pineapple guava	*Feijoa sellowiana*	5-10	41-50	90	2-3 weeks
Fennel anise	*Foeniculum vulgare*	0-2	32-36	90-95	2-3 weeks
Fig	*Ficus carica*	-0 5-0	31-32	85-90	7-10 days
Garlic	*Allium sativum*	0	32	65-70	6-7 months
Ginger	*Zingiber officinale*	13	55	65	6 months
Gooseberry	*Ribes grossularia*	-0 5-0	31-32	90-95	3-4 weeks
Grape	*Vitis vinifera*	-0 5 a 0	31-32	90-95	2-8 weeks
American grape	*Vitis labrusca*	-1 a -0 5	30-31	90-95	1-6 months
Grapefruit	*Citrus paradisi*				
CA,AZ dry regions		14-15	58-60	85-90	6-8 weeks
FL humid regions		10-15	50-60	85-90	6-8 weeks
Guava	*Psidium guajava*	5-10	41-50	90	2-3 weeks
Horseradish	*Armoracia rusticana*	-1 a 0	30-32	98-100	10-12 months
Jaboticaba	*Myrciaria cauliflora= Eugenia cauliflora*	13-15	55-60	90-95	2-3 days
Jackfruit	*Artocarpus heterophyllus*	13	55	85-90	2-6 weeks
Japanese eggplant	*Solanum melongena*	8-12	46-54	90-95	1-2 weeks
Jerusalem artichoke	*Helianthus tuberosus*	-0 5-0	31-32	90-95	4 months
Jicama, Yambean	*Pachyrrhizus erosus*	13-18	55-65	85-90	1-2 months
Kiwi, Chinese gooseberry	*Actinidia chinensis*	0	32	90-95	3-5 months
Kohlabi	*B oleracea* var *Gongylodes*	0	32	98-100	2-3 months
Kumquat	*Fortunella japonica*	4	40	90-95	2-4 weeks
Langsat	*Aglaia spp Lansium spp*	11-14	52-58	85-90	2 weeks
Leek	*Allium porrum*	0	32	95-100	2 months
Lemon	*Citrus limon*	10-13	50-55	85-90	1-6 months
Lettuces	*Lactuca sativa*	0	32	98-100	2-3 weeks
Lime, Mexican, Tahiti or Persian	*Citrus aurantifolia C latifolia*	9-10	48-50	85-90	6-8 weeks
Longan	*Dimocarpus longan =Euphoria longan*	1-2	34-36	90-95	3-5 weeks
Loquat	*Eriobotrya japonica*	0	32	90	3 weeks
Luffa, Chinese okra	*Luffa spp*	10-12	50-54	90-95	1-2 weeks
Lychee Litchi	*Litchi chinensis*	1-2	34-36	90-95	3-5 weeks
Malanga, Tania, New cocoyam	*Xanthosoma sagittifolium*	7	45	70-80	3 months
Mamey	*Calocarpum mammosum*	13-15	55-60	90-95	2-3 weeks
Mandarin, Tangerine	*Citrus reticulata*	4	40	90-95	2-4 weeks
Mango	*Mangifera indica*	13	55	85-90	2-3 weeks
Mangosteen	*Garcinia mangostana*	13	55	85-90	2-4 weeks
Melon					
Cantaloupe melon	*Cucurbita melo* var *reticulatus*	2-5	36-41	95	2-3 weeks
Casaba, Crenshaw Honeydew etc	*Cucurbita melo*	7-10	45-50	90-95	2-3 weeks
Mint	*Mentha spp*	0	32	95-100	2-3 weeks

Common Name in English	Scientific Name	Temperature °C	°F	R.H %	Approximate Shelf-life
Mombin, Jobo Hog plum	*Spondias spp*	13	55	85-90	1-2 weeks
Mushrooms	*Agaricus y otros generos*	0	32	90	7-14 days
Nectarine	*Prunus persica*	-0 5-0	31-32	90-95	2-4 weeks
Okra	*Abelmoschus esculentus*	7-10	45-50	90-95	7-10 days
Olives, fresh	*Olea europea*	5-10	41-50	85-90	4-6 weeks
Onions	*Allium cepa*				
Mature onion bulbs		0	32	65-70	1-8 months
Green onions		0	32	95-1–	3 weeks
Orange	*Citrus sinensis*				
CA AZ dry regions		3-9	38-48	85-90	3-8 weeks
FL humid regions		0-1	32-34	85-90	8-12 weeks
Blood orange		4-7	40-44	90-95	3-8 weeks
Oregano fresh	*Origanum vulgare*	0-5	32-41	90-95	1-2 weeks
Papaya	*Carica papaya*	7-13	45-55	85-90	1-3 weeks
Parsley	*Petroselinum crispum*	0	32	95-100	1-2 months
Parsnips	*Pastinaca sativa*	0	32	95-100	4-6 months
Passionfruit	*Passiflora spp*	10	50	85-90	3-4 weeks
Peach	*Prunus persica*	-0 5-0	31-32	90-95	2-4 weeks
Pear	*Pyrus communis*	1 5-0 5	29-31	90-95	2-7 months
Peas pod	*Pisum sativum*	0	32	95-98	1-2 weeks
Snow peas	*Pisum sativum*	0-1	32-34	90-95	1-2 weeks
Southern peas, cowpeas	*Vigna sinensis =V unguiculata*	4-5	40-41	95	6-8 days
Peppers					
Bell Pepper	*Capsicum annuum*	7-10	45-50	95	2-3 weeks
Hot peppers Chiles	*Capsicum annuum y C frutescens*	5-10	41-50	85-95	2-3 weeks
Dried hot chiles	*C annuum y C frutescens*	0-10	32-50	55-65	6 months
Persimmon	*Dispyros kaki*	-1	30	90	3-4 months
Pineapple	*Ananas comosus*	7-13	45-55	85-90	2-4 weeks
Plantain	*M paradisiaca var paradisiaca*	13-15	56-59	90-95	1-5 weeks
Plums and Prunes	*Prunus dometica*	-0 5 - 0	31-32	90-95	2-5 weeks
Pomegranate	*Punica granatum*	5	41	90-95	2-3 months
Potato	*Solanum tuberosum*				
early crop		10-15	50-59	90-95	10-14 days
late crop		4-12	40-54	95-98	5-10 months
Pummelo	*Citrus grandis*	7-9	45-48	85-90	12 weeks
Pumpkin	*Cucurbita maxima*	12-15	54-59	50-70	2-3 months
Quince	*Cydonia oblonga*	-0 5-0	31-32	90	2-3 months
Raddichio	*Cichorium intybus*	0-1	32-34	95-100	3-4 weeks
Radish	*Raphanus sativus*	0	32	95-100	1-2 months
Rambutan	*Nephelium lappaceum*	12	54	90-95	1-3 weeks
Raspberries	*Rubus idaeus*	-0 5-0	31-32	90-95	3-6 days
Rhubarb	*Rheum rhaponticum*	0	32	95-100	2-4 weeks
Rutabaga	*B napus var Napobrassica*	0	32	98-100	4-6 months

Common Name in English	Scientific Name	Temperature °C	°F	R.H %	Approximate Shelf-life
Sage	*Salvia officinalis*	0	32	90-95	2-3 weeks
Salsify Vegetable oyster	*Trapopogon porrifolius*	0	32	95-98	2-4 months
Santol	*Sandoricum indicum*	7-9	45-48	85-90	3 weeks
Sapodilla	*Achras sapota*	15-20	59-68	85-90	2 weeks
Sour cherries	*Prunus cerasus*	0	32	90-95	3-7 days
Soursop	*Annona muricata*	13	55	85-90	1-2 weeks
Spinach	*Spinacia oleracea*	0	32	95-100	10-14 days
Sprouts from seeds	*various genera*	0	32	95-100	5-9 days
Squash, summer	*Cucurbita pepo*	5-10	41-50	95	1-2 weeks
Squash, winter	*Cucurbita moschata C maxima*	12-15	54-59	50-70	2-3 months
Strawberry	*Fragaria spp*	0	32	90-95	7-10 days
Sugar apple Custard apple	*Annona squamosa Annona spp*	7	45	85-90	4 weeks
Sweet cherries	*Prunus avium*	1 a -0 5	30-31	90-95	2-3 weeks
Sweet corn	*Zea mays*	0	32	95-98	5-8 days
Sweetpotato	*Ipomea batatas*	13-15	55-60	85-95	4-7 months
Tamarillo Tree tomato	*Cyphomandra betacea*	3-4	37-40	85-95	- 10 weeks
Tamarind	*Tamarindus indica*	2-7	36-45	90-95	3-4 weeks
Taro Cocoyam, Eddoe Dasheen	*Colocasia esculenta*	7-10	45-50	85-90	4 months
Thyme	*Thymus vulgaris*	0	32	90-95	2-3 weeks
Tomatillo, Husk tomato	*Physalis ixocarpa*	7-13	45-55	85-90	3 weeks
Tomato	*Lycopersicon esculentum*	10-13	50-55	90	1-3 weeks
Turnip	*B campestris* var *Rapifera*	0	32	95	4-5 months
Water Chestnuts	*Eleocharis dulcis*	1-2	32-36	98-100	1-2 months
Watercress garden cress	*Lepidium sativum Nasturtium officinales*	0	32	95-100	2-3 weeks
Watermelon	*Citrullus vulgaris*	10-15	50-60	90	2-3 weeks
White sapote	*Casimiroa edulis*	20	68	85-90	2-3 weeks
Winged Bean	*Psophocarpus tetragonolobus*	10	50	90	4 weeks
Yam	*Dioscorea spp*	15	59	70-80	2-7 months

Sources include unpublished information and

Facciola S 1990 *Cornucopia A Source Book of Edible Plants* Vista CA Kampong Publications 678 pp

Kader A A et al 1992 Postharvest Technology of Horticultural Crops (2nd ed) UC DANR Publications 3311 296 pp

McGregor B M 1989 Tropical Products Transport Handlbook USDA Handbook 668 148 pp

APPENDIX C

MODIFIED ATMOSPHERE PACKAGING: RECOMMENDATIONS and REQUIREMENTS

The source for the information provided in this Appendix is CA '97 Proceedings Volumes 1 to 5 Postharvest Horticulture Series No 15 - 19 University of California, Davis Specific references can be found at the end of Chapter 5 Containers and Packaging Materials

Recommendations and requirements for MAP of selected vegetables
Source Saltveit, 1997

	Temperature[1]		Atmosphere[2]		
Vegetable	Optimum	Range	$\%O_2$	$\%CO_2$	Application
Artichokes	0	0-5	2-3	2-3	Moderate
Asparagus	2	1-5	Air	10-14	High
Beans green snap	8	5-10	2-3	4-7	Slight
Beans processing	8	5-10	8-10	20-30	Moderate
Broccoli	0	0-5	1-2	5-10	High
Cabbage	0	0-5	2-3	3-6	High
Cantaloupes	3	2-7	3-5	10-20	Moderate
Herbs[3]	1	0-5	5-10	4-6	Moderate
Lettuce (crisphead)	0	0-5	1-3	0	Moderate

	Temperature[1]		Atmosphere[2]		
Vegetable	Optimum	Range	$\%O_2$	$\%CO_2$	Application
Lettuce (crisphead)					
cut or shredded	0	0-5	1-5	-20	High
Lettuce (leaf)	0	0-5	1-3	0	Moderate
Mushrooms	0	0-5	3-21	5-15	Moderate
Peppers chilies					
for processing	5	5-10	3-5	10-20	Moderate
Tomatoes (green)	12	12-20	3-5	2-3	Slight
ripe	10	10-15	3-5	3-5	Moderate

[1] Optimum and range of usual and/or recommended temperatures A relative humidity of 90% to 95% is usually recommended

[2] Specific CA recommendations depends on cultivar temperature and duration of storage

[3] Herbs chervil chives coriander dill sorrel and watercress

Recommendations for MAP of apples, pears and asian pears at -1 to 0 C
Sources Kupferman, 1997, Richardson and Kupferman, 1997

	O_2 (%)	CO_2 (%)	Temp (°C)	Storage (months)
Apple Variety				
Braeburn	1 8	1 0	0 7	6-9
Fuji	1 4	1 0	0 3	7-11
Gala	1 7	1 6	1 3	2-9
Golden Delicious	1 6	2 3	0 5	7-11
Granny Smith	1 4	2 0	0 6	7-11
Idared	2 1	2 5	1 9	7-10
Jonagold	1 4	2 7	0 9	5-10
McIntosh	2 1	2 9	2 5	5-10
Red Delicious	1 6	1 8	0 0	6-11
Royal Gala	1 5	1 8	-0 2	5-8

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	$\%O_2$	$\%CO_2$	Storage (months)	CA-disorders
Pear Variety				
Abate Fetel	1	1	5-6	IB
Alejandrina	3	2	4-5	IB
Anjou d Anjou	1-2 5	0-0 5	7-8	IB PBC Cav
Bartlett (=William s Bon Chretien)	1-2	0-0 5	3-5	CF PBC
Blanquilla (=Blanca de Aranjuez)	3	3	6-7	
Bosc Kaiser	1-2 5	0 5-1 5	4-8	PBC Cav
Buena Luisa (=Buona Luisa)	3	2	6	IB CF
Clapp s Favorite	2	<0 7	3-4	IB PBC
Comice	1 5-4	0 5-4	5-6	IB(overmature)
Conference	1-2 5	0 6-1 5	6-8	BH IB Cav
Coscia	1 5	2-3	6-7	CF
Flor d Hivern(=Invernо)	3	3	4-5	IB
Forelle	1 5	0-1 5	6-7	
General Leclerc	2-3	2-3	3-5	
Grand Champion	3	2-2 5	4	
Hardy	2-3	3-5	4-6	
Josephine	1-2	1-2	8	
Krystalli	2	1-2	3-5	
Limonera Llimonera	3	3	3-4	
Packham s Triumph	1 5-1 8	1 5-2 5	7-9	CB
Passe Crassane	3	4-5	5-8	IB
Rocha	2	2	8	
Spadona	1 5-2 5	1 5-3 5	8-9	IB
Asian pears				
Chojuro	2	1-2	3-4	
Kosui	1-2	0-2	3-4	
Nijiseiki (=20th Century)	0 5-3	0-1	5	
Tsu Li	1-2	0-3	3-5	IB
Ya Li	4-5	0-4	3-4	IB Cav Cl?

Ya Li may show a type of chill injury at temperatures <5°C
Optimum storage temperature is -1 to 0°C unless otherwise indicated (CA-disorder abbreviations are IB=internal breakdown or browning BH= brown heart PBC= pithy brown core CF= core flush Cav= cavity usually lens-shaped Cl= chilling injury)

Recommendations and requirements for MAP of other fruits (CA[2] conditions) Source Kader 1997

Commodity	Temperature Range[1]	% O_2	%CO_2	Commercial use (June 1997)
Apricot	0-5	2 3	2-3	
Avocado	5-13	2-5	3 10	Used during marine transport
Banana	12-16	2-5	2-5	Used during marine transport
Blackberry	0-5	5-10	15-20	Used within pallet covers during transport
Blueberry	0-5	2-5	12-20	Limited use during transport
Cherimoya & Atemoya	8-15	3-5	5-10	
Cherry sweet	0-5	3-10	10-15	Within pallet covers or marine containers during transport
Cranberry	2-5	1-2	0-5	
Durian	12-20	3-5	5-15	
Fig	0-5	5-10	15-20	Limited use during transport
Grape	0 5	2-5	1-3	Incompatible with SO_2
		or 5-10	10-15	Can be used instead of SO_2 for decay control up to 4 weeks
Grapefruit	10-15	3-10	5-10	
Kiwifruit	0-5	1 2	3-5	Expanding use during transport/ storage with ethylene < 20 ppb
Lemon	10-15	5-10	0-10	
Lime	10-15	5-10	0-10	
Lychee (litchi)	5-12	3-5	3-5	
Mango transport	10-15	3-7	5-8	Increasing use during marine
Nectarine	0-5	1-2	3-5	Limited use during marine transport
		or 4-6	15-17	Used to reduce chilling injury (internal breakdown) of some cvs
Olive	5-10	2-3	0-1	Limited use to extend processing season
Orange	5-10	5-10	0-5	
Papaya	10-15	2 5	5-8	
Peach clingstone	0 5	1 2	3-5	Limited use to extend canning season
Peach freestone	0-5	1 2	3 5	Limited use during marine transport
		or 4 6	15 17	Used to reduce incidence/severity of chilling injury of some cvs
Persimmon	0 5	3 5	5 8	Limited use of MA packaging
Pineapple	8-13	2 5	5 10	Waxing is used to create MA and reduce endogenous brown spot
Plum	0-5	1 2	0-5	Limited use for long term storage of some cultivars
Pomegranate	5 10	3-5	5-10	
Rambutan	8 15	3 5	7-12	
Raspberry	0-5	5-10	15-20	Within pallet covers during transport
Strawberry	0 5	5 10	15-20	Within pallet covers during transport
Sweetsop (custard apple)	12 20	3 5	5 10	

[1]Usual and/or recommended range a relative humidity of 90 95% is recommended

[2]Specific CA combination depends on cultivar temperature and duration of storage These recommendations are for transport and/or storage beyond 2 weeks Exposure to lower O_2 and or higher CO concentrations for shorter durations may be used for control of some physiological disorders pathogen and/or insects

Recommendations and requirements for MAP of fresh-cut vegetables and fresh-cut fruits Source Gorny 1997

Fresh-Cut Product	Temperature (°C)	Atmosphere %O_2	% CO_2	Effectiveness
Fresh-cut Vegetables				
Beets (Red)				
Grated Cubed or Peeled	0-5	5	5	Moderate
Broccoli Florets	0-5	2-3	6-7	Good
Cabbage Shredded	0-5	5-7 5	15	Good
Cabbage (Chinese) Shredded	0-5	5	5	Moderate
Carrots				
Shredded Sticks or Sliced	0-5	2-5	15-20	Good
Leek Sliced	0 5	5	5	Moderate
Lettuce (Butterhead) Chopped	0-5	1-3	5-10	Moderate
Lettuce (Green Leaf) Chopped	0-5	0 5-3	5-10	Good
Lettuce (Iceberg)				
Chopped or Shredded	0-5	0 5-3	10-15	Good
Lettuce (Red Leaf) Chopped	0-5	0 5-3	5-10	Good
Lettuce (Romaine) Chopped	0-5	0 5-3	5-10	Good
Mushrooms Sliced	0-5	NOT RECOMMENDED		
Onion Sliced or Diced	0-5	2-5	10-15	Good
Peppers Diced	0-5	3	5-10	Moderate
Potato Sliced or Whole-Peeled	0-5	1-3	6-9	Good
Rutabaga Sliced	0-5	5	5	Moderate
Spinach Cleaned	0-5	0 8-3	8-10	Moderate
Tomato Sliced	0-5	3	3	Moderate
Zucchini Sliced	5	0 25-1	-	Moderate
Fresh-cut Fruit				
Apple Sliced	0-5	<1	-	Moderate
Cantaloupe Cubed	0-5	3-5	6-15	Good
Honeydew Cubed	0-5	2	10	Good
Kiwifruit Sliced	0-5	2-4	5-10	Good
Orange Sliced	0-5	14-21	7 10	Moderate
Peach Sliced	0	1-2	5-12	Poor
Pear Sliced	0-5	0 5	<10	Poor
Persimmon Sliced	0-5	2	12	Poor
Pomegranate Arils	0 5	-	15-20	Good
Strawberry Sliced	0 5	1-2	5-10	Good

APPENDIX D

ADDRESSES/PHONE and FAX NUMBERSof SUPPLIERS of POSTHARVEST TECHNOLOGIES

Company list is in alphabetical order

Action Bag Co
501 N Edgewood Ave Wood Dale Illinois 60191 (800) 824-BAGS

Adelman-Fisher Packaging
207 Walnut Street Kansas City Missouri 64106 (816) 842-3961

Ag-Pak Inc
Gasport NY 14067 (716) 772-2651 TELEX 64-6865

Agri-Tech Inc
P O Box 448 100 Lakeview Drive Woodstock, Virginia 22664 (703) 459-2142
FAX (703) 459-4731

Aladdin Industries Inc
Nashville Tennessee 37210

Alternative Energy Engineering
P O Box 339 Redway CA 95560

American Machinery Corp
2730 Eunice Ave P O Box 3228 Orlando FL 32802 (407) 295-2581

American Ripener Co Inc
803 Pressley Road Suite 106 Charlotte North Carolina 28217 (704) 527-8813
FAX (704) 527-6705

Bradbury Barrel Co
P O Box A 100 Main Street Bridgewater Maine 04735 (207) 429-8141 or (800) 332-6021

Brogdex Company
1441 West Second Street Pomona California 91766 (909) 622-1021 FAX (909) 629-4564

Buckhorn
55 West Technocenter Drive Milford Ohio 45150 (513) 831-4402 FAX (513) 831-5474

Burpee
W Altee Burpee & Co Warminster PA 18974

California Controlled Atmospheres
39138 Road 56 Dinuba California 93618 (209) 591-8874 FAX (209) 591-8896

Cargo Technology Corp
San Diego California FAX (619) 483 0088 sales@cargotech com

Carrier Transicold
P O Box 4805 Carrier Parkway Syracuse New York 13221 (315) 432 6397
FAX (315) 432 3226

Catalytic Generators Inc
1185 Pineridge Road Norfolk, Virginia 23451 (804) 855 0191 FAX (804) 855-4155

Chinook Packing Equipment
P O Box 15554 Boise Idaho 83715 (208) 384-5418 FAX (208) 855-4155

Clarkesville Machine Works Inc
P O Box 378 Clarkesville Arkansas 72830 (501) 754 7161 FAX (501) 754 8602

CMF Corp
1524 West 15th Street Long Beach California 90813 (310) 437-2166

The Cook's Garden
P O Box 65054 Londonderry Vermont 05148

Cool Care Consulting Inc
2300 Glades Avenue Suite 100 East Tower Boca Raton Florida 33431
(407) 392-2241 FAX (407) 392-2839

Countryside General Store
Highway 19 East S U Waterloo Wisconsin 53594

Dade Service Corporation
P O Box 11137 Daytona Beach Florida 32120 (904) 274 5655 FAX (904) 274 5664

DeltaTRAK Inc
P O Box 398 Pleasanton California 94566 (510) 426-3011 FAX (510) 846-1147

Dickson
930 South Westwood Avenue Addison Illinois 60101-4917 www dicksonweb com

Duluth Trading Co
5200 Quincy Street St Paul Minnesota 55112-1426 (800) 505-8888 www duluthtrading com

Durand-Wayland Inc
P O Box 1404 LaGrange Georgia 30241 (706) 882-8161 FAX (706) 882-8161

Dver Fruit Box Manufacturing Co
130 Parkview Drive P O Box 245 Dyer Tennessee 38330 (901) 692-2241

Elberta Crate and Box Co
P O Box 795 Bainbridge Georgia 31717 (912) 246-2266

Ethylene Control Inc
P O Box 571 Selma, California 93662 (209) 896-1909 FAX (209) 896-3232

Farber Bag & Supply Co
8733 Kapp Dr P O Box 78 Poesta IA 52068-0078 (800) 553-9068 FAX (319) 583-2701

Fisher
Phone (800) 766 7000 or FAX (800) 926 1166

Franklin Crates Inc
P O Box 275 Micanopy Florida 32667 (904) 466-3141

Friend Manufacturing Corp
P O Box 385 Prospect Street Gasport New York 14067 (716) 772-2622 FAX (716) 772-2370

Frontier Technology Inc
609 N Eastern Ave Allegan MI 49010 (616) 673-9464 FAX (616) 673-9629

Garden Way Country Kitchen
48 Maple Street P O Box 944 Burlington Vermont 05401

Gardener's Supply Co
128 Intervale Road, Burlington Vermont 05401

General Bottle Supply Co Inc
1930 East 51st Street P O Box 58734 Los Angeles California 90058 (213) 581-2001

Glacier Valley Enterprises
S 2907 County Hwy A Baraboo WI 53913-9744 (608) 356-6670 (800) 236-6670

Goodnature Products Inc
P O Box 866 Buffalo New York 14240 (716) 855-3325 FAX (716) 855-3328

Growers Container Cooperative Inc
P O Box 491355 Leesburg, Florida 34748 (904) 787-3579

Gurney's Seed and Nursery Co
110 Capital Street Yankton South Dakota 57079

HACH Company
P O Box 608 Loveland Colorado 80539 (800) 227 4224 or FAX (970) 669 2932

Henry Field's Seed and Nursery Co
Shenandoah Iowa 51602

Hydro-Gardens Inc
P O Box 25845 Colorado Springs Colorado 80936 (719) 495-2266/ (800) 634-6362
FAX (719) 531-0506

IFC
1011 Walnut Ave Pomona California 91766-6528 (909) 517 1080 FAX (800) 551 0277
Independence Box Co
935 N Main Street Independence Oregon 97351 (503) 838-3763

Industrial Ventilation Inc
960 Broadway Suite 460 Boise Idaho 83706 (208) 344-3531 FAX (208) 344-3540

Inland Container
Park Fletcher Station Box 41264 Indianapolis Indiana 46241 (317) 248-8086

Intermediate Technology Publications
9 King Street London WC2E 8HW UK Tel 0602-784-505

International Ripening Corporation
1185 Pineridge Road Norfolk Va 23502 Phone (800) 472 7205

Jade Mountain Inc
P O Box 4616 Boulder Colorado 80306 (800) 442-1972 (303) 449-6601

JAMarketing
942 Virginia Lane Elmhurst Illinois 60126 (708) 279-5806

Johnny s Selected Seeds
299 Foss Hill Road Albion Maine 04910

A M Leonard Inc
241 Fox Drive P O Box 816 Piqua Ohio 45356 (800) 543 8955 www amleo com

Lifelines Technology Inc
116 American Road Morris Plains NJ 07950 (201) 984 6000 FAX (201) 984 1520

Market Farm Implement
RD # 2 Box 206 Friedens Pennsylvania 15541 (814) 443-1931 FAX (814) 445-2238

McCormick Fruit Tech
615B South 48th Ave Yakima WA 98908 Phone (509) 966 3999 FAX (509) 966 7635

Mellinger's Inc
2310 W South Range Road North Lima Ohio 44452

Michigan Orchard Supply
07078 73 1/2 Street Southhaven Michigan 49090 (616) 637-1111/ (800) 637-6426
FAX (616) 637-7419

Mid-State Manufacturing
P O Box 807 Ripon California 95366 (209) 599-4181 FAX (209) 599-4863

Monitor Company
(209) 537 3200 FAX (209) 537 3242 or (800) 537 3201

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Thomas E Moore Inc
P O Box 794 Dover Delaware 19903 (302) 653-2000 FAX (302) 653-3476

Natural Gardening Company
217 San Anselmo Ave San Anselmo California 94960

Northern
P O Box 1499 Burnsville Minnesota 55337 (800) 533 5545 FAX (612) 894 0083
www northern-online com

Northwest International Equipment Co Inc
P O Box 10932 Yakima Washington 98909 (509) 575-1950 FAX (509) 452-3307

NSW Corp
530 Gregory Avenue Roanoke Virginia 24016 (703) 981-0362 FAX (703) 345-8421

Orchard Equipment and Supply Co
P O Box 540 Route 116 Conway Massachussetts 01341
(413) 369-4335 or (800) 634-5557 FAX (413) 369-4431

Pacific States Box and Basket
1295 S Los Angeles Street Glendale California 91209 (818) 244-8688

Peaceful Valley Farm Supply
P O Box 2209 Grass Valley California 95945

Pinetree Garden Seeds
Box 300 New Gloucester Maine 04260

Plants of the Southwest
Route 6 Box 11A, Agua Fria, Santa Fe New Mexico 87501

Polybags Plus
P O Box 3043 Port Charlotte Florida zip?

Post-Harvest Technologies Inc
P O Box 1936 Salinas CA 93902 Phone (800) 845 3092 FAX (408) 758 4570

Precision Generators Company Inc
200 Goldenoak Court Virginia Beach Virginia 23452 (757) 498 4809

Pressure Cool Co
P O Drawer Y Indio California 92202 FAX (760) 342 7578

Ramsay Welding and Machine Inc
478 Brunken Salinas California 93901 (408) 422-6429 FAX (408) 422-9254

Real Goods
555 Leslie Street Ukiah California 95482-5576 (800) 762-7325 Foreign Orders (707) 468-9214

Reflectix Inc
P O Box 108 Markleville Indiana 46056 (800) 879-3645

285

Roadway Express
1077 Gorge Blvd P O Box 471 Akron Ohio 44309 (800) 257 2837 http //www roadway com
Rockford Package Supply Inc
10421 Northland Drive Rockford Mississippi 49341 (800) 444-7225 FAX (616) 866-4921

Robic Refrigeration Inc
1105 North Broadway P O Box 109 Turlock, California 95381 (209) 632-8851
FAX (209) 632-5303

N H Savage Equipment Inc
400 Industrial Road Madill Oklahoma 73446 (405) 795-3394 FAX (405) 795-2448

Sealand Service Inc
6000 Carnegie Blvd Charlotte North Carolina 28209

Seal-o-Matic Co
900 Passaic Avenue East Newark New Jersey 07029 (201) 481-6500 FAX (201) 485-7818

Semco Manufacturing Company
P O Box H 705 E Bus Hwy 83 Pharr Texas 78577 (512) 787 4203 FAX (512) 781-0620

Sensitech Inc
123 Brimbal Ave Beverly Massachussetts 01915 (978) 927 7033 FAX (978) 921 2112
info@sensitech com

Rod Smith Canvas Co
2514 Easy Street Wenatchee Washington 98801 (509) 663-1967 FAX (509) 662-1780

Sorting Technology Inc
P O Box 479 American Falls Idaho 83211 (208) 226-2727 FAX (208) 226-2750

Stokes Ladders Inc
4545 Renfro Drive P O Box 445 Kelseyville California 95451 (707) 279 4306/ (800) 842-7775
FAX (707) 279-2232

Territorial Seed Company
P O Box 157 Cottage Grove Oregon 97424-0061

TEW Manufacturing Corp
P O Box 87 Penfield NY 14526 (716) 586-6120

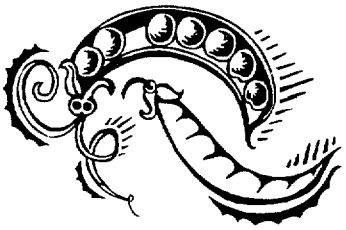
Texas Basket Co
100 Myrtle Drive P O Box 1110 Jacksonville Texas 75766 (903) 586-8014 or (800) 657-2200
FAX (903) 586-0988

ThermaGard Inc
6312 Shortcut Road Moss Point Mississippi 39563 (601) 474-2314

TUBAMET AG
P B 879 FL-9490 Vaduz Europe (41)75-232-81-41 FAX (41) 75-232-66-41

Zellerbach
4603 East Vine Street Fresno California 93725 (209) 233-7201

APPENDIX E



SUPPLIERS of POSTHARVEST TECHNOLOGIES in INDIA

Chapter 2

Bird/pest control

Intensive Pest Control Services
Arch Arun C Vakil's Bldg 2nd Fl Opp Lal Court, Rajmahal Rd ,
390001 Baroda, India
Phone +91-265-66239,554693

Pest Control (I) Ltd
23,Mirza Ghalib St , 700016 Calcutta, India
Phone +91-33-2451184
Fax +91-33-2444652

Pest Control M Walshe
3, Clover Bldg , 3rd Fl , 240/2,Thambu Chetty St , 600001 Chennai,
India
Phone +91-44-5228578,5229008
Fax +91-44-5228578

Reliance Pest Control
83,2nd Sector,9th St ,K K Ngr 600078 Chennai, India
Phone +91-44-4831346

Esk Pest Control
6-3-609/93 Anand Ngr Cly, Nr Comm , Hall, Khairatabad, 500004
Hyderabad India
Phone +91-40-315016

Pest Control M Walshe
503,Embassy Centre, Nariman Point, 400021 Mumbai, India
Phone +91-22-2850615,2850277
Fax +91-22-2040634

Cloches greenhouse film and clips for plastic tunnels

M H Polymers
3rd Fl Navdeep House Nr Income Tax Char Rasta Ashram Rd , 380014
Ahmedabad India
Phone +91-79 6568870 6561744
Fax +91-79-6425439

B & V Agro Irrigation Co
410, AGH Chmbrs , 379/81,Narshi Natha St ,Masjid, Bunder, 400009
Mumbai, India
Phone +91-22-3436575,3449568

Theta Polymers Pvt Ltd
109, Arenja Corner Sector 17 Vashi 400705 Mumbai India
Phone +91-22-7631490 7631121
Fax +91-22-7631121

Floating Row Corners

Not available

Irrigation Supplies (Drip & soaker systems)

Premier Irrigation Equipment Ltd
Niharika, 17/1C, Alipore Rd 700027 Calcutta India
Phone +91-33-4797455 4795155
Fax +91-33-4797626

Pasumai Irrigations Ltd
1,Avenue Rd ,Nungambakkam 600034 Chennai India
Phone +91-44-8255404
Fax +91-44-8240288

Harvel Irrigations Pvt Ltd
301-304, Meghdoot, 94,Nehru Place, 110019 New Delhi India
Phone +91-11-6413370 6485365
Fax +91-11-6464819

Mulch, Paper and Plastic

Not available

Pruners, Hand Tools

Shri Ganga Rolling Mills
B-6,Udyog Ngr ,Naini 211010 Allahabad India
Phone +91-532-7279

Vasco Trading Co
Vasco House M G Rd 390001 Baroda India
Phone +91-265-555245

Pettal Floral Studio The
S C O 816 Sector 22-A 160022 Chandigarh India
Phone +91-172-701908
Fax +91-172-530513

Shade Cloth

Not available

Trellises, Bean Towers

Not available

Wall-O-Water Hot Caps

Not available

Chapter 3

Sizers Sizing Rings

Endeavour Instrument Pvt Ltd
307 Anand Chmbrs Nr High Court 380009
Ahmedabad India
Phone +91-79-6440606 6440607
Fax +91-79-6421221

Weldeal Corp
407 World Trade Centre P O Box 2534 Sayaji Ganj
390005 Baroda
india
Phone +91-265-3427172 3429390
Fax +91-265-338790

Arkay Engineering Enterprises
319,Mount Rd Nandanam, 600035 Chennai, India
Phone +91-44-452248,4335443
Fax +91-44-4338166

Atco Marketing Pvt Ltd
104 Creative Indl Est ,72, N M Joshi Marg, 400011
Mumbai India
Phone +91-22-896472

Essae-Teraoka Pvt Ltd
914 Raheja Center, Plot No 2142 Backbay
Reclamation Nariman Point,
400021 Mumbai, India
Phone +91-22-225223

India Optics & Scientific Works
4270-71, Hosp Rd , 133001 Ambala Cantt India
Phone +91-171-20137,20382
Fax +91-171-642439

Refractometers

Omega Instruments (I) Pvt Ltd
4 Ripon St 700016 Calcutta India
Phone +91-33-295019 299839

Elico Ltd [Image]
B 17 Indl Est Sanatnagar, 500018 Hyderabad India
Phone +91-40-3770134,3771262
Fax +91-40-3771639, 3350840

Unitech Engg Co
A-6 Royal Indl Est Naigaum Cross Rd Wadala
400031 Mumbai India
Phone +91-22-4142204

Unikon Scientific Co
170-A-B Housing Board Cly 133001 Ambala Cantt ,
India
Phone +91-171-642053

National Scientific Equipment Co The
4 Chandney Chowk St 700072 Calcutta India
Phone +91-33 274634

Decibel Instruments
182/45 Phase-I Indl Area 160002 Chandigarh India
Phone +91-172 650130
Fax +91-172 562128

Penetrometers

Not available

pH Meters

PH Products Co
313 Model House, 6-3 456/A/1 Punjagutta 500082
Hyderabad, India
Phone +91-40-3323265,274897
Fax +91-40-3319840

Scientific Instrument Services
2, Comm Centre, Indl Area, Phase I Naraina, 110028
New Delhi India
Phone +91-11 535720 5193663
Fax +91-11-535720

D S Engineering Works
142-B,Co-op Indl Est 208022 Kanpur India
Phone +91-512-296006

Engent Graphics Pvt Ltd [Image]

F-34/42,Nand-Dham Indl Est Marol Maroshi Rd ,
Marol Andheri (E)
400059 Mumbai, India
Phone +91-22-8503653 8502838
Fax +91-22-8508874

Engineering Enterprise
F-34/42 Nand-Dham Indl Est Marol Maroshi Rd
Marol, Andheri (E)
400059 Mumbai India
Phone +91-22-8503653 8502838
Fax +91-22-8508874

Adept Recording Instruments Pvt Ltd
Plot No-4 S No 17/1 B Kothrud Indl Est Kothrud

411029 Pune India
Phone +91-212-331474 341124
Fax +91-212-340480

Color Charts

Not available

Granny Smith Apple Starch Scale

Not available

Temperature Probes

Fykays Engineering Pvt Ltd
10/11 Subhash Rd ,Jogeshwari (E), 400060 Mumbai, India
Phone +91-22-8378678 8378679
Fax +91-22-8378754

Olympus Controls Pvt Ltd
64F/1 Linton St 700014 Calcutta, India
Phone +91-33-2449973 2451611
Fax +91-33-2491062

Pressure & Temperature Control Instruments Co
1/B Topsia Rd 700039 Calcutta, India
Phone +91-33-3434533,3432036
Fax +91-33-3434533

Tempsens Instruments (India) Pvt Ltd
B-188 Mewar Indl Area,Rd No 5,Madri, 313001 Udaipur, India
Phone +91-294-28635
Fax +91-294-526649

Calipers

Black Jack India Pvt Ltd
C-7 Focal Point 144004 Jalandhar, India
Phone +91-181-293890,290889
Fax +91 181-290562

Perfectools
Heena Smruti North South Rd No 2 Juhu Vile Parle Scheme Vile Parle
(W) 400056 Mumbai, India
Phone +91-22 6143139

Yamani Tools & Hardware Corp
247,Nagdevi St , 400003 Mumbai India
Phone +91-22 3400587 3420138
Fax +91-22-3411907

Pressure Testers

Instrument Research Associates Pvt Ltd
19 Gopalapuram 560023 Bangalore India
Phone +91-80-3300382,3380996
Fax +91-80 3301969

A N Instruments Pvt Ltd
59-B, 5th Fl Chowringhee Rd , 700020 Calcutta India
Phone +91-33-2472509 2402222
Fax +91-33-4752246

Olympus Controls Pvt Ltd
64F/1,Linton St , 700014 Calcutta, India
Phone +91-33-2449973,2451611
Fax +91-33-2491062

Manometer (I) Pvt Ltd
Manu Mansion, 1st Fl , 16,Shahid Bhagat Singh Rd , 400023 Mumbai
India
Phone +91-22 2662076,2662942
Fax +91-22-2662397

Chlorine Meters

Materials Research Instruments
63, Mittal Court B-Wing, Nariman Point, 400021 Mumbai India
Phone +91-22-2830298,2852734
Fax +91-22-2852301

Cambridge Hightech Sensors (I) Pvt Ltd
39, Shubhanand Apts, NIT Layout 440022 Nagpur
India
Phone +91-712-23781

Titrators

Not available

Baskets/Buckets/Crates/Barrels

Jyoti Udyog (India)
125/6 Mittal Indl Est Andheri Kurla Rd Andheri, (E) 400059 Mumbai
India
Phone +91 22 8504500 8502536

Tushar Industries
412 Bussa Udyog Bhavan T J Rd Sewree (W) 400015 Mumbai India
Phone +91-22-4133523 4133845

Ruby Products
Ashok Ngr C Ashok Rd Kandivli (E) 400101 Mumbai India
Phone +91-22-8871791

Fax +91-22-8878828

Natco Polyplast Ltd
405 Kalyan Chmbrs Khadia Char Rasta Khadia
380001 Ahmedabad, India
Phone +91-79-387590 337151
Fax +91-79-2123441

Reliance Plastics
11-A Unique Indl Est Dr R P Rd Mulund (W)
400080 Mumbai India
Phone +91-22 5618131 5619994

Silver Plastochem Pvt Ltd
C-101 Hind Saurashtra Indl Est Marol Naka
Andheri (E) 400059
Mumbai India
Phone +91-22-8509056 8509057
Fax +91-22-8505797

Buckets/Bucket Straps

Not available

Bucket Liners/Bucket Skirts

Not available

Fruit Pickers (Long poles with basket)

Abhishek International
Opp K M V College Tanda Rd 144004 Jalandhar, India
Phone +91-181-295477
Fax +91-181-295477

Shivgrico Implements Ltd
A-404/405 Adinath Apts, 281,Tardeo Rd 400007
Mumbai, India
Phone +91-22-3893022,3893023
Fax +91-22-3882678

Jaikvin Enterprises
504, Matru Chaya Bldg ,378/80 Narsi Natha St
400009 Mumbai India
Phone +91-22-3441968,3415648
Fax +91-22-3401715

Unique Impex Pvt Ltd
Kennedy House 4 Harishchandra Goregaonkar
Rd Kennedy Bridge 400007
Mumbai India
Phone +91-22-6211912 3676090
Fax +91-22-6211912

Gloves

Jiwanram Sheoduttrai
3rd Fl , Chowringhee Rd Jawarlal Nehru Rd 700016
Calcutta, India
Phone +91-33 2496507 299586
Fax +91-33 2499511

Ordinance Factory Board
10A Ayudh Bhawan Aukland Rd 700001 Calcutta
India
Phone +91-33-2481748,2489027
Fax +91 33-2482927

Archit Safety Product
Shop No 12 Bhagyoday Cmplx Nr Krishna Cinema
390001 Baroda India
Phone +91-265-453102

Jyoti Traders
4127 Gali Sitara Ajmeri Gate 110006 Delhi India
Phone +91 11-522637

Harnesses

Standard Leather Pvt Ltd
129/A, South Tangra Rd 700046 Calcutta India
Phone +91-33-2448583

Super House Group
150 Feet Rd , Jajmau, 208010 Kanpur, India
Phone +91-512-350391 350398
Fax +91-512-350814

Harvesting Aids for Field Packing

Navinchandra & Co
179, Navin Hse ,Thambu Chetty St , 600001 Chennai
India
Phone +91-44-5228675 5228676
Fax +91-44-5229450

Guru Nanak Agriculture Impliments Mfrs
Bye Pass, Nr Focal Point, G T Rd , 144004 Jalandhar,
India
Phone +91-181-294670 292302

Pacific Innovative Technology Instruments Pvt Ltd
2099, 1st Fl , 105, Sevak Chmbrs -I Naiwala Karol
Bagh 110005 New Delhi India
Phone +91-11-5737722 5750926
Fax +91-11-5750926

Harvesting Equipment/Potatoes

Navinchandra & Co
179 Navin Hse Thambu Chetty St 600001 Chennai
India

Phone +91-44-5228675,5228676
Fax +91-44-5229450

Indopol Food Processing Machinery Pvt Ltd
Indl Plot No 28 Sect 27-C 121003 Faridabad, India
Phone +91 129-2676162 2675823

Guru Nanak Agriculture Impliments Mfrs
Bye Pass Nr Focal Point G T Rd 144004 Jalandhar
India
Phone +91-181-294670,292302

Harvesting Tools

Navinchandra & Co
179 Navin Hse Thambu Chetty St , 600001 Chennai
India
Phone +91-44-5228675,5228676
Fax +91-44-5229450

Indopol Food Processing Machinery Pvt Ltd
Indl Plot No 28 Sect 27-C, 121003 Faridabad India
Phone +91-129-2676162,2675823

Guru Nanak Agriculture Impliments Mfrs
Bye Pass,Nr Focal Point G T Rd , 144004 Jalandhar
India
Phone +91-181-294670 292302

Pacific Innovative Technology Instruments Pvt Ltd
2099 1st Fl , 105 Sevak Chmbrs -I Naiwala Karol
Bagh 110005 New
Delhi India
Phone +91-11-5737722,5750926
Fax +91-11-5750926

Ladders

Vasco Trading Co
Vasco House M G Rd 390001 Baroda, India
Phone +91-265-555245

Nut Harvesters, Shakers

Damil Engineers Pvt Ltd
N H No 8 Nr Kashiram Textiles Post Narol Narol
382405 Ahmedabad
India
Phone +91-79-6746361

Nahar Motors
63 Shastri Mkt 452001 Indore, India
Phone +91-731-431995 544238
Fax +91-731-531730

Picking Containers

Navlakha Agro Equipments
38,Shankar Sheth Rd , 411037 Pune India
Phone +91-212-541235 545788
Fax +91-212-425877

Jyoti Udyog (India)
125/6 Mittal Indl Est , Andheri Kurla Rd Andheri
(E), 400059 Mumbai
India
Phone +91-22-8504500,8502536

Ruby Products
Ashok Ngr ,C Ashok Rd , Kandivli (E), 400101
Mumbai, India
Phone +91 22-8871791
Fax +91-22-8878828

Natco Polyplast Ltd
405, Kalyan Chmbrs, Khadia Char Rasta, Khadia,
380001 Ahmedabad, India
Phone +91-79-387590 337151
Fax +91-79-2123441

Potato Separator/Cleaner

Darshan Singh & Co
P O Box 30 G T Rd 144409 Jalandhar India
Phone +91-1827-2253 2692

Guru Nanak Agriculture Impliments Mfrs
Bye Pass,Nr Focal Point G T Rd , 144004 Jalandhar,
India
Phone +91-181-294670 292302

Reusable Plastic Containers

Cooper Plastics Pvt Ltd
23-A 2nd Fl R No-10 N S Rd , 700001 Calcutta
India
Phone +91-33-2205901 492928
Fax +91-33-492928

Jolly Containers
3 Sona Udyog Bhavan Andheri (E) 400069 Mumbai
India
Phone +91-22-8323253

Miltech Industries Pvt Ltd
F-27/1 MIDC Indl Area Hingna 440016 Nagpur
India
Phone +91-7104-37210 37451
Fax +91 7104-37573

Safety Supplies

Not available

U-Pick Containers

Not available

Chapter 4

Brusher/Washer

Guru Nanak Agriculture Impliments Mfrs
Bye Pass Nr Focal Point G T Rd 144004 Jalandhar India
Phone +91-181-294670 292302

Sonalika Agriculture Industries
704 Nirmal Tower 26,Barakhamba Rd 110001 New Delhi India
Phone +91-11-3318911 3739539
Fax +91-11-3714768

Navlakha Agro Equipments
38,Shankar Sheth Rd 411037 Pune India
Phone +91-212-541235 545788
Fax +91-212-425877

S R Trading Co
7,Hazari Mull Shah Rd ,Salkia, 711106 Howrah India
Phone +91-33-6657890,6657891
Fax +91-33-2206274

Chlorination System

Kay Mohan Corp
88/473,Dalel Purwa, 208001 Kanpur, India
Phone +91-512-316238,357024
Fax +91-512-318528

Chloro Control Equipment Co
13/M-E Laxmi Indl Est ,New Link Rd , Andheri (W), 400053 Mumbai India
Phone +91-22-6266891,6260066
Fax +91-22-6268185

Cleaners

Osaw Agro Industries
P O Box 5 Jagadhri Rd 133001 Ambala Cantt India
Phone +91-171-643147,643167
Fax +91-171-641018

Sampac Enterprises
23/2, Pan Asia,Tiffany's Annexe, Vittal Mallya Rd 560001 Bangalore
India
Phone +91-80-2275308
Fax +91-80-2275604

S R Trading Co
7,Hazari Mull Shah Rd Salkia, 711106 Howrah India
Phone +91-33-6657890,6657891
Fax +91-33-2206274

Conveyors

VKR Engineers
51 Nagoji Rao St Triplicane 600005 Chennai India
Phone +91-44-832683 8551004
Fax +91-44-8547092

Grace Enterprise
A 1 Patel Est Pratapnagar Rd 390004 Baroda India
Phone +91-265-541842

Planeta Engineering Co
2A Baldota Bhavan, 117 Queen's Rd Churchgate 400020 Mumbai India
Phone +91-22-293777

Dumpers Bin

Abco Plastics
24/B Nelson Manickam Rd Aminjikarai 600029 Chennai, India
Phone +91-44-4838810,4838473
Fax +91-44-4838810

Domacles Engineering Pvt Ltd
214 1 Cross Phase-III Peenya 560058 Bangalore, India
Phone +91-80-8392645
Fax +91-80-8392645

Vescon Industries
Plot No 480 (B), Indl Area, Phase-IV Peenya 560058 Bangalore, India
Phone +91-80-8391055
Fax +91-80-8395082

Planeta Engineering Co
2A, Baldota Bhavan 117 Queen's Rd Churchgate 400020 Mumbai India
Phone +91-22-293777

Fruit and Vegetable Waxes

International Pharma & Industrial Wax Industries
AF-32,New Empire Indl Est Kondivita Rd Andheri (E), 400059 Mumbai,
India
Phone +91-22-8326825

Planets The
7/8 Ratna Deep Amboli Caeser Rd Andheri (W)
400058 Mumbai India
Phone +91-22-6234942 6288408
Fax +91-22-6267298

Moerls India Pvt Ltd
M-279 Part II Greater Kailash, 110048 New Delhi
India
Phone +91-11-6415056
Fax +91-11-6474978

Inspection Roller Tables

Petro General Engineering Works
43 Indl Est 490006 Bhilai, India
Phone +91-788-3826988,3826989

Modern India Enterprises
61/1,Sree Aurobindo Rd , Salkia, 711106 Howrah,
India
Phone +91-33-6659322

Annapurna Engineering Pvt Ltd
B-18,Indl Est , 769004 Rourkela India
Phone +91-661-7462

Lifting/Handling Equipment
Folding Mini-Dolly
Fork Lift Attachment for Tractor

Bharat Mechanical Hoists & Co
206, Ajmeri Gate 110006 Delhi, India
Phone +91-11-3239198 3232726

Asian Cables & Industries Ltd
Ceat Mahal, 463 Dr Annie Besant Rd Worli, 400025
Mumbai India
Phone +91-22-4937244
Fax +91-22-4930206

Elektromag Methods
Blk No 7 3rd Fl 402, Prabhadevi Indl Est Veer
Savarkar
Marg Prabhadevi Indl Est 400025 Mumbai India
Phone +91-22-4226953 4302558

Prakash Industrial Agencies
Off Lohar Chawl 52/58 Babu Genu Rd 400002
Mumbai India
Phone +91-22-2016107 4953267

Speed-N-Telecontrols (India) Ltd
107 Mamta House S V Rd Bandra (W), 400050
Mumbai India
Phone +91-22-4130220 6441180
Fax +91-22-6400359

Pallet Jack

Not available

Packing Lines

Cosmo International
W-115-A, 3rd Avenue, Anna Ngr, 600040 Chennai,
India
Phone +91-44-6214555,6285880
Fax +91-44-6268666

K U Sodalamuthu & Co Pvt Ltd [Image]
428,Mettupalayam Rd , 641043 Coimbatore, India
Phone +91-422-441223 441805, 438346
Fax +91-422-431279,855-8514 kus in

Modi Traders
829,Mettupaiayam Rd , 641002 Coimbatore, India
Phone +91-422-4136192 471029
Fax +91-422-445403

Indian Packaging Machineries
I-15,DLF Indl Area Phase-I, 121001 Faridabad India
Phone +91-129-276112 278737
Fax +91-129-274518

Globe Packers
4, Shree Sita Ram Mills Compound Tantia Indl N M
Joshi, Lower Parel,
400011 Mumbai India
Phone +91-22-3099798 3085452
Fax +91-22-3085452

Rotary Tables

Lokesh Machines Ltd
B-29 EEIE Stage 2 Balanagar 500037 Hyderabad
India
Phone +91-40-278450 278543
Fax +91-40-278274

J P Machine Tools
Dholewal Chowk G T Rd Miller Ganj 141003
Ludhiana India
Phone +91-161-531156

Ishwarkrupa Moulding Works
Behind P T C Near Dealait Siremic Aji Vasahat
360003 Rajkot India
Phone +91-281-82913

Scales

I P A Pvt Ltd [Image]
472/B2 Peenya Indl Area Phase-IV 12th Cross
560058 Bangalore India
Phone +91-80-8395851,8395853
Fax +91-80-8396820

Promises Marketing
107/1, 2nd Fl Park St , 700016 Calcutta India
Phone +91-33-297841 2016280
Fax +91-33-408067

Tamil Nadu Scale Industries
166 Broadway 600108 Chennai India
Phone +91-44-517096 5223259

Avery India Ltd
1 Ansari Rd , Darya Ganj 110002 Delhi India
Phone +91-11-3277958

Water Dump

PH Products Co
313 Model House, 6-3-456/A/1 Punjagutta 500082
Hyderabad India
Phone +91-40-3323265,274897
Fax +91-40-3319840

Materials Research Instruments
63, Mittal Court, B-Wing, Nariman Point, 400021
Mumbai, India
Phone +91-22-2830298,2852734
Fax +91-22-2852301

Netel Chromatographs
Liberty Bldg ,Sir V Thackersey Marg 400020
Mumbai India
Phone +91-22-5343361 5343279
Fax +91-22-5346433

Water Quality Analyses Equipment

Not available

Chapter 5

MAP Film or Resin Manufacturers

Puneet Polypack Pvt Ltd
25, Nawal Kishore Rd , 226001 Lucknow, India
Phone +91-522-245258

United Plastics Corp
162, Gala No 3 Janta Indl Est Compound S B Marg (South) Lower
Parel 400013 Mumbai India
Phone +91-22-4926261
Fax +91-22-4924367

Vinyoflex Ltd
Silver Chmbrs 307 Tagore Rd 360002 Rajkot India
Phone +91-281-4131299 4131692
Fax +91-281-449548

Bagging Equipment

Buch Plastics & Packaging Pvt Ltd
25 Bijal Park Soc Nr Arihant Ngr Memnagar
380052 Ahmedabad India
Phone +91-79 7475407

Vivega Engineers
143 C Nava India Rd Peelamedu 641004
Coimbatore India
Phone +91-422-571698

Modern Plastic Packing Products
123/377 Fazalganj, 208012 Kanpur India
Phone +91-512-295446
Fax +91-512-295446

Lyncil Plastics Pvt Ltd
NSE Est P O Box 9015 Goregaon (E), 400063
Mumbai India
Phone +91-22-8735357
Fax +91-22-8733628

Bag Sealers

Vivega Engineers
143-C,Nava India Rd , Peelamedu, 641004
Coimbatore, India
Phone +91-422-571698

Modern Plastic Packing Products
123/377 Fazalganj, 208012 Kanpur India
Phone +91-512-295446
Fax +91-512-295446

Lyncil Plastics Pvt Ltd
NSE Est P O Box 9015,Goregaon (E) 400063
Mumbai India
Phone +91-22-8735357
Fax +91-22-8733628

Uthra Packs
Qureshi Ngr Kurla (E) 400070 Mumbai India
Phone +91-22-5528689

Bags, Paper

Safepack Plastics Pvt Ltd
7th Mile Bannerghatta Rd 560076 Bangalore India

Phone +91-80-643523
Fax +91-80 6637520

T P I India Ltd
102 Atlanta Nariman Point 400021 Mumbai India
Phone +91 22-2873087 2873088
Fax +91-22-2874479

Hindustan Packers
2E, Electronic Centre, 1/14,Biplabi Ankul Chandra St , 700072
Calcutta, India
Phone +91-33-265131 267413

Package India
4-A (NP), Mathiazhakan Ngr , Kubera Ganapathy, St ,Padi 600050 Chennai
India
Phone +91-44-6257260
Fax +91-44-6257260

Bags, Plastic

Manish Packaging Pvt Ltd
2, Navchetan Soc ,Opp Krishimangal Hall, Ring Rd , 395001 Surat, India
Phone +91-261 872319,872325
Fax +91-261-872709

Impulse Enterprise Pvt Ltd
31 Omkar House, Navarangpura 380009 Ahmedabad, India
Phone +91-79-461202,461472
Fax +91-79-6423627

Lakshmans Plastics Pvt Ltd
1st Fl 21/23,Mohatta Mkt Palton Rd Fort, 400001 Mumbai, India
Phone +91-22 2616657 2614992
Fax +91-22-2616875

Bags, Net

Prince Plastic Products
107 61 Jawahar Ngr 208012 Kanpur India
Phone +91-512-540777

Netlon India (Div of Parry & Co Ltd)
201/202 Regent Tower Race Course Circle 390007 Vadodara India
Phone +91-265-326223 313683
Fax +91 265-339352

Quality Packaging
16th Fl 10,Camac St , 700017 Calcutta, India
Phone +91-33-2491802 2148339
Fax +91-33-2424998

Modern Plastic Packing Products
123/377 Fazalganj 208012 Kanpur India
Phone +91-512-295446
Fax +91-512 295446

Boxes - Berry Boxes

Kaveri Wood & Card Containers
287,Indl Area, Phase-IV,Peenya, 560058 Bangalore India
Phone +91-80-8396209 3372498

Hind Process Pvt Ltd
63,Triplicane High Rd 600005 Chennai, India
Phone +91-44-8546082

Pack Woods
224,M T H Rd ,Padi, 600050 Chennai, India
Phone +91-44-6963160 6963193

Nasik Wood Packers Pvt Ltd
F-52 MIDC,Ambad, 422010 Nasik, India
Phone +91-253-22128

P A Mane & Co
231/C Lalbaug Dr S S Rao Rd , Tandepal Lane Parel 400012 Mumbai
India
Phone +91-22-4132466

United Box Manufacturing Co Pvt Ltd
86,MIDC Satpur, 422007 Nasik, India
Phone +91-253-350782

Bharati Box Mfg Co
T-56 MIDC Bhosari, 411026 Pune, India
Phone +91-212-792830 792831
Fax +91-212-792832

Box Pack Paper Co
J-440 M I D C Bhosari 411026 Pune India
Phone +91-212-792151,792279
Fax +91-212-792636

Brocolli Buncher

Not available

Ethylene Absorber Sachets

Not available

Fruit Protector Trays

Krishna Dye-Chem
Opp Baranpura Petrol Pump, Behind Wadishak Mkt ,Pratap Ngr Rd.,
390004 Baroda India
Phone +91-265-540496

Jolly Containers
3, Sona Udyog Bhavan Andheri (E), 400069 Mumbai India
Phone +91-22-8323253

Miltech Industries Pvt Ltd
F-27/1 MIDC Indl Area, Hingna 440016 Nagpur India
Phone +91-7104-37210 37451
Fax +91-7104-37573

Wonderpack Industries Pvt Ltd
Plot No 25/2/2 MIDC Satpur 422007 Nasik India
Phone +91-253-351080
Fax +91-253-350949

Insulated Pallet Covers

Sudarsan Equipments Pvt Ltd
C-35 Indl Est ,Guindy, 600032 Chennai India
Phone +91-44-2341968,2335366
Fax +91-44-2349011

Y S Patrawala & Co
162-A,Mumbadevi Rd , 400002 Mumbai India
Phone +91-22-3437094,3446011

Kaveri Wood & Card Containers
287 Indl Area, Phase-IV,Peenya 560058 Bangalore, India
Phone +91-80-8396209,3372498

Shree Sakthi Agencies
58,Josier St Nungambakkam, 600034 Chennai, India
Phone +91-44-8274819,8276921

Pads/Foam Paper

Shreenath Packaging Industries
C-1 285 Phase-I G I D C Est Naroda, 382330 Ahmedabad India
Phone +91-79-811293 817402

Kaypee Paper Industries Pvt Ltd
3rd Fl 8/1 Lalbazar St , 700001 Calcutta India
Phone +91-33-2204727
Fax +91-33 2430244

Super Packaging Industries
39/3128,Ravipuram 682016 Cochin India
Phone +91-484-354402

Fag Fog Fizzer Foam Pvt Ltd
Vill Desu Majra,P O Kharar Distt Ropar 140001 Mohali India
Phone +91-172-5259

Diana Foams Pvt Ltd
Indl Est , 757043 Rairangpur, India
Phone +91-6794-2471 2472
Fax +91-6794-2474

Polyethylene Pallet Covers

Sudarsan Equipments Pvt Ltd
C-35 Indl Est Guindy 600032 Chennai India
Phone +91-44-2341968 2335366
Fax +91-44-2349011

Y S Patrawala & Co
162-A Mumbadevi Rd , 400002 Mumbai, India
Phone +91-22-3437094,3446011

Shree Sakthi Agencies
58,Josier St , Nungambakkam, 600034 Chennai India
Phone +91-44-8274819,8276921

Shrink Wrap Equipment

C D Corp
Somaiya House,Nr Anjani Kumar Indl Est , Sonapur Rd Bhandup (W),
400078 Mumbai, India
Phone +91-22-5614630,5134682
Fax +91-22-5649586

Pac Wel Equipments
233, Gobind Udyog Bhavan Bal Rajeshwar Rd ,Mulund, (W), 400080 Mumbai, India
Phone +91-22-5603491,4148083
Fax +91-22-5603491

R R International
Ground Fl , Unit No A/4,Shah & Nahar Indl Est Dr E Moses
Rd Worli Naka 400018 Mumbai India
Phone +91-22-4931615 6268118
Fax +91-22-4931505

Staplers

Bhavna Enterprise
803,Anand Indl Cmplx Nr C Cly Opp Ashok Mill Naroda Rd 380025
Ahmedabad, India

Phone +91-79-375118,375118

Kanin (I) Pvt Ltd
Indl Plot No 79,Sect -25, 121004 Faridabad India
Phone +91-129-233369,233370
Fax +91 129 2311183

Ankit International
Unit No 125, Sanjay Bldg , No 6 Mittal Indl Est Sir M V Rd ,Andheri
(E), 400059 Mumbai, India
Phone +91-22-8502536,8593867
Fax +91-22-8593868

Rays Engineers
Nirmal Rubber Compound,I B Patel Rd ,Goregaon (E), 400063 Mumbai
India
Phone +91-22-8730388
Fax +91-22-8730388

Tapes Tape Dispensers

Aadhunic Enterprises
1st Fl , 3796/104,Chawri Bazar, 110006 Delhi, India
Phone +91-11-2915242,2933166
Fax +91-11-2912128

A 1 Packaging
123 Vyapar Bhavan, 49 P D'Mello Rd , Carnac Bunder 400009 Mumbai, India
Phone +91-22-3762434,3720420
Fax +91-22-3756043

Interlaminates
17 Ravi Indl Est ,Off Mahakali Caves, Rd , Andheri (E) 400093
Mumbai, India
Phone +91-22-8346442 8329926
Fax +91-22-8378981

Sonal Adhesives Ltd
2-NE Laxmi Indl Est New Link Rd Andheri (W) 400053 Mumbai India
Phone +91-22-6264252 6324041
Fax +91-22 6321675

Chapter 6

Air-Exhaust Doors/Louvers

B A Enterprise
South Stn Rd , Agarpara 743177 24 Parganas (N) India
Phone +91-33-5534293

Datta Air System Pvt Ltd
6 Sandeep Indl Est I B Patel Rd Goregaon (E) 400063 Mumbai India
Phone +91 22-8735860
Fax +91-22-8728418

United Air Control
Clipwala Compound,Nr L & T Saki-Vihar Rd Powai 400072 Mumbai India
Phone +91-22-8521126,8521044
Fax +91-22-5791044

Cool-and-Ship (Mobile Cooler) Plans

Not available

Evaporative Cooling Pads

Metro Refrigeration Industries
D-35,Indl Area, Meerut Rd , 201003 Ghaziabad India
Phone +91-575-712176

A S International
16, Comm Hse ,Ropewalk Lane,Fort 400001 Mumbai, India
Phone +91-22-272273

United Sales Corp
Ravi Shashi Soc , Tilak Rd Santacruz (W) 400054 Mumbai, India
Phone +91-22-6491822

M-Sun Systems
5, Sarvadarshan Soc ,Opp Saraswat Bank Karve Rd Nal Stop 411004
Pune, India
Phone +91-212-361109
Fax +91-212-331250

Forced-Air Cooling Pads

Cooling Tower Corp
40-B GIDC Makarpura 390010 Baroda India
Phone +91 265-324015

Air Fridge Industries
10/65 Indl Area Kirti Ngr 110015 New Delhi India
Phone +91 11-531909 6461972
Fax +91-11 5436781

Hydro-Coolers

Super Coolers
Arora Bhawan Opp Parimal Garden Police Chowky Ambawadi Bazar,
380006 Ahmedabad India

Phone +91 79-6442400

Freeze Tech
52 Nehru Ngr Kottivakkam Village 600041 Chennai India
Phone +91-44-4925711

Rajnish A C Products
76-B Indl Area Rachhai 482009 Jabalpur India
Phone +91 761-3676833
Fax +91-761 3631182

Kool Pack
Opp ESI Dispansiry 80 Feet Rd Rambagh 208012 Kanpur India
Phone +91-512 255083

Olympus Refrigeration
P O Box 1006 Yeyyadi Indl Est 575008 Mangalore India
Phone +91-824-412285

Humidifiers

C M Equipments & Instruments (I) Pvt Ltd
B-194,2nd Stage Peenya Indl Est 560058 Bangalore India
Phone +91-80-8393711 8394361
Fax +91-80-8395343

Coimbatore Aerodyne Pvt Ltd
Sf No 553,Avanashi Rd , Neelambur Post 641065 Coimbatore India
Phone +91-422-6204874 88687

Artic Corp
1 Rizvi Palace, Behind Golden Door, Hill Rd Bandra (W) 400050
Mumbai, India
Phone +91-22-6439647,6427589

Mansfield Industries
A-2 Swojas Cmplx , Aundh, 411007 Pune, India
Phone +91-212-443482 323360
Fax +91-212-382540

Ice-Makers (3 to 6 Ton/Day, Portable)

Asian Ice Factory
Opp S R P Head Quarters Near S T Workshop
Sajjpur Bogha 382330
Ahmedabad India
Phone +91-79-2813172 2819115

Deltech Engineering Pvt Ltd
140 3rd Fl Shanti Vihar Cmplx Royalpettah High Rd Mylapore
600004 Chennai, India
Phone +91-44-8543340 8541538
Fax +91 44-4997005

J K Enterprises
A-13,DLF Indl Area, Phase-I, Mathura Rd , 121003 Faridabad India
Phone +91-129-270868

The Ice Machinery Mart
37,Netaji Subash Chandra Marg Daryaganj 110002 New Delhi India
Phone +91-11-3271491 3269551
Fax +91-11 3271491

Ice Storage

Asian Ice Factory
Opp S R P Head Quarters Near S T Workshop
Sajjpur Bogha, 382330
Ahmedabad India
Phone +91-79-2813172 2819115

Dashnesh Ice Factory
Opp S R P Head Quarters Nr S T Workshop, Saijpur Bogha, 382345
Ahmedabad, India
Phone +91-79-2822171

Shree Patel Ice Factory
235 GIDC Est 393002 Ankleshwar India
Phone +91-2646-21939

Neptune Refrigeration Co Pvt Ltd
153,Mount Rd , 600002 Chennai, India
Phone +91-44-8525393,8522422
Fax +91-44-8523387

The Ice Machinery Mar+
37,Netaji Subash Chandra Marg, Daryaganj, 110002 New Delhi, India
Phone +91-11-3271491,3269551
Fax +91-11-3271491

Insulation

Sureka Insulation & Packagings
510/512 Chetak Centre,12/2 R N T Marg, 452001 Indore India
Phone +91-731-434362 6460049
Fax +91-731-434362

Dugar Insulations India Pvt Ltd
Dugar Towers No 123,Marshalls Rd , Egmore 600008 Chennai India

3.4

Phone +91-44-8553535,8554154
Fax +91-44-8552244

Apexa Enterprises
Devi Heights 3rd Fl 269 Shaniwar Peth 411030
Pune India
Phone +91-212-458918,455233
Fax +91-212-453403

Apexa Enterprises
Devi Heights, 3rd Fl 269,Shaniwar Peth, 411030
Pune, India
Phone +91-212-458918,455233
Fax +91-212-453403

Mini-Reefers

Ondez (India) Pvt Ltd
Bharucha Bldg ,144, Mody St ,Fort 400001 Mumbai, India
Phone +91-22-2691321,3452330
Fax +91-22-2615434

Portable "Hydro-Chillers '

Not available

Radiant Barriers (Screening, Shadecloth)

Jayshree Enterprises
48,Adarsh Est , Chakudia Mahadeo Rd , Rakhial, 380023 Ahmedabad, India
Phone +91-79-2748083
Fax +91-79 2747365

M H Polymers
3rd Fl Navdeep House Nr Income Tax Char, Rasta Ashram Rd 380014
Ahmedabad, India
Phone +91-79-6568870,6561744
Fax +91-79-6425439

Garware Plastics & Polyester Ltd
50-A Swamy Nityanand Marg,Vile Parle (E), 400057
Mumbai India
Phone +91-22-6346381 8380701
Fax +91-22-8380384

Refrigeration Equipment

A S International
16 Comm Hse Ropewalk Lane, Fort, 400001
Mumbai, India
Phone +91-22-272273

United Sales Corp
Ravi Shashi Soc Tilak Rd Santacruz (W) 400054
Mumbai India
Phone +91-22-6491822

Frick India Ltd
1st Fl Jivan Vihar Bldg Parliament St , 110001 New Delhi, India
Phone +91-11-3360104,3735793
Fax +91-11-312610

Hindustan Refrigeration Stores
2, 4 & 5,Netaji Subhash Marg, Daryaganj, 110002
New Delhi, India
Phone
+91-11-3271898,3277725 ,3277735,3288884,3288886 ,7524672,7524873
Fax +91-11-3271152

Chapter 7

C A Equipment

A S International
16, Comm Hse , Ropewalk Lane Fort 400001
Mumbai, India
Phone +91-22-272273

Hindustan Refrigeration Stores
2, 4 & 5,Netaji Subhash Marg, Daryaganj, 110002
New Delhi India
Phone
+91-11 3271898,3277725,,3277735 3288884 3288886 ,7524672 7524873
Fax +91-11-3271152

Super Refrigeration Pvt Ltd
2nd Fl Samrat Bhavan Comml Cmplx Ranjit Ngr 110008 New Delhi
India
Phone +91-11 5709444 5707695
Fax +91 11-5705905

Filters Scrubbers

Wrachets India
K 1 Indl Est 2nd Cross Rd Guindy 600032 Chennai India
Phone +91-44-2341604

Southwest Compressor Technologies Pvt Ltd
201 Shiv-Parvati Apts 1453 Shukrawar Peth 411002
Pune India
Phone +91 212-451895 452887
Fax +91-212-454787

Hyderabad Pollution Controls Ltd
7-1-27 1st Fl Srinivasa Cmplx Ameerpet 500016
Hyderabad India
Phone +91-40-290033
Fax +91-40-293624

Dyna Filters Pvt Ltd
98/A5 Dyna Hse Hadapsar Indl Est 411013 Pune
India
Phone +91-212-673705 672772
Fax +91-212-677955

Filter-On (India) Pvt Ltd
Maharashtra Sahitya Parishad Bldg , Tilak Rd
Sadashiv Peth 411030
Pune, India
Phone +91-212-478992
Fax +91-212 478992

Fans, Ventilation Systems

B A Enterprise
South Stn Rd Agarpara, 743177 24 Parganas (N),
India
Phone +91-33-5534293

Datta Air System Pvt Ltd
6 Sandeep Indl Est ,I B Patel Rd , Goregaon (E),
400063 Mumbai, India
Phone +91-22-8735860
Fax +91-22-8728418

United Air Control
Clipwala Compound Nr L & T Saki-Vihar Rd ,
Powai, 400072 Mumbai, India
Phone +91-22-8521126,8521044
Fax +91-22-5791044

12 Volt Evaporative Coolers, Air Conditioners, Ceiling Fans

Super Coolers
Arora Bhawan,,Opp Parimal Garden Police Chowky,
Ambawadi Bazar,
380006 Ahmedabad India
Phone +91-79-6442400

Rajnish A C Products
76-B Indl Area Rachhai 482009 Jabalpur India
Phone +91-761-3676833
Fax +91-761-3631182

Khaitan Electricals Ltd
Everest 20th Fl 46-C J L Nehru Rd 700071
Calcutta India
Phone +91-33-2144391 2478392
Fax +91-33-2423961

Berlia Electricals Pvt Ltd
1826, Amarnath Bldg , Bhagirath Palace Chandni
Chowk 110006 Delhi
India
Phone +91-11-2965085,2966099
Fax +91-11-2118046

Trac Airconditioning Systems Ltd
38 1st Stage 1st Main Domlur Layout 560071
Bangalore India
Phone +91-80-5511393 5511617
Fax +91-80 5511392

Neptune Refrigeration Co Pvt Ltd
153 Mount Rd 600002 Chennai India
Phone +91-44-8525393 8522422
Fax +91-44-8523387

Advance Cooling Systems Pvt Ltd
5 B Thacker Indl Est ,N M Joshi Marg, Lower Parel
(E), 400011 Mumbai
India
Phone +91-22-3088032
Fax +91-22-5643194

Hygrometers (to measure RH)

Sunshine International Pvt Ltd
57,LIG KHB Cly Basaveshwarnagar, Vijayanagar,
560079 Bangalore India
Phone +91-80-3303292
Fax +91-80-3323357

Switzer Instrument Ltd [Image]
P O Box 1423 14 Thanikachalam Rd T Ngr 600017
Chennai, India
Phone +91-44-4340999 4344321, 4343956
Fax +91-44-4347887 041-23049 swiz in

Dynalab Weathertech Pvt Ltd
C-2 Bldg Brahma Memories, C-3,Bhosale Ngr
411007 Pune, India
Phone +91-212-327109 327246
Fax +91-212-327246

Solar Powered Evaporative Coolers

S D Solar Systems India Pvt Ltd
11 Manish Bhawan Opp Thana Shajahanabad
462001 Bhopal India
Phone +91-755-536086 5163596
Fax +91-755-543310

Solker Industries Ltd

101

37 Solker House, Jayalakshmipuram,1st, St ,
Nungambakkam 600034
Chennai India
Phone +91-44-8274142 8271819
Fax +91-44-8273435

Machinocraft
15/4A Opp Shankar Maharaj Temple, Vasudeo Est
411043 Pune, India
Phone +91-212-522623,521457
Fax +91-212-520623

Solar Powered Fans and Storage Ventilators

S D Solar Systems India Pvt Ltd
11 Manish Bhawan,Opp Thana,Shajahanabad,
462001 Bhopal India
Phone +91-755-536086,5163596
Fax +91-755-543310

Solker Industries Ltd
37 Solker House Jayalakshmipuram,1st St ,
Nungambakkam, 600034
Chennai, India
Phone +91-44-8274142 8271819
Fax +91-44-8273435

Machinocraft
15/4A,Opp Shankar Maharaj Temple, Vasudeo Est ,
411043 Pune, India
Phone +91-212-522623 521457
Fax +91-212-520623

Temperature Alarm/Timers

Process Controls
C-304 1st Stage, 9th Cross Peenya Indl Est , 560058
Bangalore India
Phone +91-80-8395571 3367650

M B Control & Systems Pvt Ltd
31/1 Ahiripukur Rd 700019 Calcutta India
Phone +91-33 2478475
Fax +91-33-2470445

Pan Systems
3 Anantalaya Bldg Sant Eknath Ngr Bibwewadi
411037 Pune, India
Phone +91-212 515044 517673
Fax +91-212 517085

Temperature Recorders

Japsin Products India
7 Netaji Subhash Marg Darya Ganj 110002 New
Delhi, India
Phone +91-11-3273214 3278846
Fax +91 11-3273214

Thermometers, Temperature/RH Meters

Serwell Instruments Inc
Sukruthi, 149 1st R Blk Chord Rd Rajajinagar,
560010 Bangalore
India
Phone +91-80-3320309,3325697
Fax +91-80-3325697

Bio-Tech India
109,Mahim Indl Est Mori Rd Mahim 400016
Mumbai, India
Phone +91-22-4463076

Sunshine International Pvt Ltd
57,LIG KHB Cly , Basaveshwarnagar Vijayanagar
560079 Bangalore, India
Phone +91-80-3303292
Fax +91-80-3323357

Switzer Instrument Ltd [Image]
P O Box 1423,14, Thanikachalam Rd , T Ngr 600017
Chennai, India
Phone +91-44-4340999,4344321, 4343956
Fax +91 44-4347887,041-23049 swiz in

Japsin Products India
7,Netaji Subhash Marg, Darya Ganj 110002 New
Delhi, India
Phone +91-11-3273214,3278846
Fax +91-11-3273214

Modular Pre-Fab Cold Rooms

Industrial Refrigeration Pvt Ltd
901, Maker Chambers V
Nariman Point, Mumbai 400 021 Maharashtra
Phone +91-22-204-1183/85/89/287-2363/79
Fax +91-22-204-4944
E-Mail allstate finance@gems vsnl net in

Chapter 8

Ice-Packs, Ice Wraps, Freezable Gel-Filled or Water-Filled Bags "Cool Guard"

Spectrum Machinery Manufacturers Pvt Ltd
1510 Maker Chmbr V Nariman Point 400021
Mumbai India
Phone +91 22-2823131 2823125
Fax +91-22-2047340

Fusion Polymers Ltd

9th Fl Comm Centre Sayajiganj 390005 Vadodara India
Phone +91 265-337035
Fax +91-265-333557

Asian Ice Factory
Opp S R P Head Quarters Near S T Workshop
Sajjpur Bogha 382330
Ahmedabad, India
Phone +91-79-2813172 2819115

Loading Guide

Not available

Temperature/Humidity Data Loggers

Japsin Products India
7 Netaji Subhash Marg, Darya Ganj, 110002 New Delhi India
Phone +91-11-3273214 3278846
Fax +91 11-3273214

Thukral Electronics
381-A 3rd Fl Narottam Wadi Kalbadevi Rd 400002 Mumbai India
Phone +91-22-2053765,2061266
Fax +91-22-2083118

Therma-Cover

Earthfield Products (Bombay)
New Excelsior Bldg , 6st Fl ,5 A A K Nayak Marg
P O Box 1148 Fort,
400001 Mumbai India
Phone +91-22-2049106
Fax +91-22-2042467

Hindustan Composites Ltd
L B Shastri Marg, Ghatkopar (W) 400086 Mumbai India
Phone +91-22-5171491,5173001
Fax +91-22 5171495

Lloyd Insulations (India) Ltd
6 Middleton St 700071 Calcutta India
Phone +91-33 2401606 2475479
Fax +91-33-2402629

Sureka Insulation & Packagings
510/512 Chetak Centre 12/2, R N T Marg 452001 Indore India
Phone +91-731 434362,6460049
Fax +91-731-434362

Transport Services

Andhra Bombay Roadways
94,Khanna Mkt St Stephen Hosp Tis Hazari 110054 Delhi India
Phone +91-11-2526501 2512483
Fax +91 11-2924131

Reliable Carriers Pvt Ltd
A-6 Koh E-Fiza Indore Rd 462001 Bhopal India
Phone +91-755-540721
Fax +91-755-540442

Road Transport Corp
2 Brabourne Rd 700004 Calcutta India
Phone +91-33-304840

Venson Transports
716 Anna Salai 600006 Chennai India
Phone +91-44-8522019 8520298

Chapter 9

Automatic Chlorine Dispenser

Top Exports Pvt Ltd
Saiman House,J A Raul St Off Saani Rd
Prabhadevi, 400025 Mumbai
India
Phone +91-22-4360093
Fax +91-22-3431935

Kelleys Engineering Works
24B/6 Indl Area, 121001 Faridabad India
Phone +91-129-2833251 2833261
Fax +91 129-241912

Fungicides

J M Chemical Co
209 Tilak Bazar Khari Baoli 110006 Delhi India
Phone +91-11-2529922 2929933
Fax +91-11-2929933

Ramachandra Pesticides Pvt Ltd
29/2,4th Main New Taragupet, 560002 Bangalore, India
Phone +91-80-603476 608390
Fax +91-80-6603728

Venkateswara Agro Chemicals & Minerals Ltd
37-F,Velachery Main Rd 600042 Chennai India
Phone +91-44-2350072

Sprayers, Knap-sack, Backpack

Agro Engineers & Traders
3 A-2 K K Pudur Rd Velandipalayam Post 641025

Coimbatore India
Phone +91-422 443925 4111691

American Spring & Pressing Works Ltd
P O Box 7602 Aspee House B J Patel Rd Malad (W) 400064 Mumbai
India
Phone +91-22-6822331
Fax +91-22-6822336

Masand Agro Equipments Industries
70,Shastri Mkt , 452007 Indore, India
Phone +91-731-6481379,470015

Navlakha Agro Equipments
38,Shankar Sheth Rd 411037 Pune, India
Phone +91-212-541235,545788
Fax +91-212-425877

Sulfur Dioxide Pads

Jaysons Chemical Industries
Saki Vihar Lake Rd , Sakinaka, 400072 Mumbai, India
Phone +91-22-8522704,5783208
Fax +91-22-5786507

Tamilnadu Chemical Products Ltd
TCP Sapthagiri Bhavan 10,Karpagambal Ngr
Mylapore, 600004 Chennai
India
Phone +91-44-4991518 4992115
Fax +91-44-4991777

Chapter 12

Citrus Peeler/Corers

Avanashiappan Industries
78-A Chekkanthottam South Rly Line, Ganapathy, 641006 Coimbatore
India
Phone +91 422-437871

Equipmart
1/16 Kamal Mansion Near Radio Club A rthur
Bunder Rd Colaba 400005
Mumbai India
Phone +91 22-2041355

Raylons Metal Works
J B Ngr Ramkrishna Mandir Rd , Andheri (W)
400059 Mumbai India
Phone +91 22-8323288,8325932
Fax +91-22 6236062

Custom Fruit/Veg Fresh-cut Equipment Vegetable Equipment

Not available

Dicers

Avanashiappan Industries
78-A Chekkanthottam South Rly Line Ganapathy
641006 Coimbatore,
India
Phone +91-422-437871

Equipmart
1/16, Kamal Mansion Near Radio Club Arthur
Bunder Rd Colaba 400005
Mumbai India
Phone +91 22-2041355

Raylons Metal Works
J B Ngr Ramkrishna Mandir Rd , Andheri (W)
400059 Mumbai, India
Phone +91-22-8323288 8325932
Fax +91 22-6236062

Freshness Labels (Time-Temperature Indicators)

Anadig Systems
B 214,Shreyas Indl Est Western Express, Highway
Goregaon (E) 400063
Mumbai India
Phone +91-22-8735654 8732236

Century Systems
27/1,2nd Main Rd , Seshadripuram 560020 Bangalore
India
Phone +91 80-3343428,3340391
Fax +91 80-3342494

Control & Measurement Services
Sharada Cinema Bldg 172 Naigaum Cross Rd
Dadar 400014 Mumbai
India
Phone +91 22 4130399 4133822
Fax +91 22 4135638

Packing/Sorting Tables

Narang s Corp
P-25 Connaught Place 110001 New Delhi India
Phone +91 11 343547
Fax +91 11-3746705

Planets, The
7/8, Ratna Deep Amboli Caeser Rd Andheri (W)
400058 Mumbai India
Phone +91 22 6234942 6288408

Fax +91-22-6267298

Micro Machinery Co Pvt Ltd
Lake Rd , Bhandup (W), 400078 Mumbai, India
Phone +91-22-5619818
Fax +91-22-5645134

Rameshwar Engg Works
81 Ground Fl A-Blk Bangur Avenue 700055
Calcutta India
Phone +91-33-5500398 5517351
Fax +91-33-5517929

Subnil Packing Machines Pvt Ltd [Image]
B-2 Ground Fl Bijlee Soc Opp Bombay Forging C
S T Rd Kalina
400098 Mumbai India
Phone +91-22-6178312,6178313 6178314
Fax +91-22-6178314

Shredders

Avanashiappan Industries
78-A, Chekkanthottam, South Rly Line, Ganapathy,
641006 Coimbatore,
India
Phone +91-422-437871

Equipmart
1/16, Kamal Mansion, Near Radio Club, Arthur
Bunder Rd ,Colaba, 400005
Mumbai, India
Phone +91-22-2041355

Raylons Metal Works
J B Ngr ,Ramkrishna Mandir Rd Andheri (W),
400059 Mumbai, India
Phone +91-22-8323288 8325932
Fax +91-22-6236062

Slicers

Avanashiappan Industries
78-A Chekkanthottam South Rly Line Ganapathy
641006 Coimbatore
India
Phone +91-422-437871

Equipmart
1/16, Kamal Mansion Near Radio Club, Arthur
Bunder Rd Colaba, 400005
Mumbai India
Phone +91-22-2041355

Raylons Metal Works
J B Ngr Ramkrishna Mandir Rd Andheri (W)
400059 Mumbai India
Phone +91-22-8323288 8325932
Fax +91-22-6236062

Spinners/Spin Driers

Raylons Metal Works
J B Ngr Ramkrishna Mandir Rd Andheri (W),
400059 Mumbai India
Phone +91-22 8323288 8325932
Fax +91-22 6236062

SSP Pvt Ltd [Image]
19 DLF Indl Area, Phase-II 13/4 Mathura Rd
121003 Faridabad India
Phone +91-129-275441 277730 274213
Fax +91-129-277441 91 11-6847665

Strip Cutters

Bell Tools Pvt Ltd [Image]
87,Nagdevi Cross Lane, 400003 Mumbai, India
Phone +91-22-3428955,3428956 3428957
Fax +91-22-3421460

Godson Engineering Corp
Dhebar Rd (S), 360002 Rajkot, India
Phone +91-281-362467,361449
Fax +91-281-361873

Sornavinayagha Engineers Pvt Ltd
24,T H Rd , 600081 Chennai, India
Phone +91-44-5956015,5956475

Gupta Trading Co
Marshall House, R No 361, 33/1,N S Rd , 700001
Calcutta, India
Phone +91-33-2207989 2209264
Fax +91-33-2206274

Sterilization Control Systems (Chlorine)

B I Industries
Flat No 912A 9th Fl Raghava Ratna Towers,Chirag
Ali Lane Abids
500001 Hyderabad India
Phone +91-40-203354 203110
Fax +91-40-201785

Raylons Metal Works
J B Ngr Ramkrishna Mandir Rd Andheri (W), 400059
Mumbai, India
Phone +91 22-8323288 8325932
Fax +91-22-6236062

Wash Tank Conveyors

405

National Indl Corp
52/53C Ancillary Indl Area Hatia 834003 Ranchi, India
Phone +91-651 408241,311136
Fax +91-651-409107

Nilos India Pvt Ltd
11,Manohar Avenue,Egmore, 600008 Chennai, India
Phone +91 44 8261521 8267601
Fax +91-44 8267823

Chapter 13

Almond Hulling/Drying

Parmar Iron Works
Nr New Bus Stand,Jasdan, 360050 Rajkot, India
Phone +91-2821-20300,20191
Fax +91-2821-365240

Patel Brothers Services & Engg Pvt Ltd
6 Elphinstone Bldg , 3rd Fl 10 Vir Nariman, Rd Fort 400001
Mumbai India
Phone +91-22-2041072 2044295
Fax +91-22-2049178

Raylons Metal Works
J B Ngr Ramkrishna Mandir Rd Andheri (W), 400059
Mumbai, India
Phone +91-22-8323288,8325932
Fax +91-22-6236062

SSP Pvt Ltd [Image]
19 DLF Indl Area,Phase-II,13/4 Mathura Rd , 121003 Faridabad India
Phone +91-129-275441,277730, 274213
Fax +91 129-277441 91-11-6847665

Apple Parer/Corer

Marlex Products Pvt Ltd
17 18 Navketan Indl Est Mahakali Caves Rd Andheri (E) 400093
Mumbai India
Phone +91-22-8384344
Fax +91-22-8374344

Sunnit Industries
15 Baba Mandir Gausala 3rd Bhoiwada Lane,Bhuleshwar 400002 Mumbai
India
Phone +91-22-3757846,3630338
Fax +91-22-3719821

A R V Engineering Industries Pvt Ltd
21,2nd Line Beach 600001 Chennai, India
Phone +91-44-5221130

Electric Food Drier

Food Tech Engineers
7/8, Ratnadeep Caesars Rd Andheri (W), 400058
Mumbai India
Phone +91-22-6269106

SSP Pvt Ltd [Image]
19, DLF Indl Area Phase-II,13/4, Mathura Rd , 121003 Faridabad, India
Phone +91-129-275441,277730, 274213
Fax +91-129-277441, 91-11-6847665

Raylons Metal Works
J B Ngr ,Ramkrishna Mandir Rd Andheri (W), 400059
Mumbai India
Phone +91-22-8323288,8325932
Fax +91 22-6236062

Glass and Plastic Bottles and Jars

Ajanta Packaging Co
313, 3rd Fl , 4/1,D B Gupta Rd ,Paharganj, 110055
New Delhi India
Phone +91-11 7529420,731589
Fax +91-11 7529420

Bharat Bottle Stores
105 Nyniappa Naicken St , 600003 Chennai, India
Phone +91-44-5353873

Bottle House
401, Adamji Bldg , 413 Narshi Natha St Masjid Bunder, 400009 Mumbai
India
Phone +91-22-3439024 3439068

Alphacon Containers Pvt Ltd
Ground Fl 12,Bhola Bhagwan Indl Est I P Patel Rd Goregaon (E),
400063 Mumbai India
Phone +91-22-8730757 3727185
Fax +91-22 8723965

Jindal Plastics
E-74 Sardar Patel Indl Est Ajwa Rd No 3 390019
Baroda, India
Phone +91 265-66445

Nampack Plastics Pvt Ltd
322,Creative Indl Est ,N M Joshi Marg,Lower Parel
400011 Mumbai,
India

Phone +91-22-3079483,3066616
Fax +91-22-3066616

Mold Tek Plastics Ltd
303 7-1-27 Srinivasa Cmplx C-Blk Ameerpet
500016 Hyderabad India
Phone +91-40-290443
Fax +91-40-291834

Chapter 14

Metal Containers

Not available

Plastic (PET) Containers

Nampack Plastics Pvt Ltd
322,Creative Indl Est ,N M Joshi Marg, Lower Parel,
400011 Mumbai
India
Phone +91-22-3079483,3066616
Fax +91-22-3066616

Mold-Tek Plastics Ltd
303 7-1-27 Srinivasa Cmplx , C-Blk Ameerpet
500016 Hyderabad, India
Phone +91-40-290443
Fax +91-40-291834

Rock Pet Chem Pvt Ltd
1, 4th Fl , Rowdon St , 700017 Calcutta India
Phone +91-33-2402891,2404288
Fax +91-33-2404288

Sunrise Containers Pvt Ltd
2-E 2nd Fl , C Wing, Satam Indl Est , B/h Bank, of Baroda Chakala Andheri (E), 400099 Mumbai, India
Phone +91-22-8321961,8352471
Fax +91-22-8369920

Glass Containers

Excel Glasses Ltd
Parijat House 2nd Fl 1076 Apte Indl Est Dr E Moses Rd Worli
400018 Mumbai India
Phone +91-22-4933050 4920611
Fax +91-22-4937743

Bottle Capper

Not available

Bottling Equipment

Fortune International Ltd
C-2,Comm Centre, Naraina Vihar 110028 New Delhi India
Phone +91-11-5794211
Fax +91-11-5794948

L-Pack
Suryodaya, 1st Fl , 1-10-60/3 Begumpet 500016 Hyderabad India
Phone +91-40-848933,840301
Fax +91-40-847793

Master Mechanical Works The
Pushpanjali S V Rd Santacruz (W) 400054 Mumbai India
Phone +91-22-6493459 6491680 6490619
Fax +91-22-6494751

Pharmalab Engineering (I) Pvt Ltd
Star Metal Compd, L B S Marg, Vikhroli (W), 400083 Mumbai India
Phone +91-22-5782559 5785631
Fax +91-22-5785329

Chapter 17

Bags (Plastic, Cotton, Paper)

Safepack Plastics Pvt Ltd
7th Mile, Bannerghatta Rd , 560076 Bangalore India
Phone +91-80-643523
Fax +91-80-6637520

T P I India Ltd
102, Atlanta, Nariman Point, 400021 Mumbai, India
Phone +91-22-2873087,2873088
Fax +91-22-2874479

Package India
4-A (NP), Mathiazhakan Ngr Kubera Ganapathy St Padi, 600050 Chennai
India
Phone +91-44-6257260
Fax +91-44-6257260

Manish Packaging Pvt Ltd
2, Navchetan Soc , Opp Krishimangal Hall Ring Rd
395001 Surat, India
Phone +91-261-872319,872325
Fax +91-261-872709

Impulse Enterprise Pvt Ltd
31, Omkar House,Navarangpura, 380009 Ahmedabad, India
Phone +91-79-461202 461472
Fax +91-79-6423627

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Lakshmans Plastics Pvt Ltd
1st Fl 21/23 Mohatta Mkt Palton Rd Fort 400001 Mumbai India
Phone +91 22-2616657 2614992
Fax +91 22-2616875

Aditya Multiwal Sacks Pvt Ltd
203 Midford House 1 Midford Garden M G Rd, 560001 Bangalore India
Phone +91-80-5583887,5583888
Fax +91-80-5585203

Ajit Packing Industries
184,Bhat Bazar Narsi Natha St 400009 Mumbai India
Phone +91-22-3715842 3712594
Fax +91-22 3712488

Bag Maker
G-29 Vardhman Tower, Comm Centre Vikaspuri, 110018 New Delhi India
Phone +91-11-5590429,5622985
Fax +91-11-5503804

Canopies and market umbrellas

Hooghly Mills Co Ltd, The
10, 3rd Fl Clive Row 700001 Calcutta India
Phone +91-33-2429801,2429790
Fax +91-33-2424306

Howrah Mills Co Ltd
135 Foreshore Rd (S) 711102 Howrah India
Phone +91-33 6601446 6602302
Fax +91-33-6601447

Madura Industrial Textiles
New Jail Rd 625001 Madurai India
Phone +91-452-26751
Fax +91-452-31330

National Umbrella Mart
Anand Bhavan Shop No 12B 213 17 Babu Genu, Rd ,Princess St 400002
Mumbai, India
Phone +91-22-2018825 2050393

South Indian Umbrella Mfg Co
23-A Jadamuni Koil St 625001 Madurai India
Phone +91-452-35615

Vaspar Concepts Pvt Ltd
16Km,MMI Indl Est Old Madras Rd Virgonagar 560049 Bangalore India
Phone +91-80-8510118,8510364
Fax +91-80-8510438

Ethylene Generators

Amba Chem Industries
272,GIDC,Makarpura 390010 Baroda India
Phone +91-265-442387

This list has been compiled by Ranjan Rawat

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