A Practical Workshop For The Optimization Of Egyptian Produce Packaging

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I would like to express thanks to the many companies that I have had the privilege to visit during my stay in Egypt. Without their help I would not have been able to begin my education into the fascinating world of Egyptian horticulture. I would also like to thank the members of ATUT and RONCO who helped facilitate my work while in Egypt. I owe particular thanks to Dr. Mohamed El Ansary (Faculty of Agriculture, Kafr EL-Sheikh), Eng. Yasser Essam and Dr. Ali El Said who were instrumental in the preparation of this packaging workshop and manual

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1. A systems approach to produce handling

Fresh fruits and vegetables are typically at their highest quality at the moment of harvest. From that moment forward quality is being lost. The products continue to live and therefore are consuming their sugars and other carbohydrates through the process of respiration and are continually producing heat, carbon dioxide and moisture vapor. The challenge for packers, shippers and exporters is to minimize the loss of quality by slowing the normal metabolism of the products.

The main enemies of quality are temperature, time and handling damage. All efforts should be directed to reducing temperature as soon as possible after harvest and keeping temperature low throughout handling and shipping. Proper temperature management is the single most effective means to maintain quality in fresh fruits and vegetables. All products should be kept at the lowest temperature possible without causing chilling or freezing damage. That optimal temperature is 0Cº for strawberries and grapes, 5-7Cº for green beans, 10-12Cº for mangos and 2-5Cº for melons (depending on the variety and maturity).

Additional efforts should go into reducing the time that elapses from harvest until sale. Any delays result in losses of quality, especially delays before the product is cooled to its optimal temperature. Product flow should be controlled so that it never sits and is allowed to warm.

The third effort should go into eliminating unnecessary handling steps to reduce both time and damage due to handling. Every time a fruit or vegetable is touched or moved, some damage results and this reduces the quality and postharvest life. The complete handling operation should be evaluated to eliminate unnecessary handling steps. The ideal system is where the product is touched one time, at the moment of harvest, and is never touched again until sale at its destination.

2. Working together: Cooperation and competition

Because produce must be handled through a coherent system, all of the people and companies involved in the different parts of handling need to cooperate to insure a successful outcome. If every part of handling is done well, but then the product waits at the airport for six hours and warms, all of the previous efforts will have been wasted. The package supplier, the packer, the shipper, the exporter and the receiver are all partners in handling the product. They must all do their parts well to assure success. Cooperation is the key.

While there is a sense of competition among different producers and exporters in Egypt, they are not really competing among themselves. The true competition is the rest of the world. When a buyer in London or Paris or Rotterdam wants to buy strawberries, beans or grapes, he does not have to choose among different Egyptian suppliers. He can choose product from South Africa, Morocco, Zimbabwe, Israel, Chile or any other country that produces those commodities.

Buyers often judge quality in terms of countries, not in terms of individual producers. Many times I have heard people say that Israel or South Africa has better cartons or better fruit or receives a better price in the market. I have not heard anybody say company X or company Y has better boxes or better product. We all think of produce in terms of country of origin. So if one Egyptian producer has a poor reputation, the whole country can develop a poor reputation. Chile has become a very successful exporter of fruit throughout the world because the growers and exporters have organized and cooperated to establish minimum quality standards for all exported fruit. Thus, no product leaves Chile that does not meet the standards. Buyers know that fruit from Chile will always meet those standards so they are willing to buy the fruit. If Egypt is to become successful as an exporter of fruits and vegetables, the export industry is going to have to organize and cooperate. You are not competitors, you are partners with the same goals and the same challenges.

Similarly, packaging suppliers in Egypt are really competing in the export market against Cyprus, Turkey, Belgium and other countries, not against each other. Buyers see weak cartons in the markets and that reflects badly on Egyptian product. They conclude that Egyptian products are of poor quality or the packages are of poor quality. Once again, organizations of Egyptian package manufactures need to establish clear standards for export packaging. Tests of packaging should become standardized and the results of those tests made readily available to their customers. Only in this way can buyers compare the performance of different packages and the industry can systematically improve its' products.

3. Produce handling systems

There are many alternative ways to harvest, move, grade, pack, package, cool and transport fresh produce. The best system will be that which achieves the three goals described above: reduce temperature, reduce time and reduce handling. All handling decisions should be made against the necessity to achieve these goals. Packing in the field is preferable if it is practical, since it reduces handling steps. The most rapid cooling method that is practical is preferred. Activities in the packing house should be designed to keep the product cool, move it fast and reduce handling. Of course, each decision must be made within the context of available facilities, technology and capabilities.

A. Harvesting. The highest quality product should be harvested at a maturity stage appropriate to the commodity and its destination. Climacteric fruits, such as mangos, that continue to ripen after harvest, might be harvested at a mature green stage if destined for distant markets, or at the fully ripe stage for local markets or processing plants. The degree and type of protection necessary from a package might depend on the status of the product at harvest. Riper, softer fruits will need more protection than more firm ones. Greater care will be necessary when sorting, grading, packing, loading and transporting softer fruits. Care should be taken in all operations before and after packing to ensure that the package has an opportunity to perform as designed and adequately protect the product. Cooling should be done as soon after harvesting as possible, preferably within two hours, in order to maximize the shelf life of the product. Whether cooling is to be done before or after packing (or both) must be considered when selecting a package design. Thus, thinking about proper packaging starts at the moment of harvest, or even before.

Many commodities are harvested into field boxes or crates and then brought to the packing shed for subsequent handling. Sometimes, the commodity can be cooled directly upon arrival at the packing house in the field bins or containers. Melons, for example, can be dumped from the field bins directly into cold water for hydrocooling before being sorted and packed. In other instances, such as with grapes, the product can be sorted, graded and repacked prior to cooling. This will depend primarily on the cooling requirements of the commodity, the ambient temperature upon arrival at the packing shed, and the cooling method employed. Other commodities, such as strawberries, can be field packed, thereby eliminating several steps. Field packing requires well trained and critical workers so that only the highest quality product is harvested, sorted properly, and packed properly so that it arrives from the field ready for cooling and shipping without further handling.

B. Cooling. As has been mentioned repeatedly, temperature management is probably the most critical factor in delivering high quality fresh produce to distant markets. The type of cooling utilized, and where in the handling system cooling is done, are important factors determining the type of package utilized for the product. There are five main types of cooling systems used for fresh produce.

*1**. Convection Cooloing.*** Convection cooling. or Room cooling, or cooling through placing product in a cold storage room, relies on the passive exchange of heat from a warm product to cooler air as the air circulates around the product. This type of cooling may be suitable for commodities of relatively low respiration rate, such as cabbage, where rapid temperature reduction is not critical. Packed fruit would be placed in a cold room and the temperature gradually brought down through the process of room. Fans can be used to maintain air circulation. This is an inexpensive method of cooling, but is not rapid enough for many commodities.

A package for use with room cooling should have adequate vents so that cool air can contact the commodity and the package does not act as an efficient insulator keeping heat inside. The placement of the vents is not critical except insofar as it affects airflow through stacked boxes (where the holes should align from box to box, and to the degree that vent holes can weaken the box. Box strength factors will be discussed later.

2. Hydrocooling*.* Hydrocooling refers to removing heat from the commodity by either placing the commodity in a cold water bath, as is often done with bulky fruits such as melons, or dripping cold water over the commodity, as is sometimes done with green beans. Hydrocooling is actually a form of convection cooling using water as a more efficient cooling medium than air. Therefore the commodity temperature can be reduced much faster with hydrocooling than with normal room cooling. It is normal practice to chlorinate the water for hydrocooling to prevent the growth of fungi and bacteria.

Commodities are typically cooled in a water bath in bulk, so they are not placed in a package until after cooling. For commodities where water drips onto them, the box must be water proof (usually wirebound crates or waxed corrugated cartons), and the boxes must have adequate openings on the top and bottom surfaces to allow cold water to penetrate the entire contents of the box. Hydrocooling is relatively inexpensive, but requires abundant water and refrigeration, as well as chlorination facilities.

***3. Forced Air Cooling**,* Forced air cooling involves moving air through packed produce by creating an air pressure differential across the produce. Thus, cold air is sucked through the boxes and rapid cooling results. For forced air cooling to be effective, there must be adequate cooling capacity, fans with enough power to create a proper pressure differential and maintain air movement, boxes that facilitate proper air movement through the product rather than around the boxes, and a proper stacking and arrangement of the boxes so that the pressure differential can be maintained. Forced air cooling is a relatively sophisticated cooling system, but it is highly efficient if used properly. It is commonly used to cool strawberries and grapes, and can be adapted to cool a broad range of fresh commodities (Table 1).

A box for use with forced air cooling must have adequate ventilation to allow sufficient air flow to cool the product in a short period of time (usually a few hours). If air flow is insufficient, cooling times will increase and the facility will be used inefficiently. As the expense of constructing and operating a forced air cooling facility is relatively high, it is prudent to minimize cooling times to maximize the amount of product that can be serviced by the facility. The arrangement of the ventilation holes should be such that air is able to flow in only one direction, thereby facilitating the maintenance of a pressure differential .

*4**. Icing**.* Some high respiration rate commodities, such as broccoli, can be cooled by applying an ice slurry to the boxed commodity. The slurry consists of a mixture of ice and water of a consistency such that the ice flows into the box and around the commodity where it solidifies and provides cooling during transportation. Specialized equipment is needed to produce and apply the ice slurry, and transportation costs can be high because the ice itself is heavy.

A box designed for use with top icing should have sufficient openings in the top so that the ice can enter the box and penetrate the entire contents of the box. The box must be waterproof so that it is not weakened by the water that is produced as the ice melts. Icing is not an appropriate cooling method if product is to be exported.

***5. Vacuum Cooling**.* Many leafy vegetables can be rapidly cooled by applying a vacuum. The reduced partial pressure causes water to rapidly evaporate from the surface of the produce, thus effecting rapid cooling. Because the evaporation can cause significant moisture loss, a variant called *HydroVac Cooling* has been devised that applies a stream of water to the product during cooling. This reduces moisture loss and consequent weight loss by the product.

Vacuum cooling requires a large and expensive machine and a trained operator to be effective. It is a sophisticated and expensive cooling method but it is very effective for lettuce and other leafy vegetables. Packages for use in a vacuum cooler must be open to allow rapid evaporation and consequent cooling. Wooden crates or wirebound crates are appropriate for this use. Vacuum cooling is not currently available in Egypt and would not be appropriate for the commodities. currently being exported

The choice of a cooling system will depend on the requirements of the commodity and on the facilities available. Many commodities are amenable to any of several cooling methods. Others have much more stringent requirements.

Table 1. Recommended Precooling Methods For Selected Fruits and Vegetables

Asparagus	***Hydrocooling***
Green Beans	Hydrocooling
Cabbage	Room Cooling
Carrots	Hydrocooling
Cauliflower	Hydrocooling, Vacuum Cooling
Cucumber	Hydrocooling
Grapes	Forced Air Cooling
Eggplant (Aubergine)	Forced Air Cooling
Lettuce	Vacuum Cooling, Hydrocooling
Melon	Forced Air Cooling, Hydrocooling
Capsicum Peppers	Forced Air Cooling
Strawberries	Forced Air Cooling
Mangos	Hydrocooling, Room Cooling
Tomatoes	Forced Air, Room Cooling
Zucchini	Forced Air, Hydrocooling

C. Sorting and Grading. A package must be able to hold the proper amount of product, and must accommodate the proper size of product. A corrugated box designed to hold four large melons may be a different size and have different size dividers than a box designed to hold six smaller melons. The contents of the box must be defined before the box is selected.

D. Stacking and Transporting. Whether produce is to be shipped by truck, by air, by sea, or by some combination of these, the packages must be combined and stacked in some pattern to allow optimum space utilization, adequate air movement, and easy handling. Boxes that are to be palletized often have vertical tabs that will facilitate stacking and add horizontal stability to the load. In addition, such tabs help align the ventilation holes on the boxes and improve air flow. Some types of boxes have interlocking vertical posts that serve similar functions.

Pallet or slipsheet size, and truck size can affect the optimal package size for maximizing a load. The stacking pattern is an important determinant of ventilation hole size and placement. The stacking pattern and load height must be known in order to calculate the minimum strength requirements for a package. This subject will be treated in more detail later.

E. Marketing. The expectations of the market must be fulfilled by a package in terms of size, weight, color, attractiveness, and information presented. The package should be convenient to set up and break down, accessible to inspectors, and easily recycled.

4. Packaging only works within the handling system

It is important in package design to consider the total handling system for the product of interest so that the box will fit into that system and maximize the benefits of the handling system. Several things should be considered before selecting packages:

- Is the product to be precooled?
- If so, will forced air cooling be utilized, or hydrocooling, or room cooling, or top icing?
- Will the product be shipped by air, by truck, by train, or by sea?
- Will the refrigeration system be a bottom air delivery one (most maritime containers), or top air delivery system (most road transport reefers)?
- Will the box be exposed to wet conditions requiring a waxed box?
- Will the boxes be loaded on pallets?
- Will the pallets be stabilized by wrapping or by rigid corner mounts?
- How long will the product be in transit before it is sold at the final market?
- What are the market requirements for package size, weight, color, quality of graphics and information?

5. The importance of measurement

How can we know what is the best cooling system, what is the best handling system and what is the best package? The answer is very simple: It is impossible to know without measuring performance. The goals of postharvest handling and packaging are clear - reduce temperature, reduce handling time and reduce handling steps. In order to optimize every aspect of handling, it is necessary to constantly measure temperature, time and handling steps. A simple approach to this is will be outlined below.

6. How to measure time and temperature from harvest through shipment

Step 1. Make a flow chart of your handling system. Start with harvest, then write a list of every step of handling. Every time the product is touched, handled or moved, write that down. When you are finished, the list should be a complete description of every step of handling. Number each step. It may be helpful to put this list of handling steps in a computer so copies can be made and modifications can be included. There should be such a list for every product handled.

Step 2. Place a temperature probe, either a thermometer or thermocouple, inside a piece of fruit or vegetable at the moment it is harvested. Take the list of handling steps compiled in Step 1 and write down the exact time and the temperature when that piece of fruit or vegetable was harvested. This must be the temperature of the inside of the fruit or vegetable, not the temperature of the air.

Step 3. Continue to record time and temperature every time the product is touched, handled or moved on the list next to the written description of that step. Continue this process until the product leaves your control.

Step 4. Graph the information after Step 3 is completed. On the vertical axis will be temperature and on the horizontal axis will be time. This will result in a complete time and temperature history of your product under your handling system.

Step 5. Study the time/temperature graph and look for any places where the temperature is above the optimal temperature for that commodity. In all of those places, attempt to alter your handling so that the temperature is brought to the optimal as rapidly as possible. Look for any steps where unnecessary time goes by while the product is waiting for the next handling step. Look for ways to improve product flow so that handling time is minimized. Study the different handling steps on your list. What is the function of each step? Are they all necessary? Look for ways to reduce handling steps.

Step 6. Continue this process continuously. Record times and temperatures every day and once every day look at the graphed data to find problems and correct them. Make this the responsibility of an employee. The person following the product and recording the temperature and time does not have to be a high level employee. You can train any worker who can read and write to do this job. But a manager should review the information every day to assess how godd a job he is doing and learn where changes will be most effective. The most efficient way to continue this process may be to use continuous time/temperature recorders, available internationally form several companies. But the first several days, perform the recording manually to get a true look at what you are doing. Do not treat the product with the temperature probe differently from any other product. Try to get accurate measurements that really reflect what happens every day.

Such a simple way to study your handling system will almost certainly result in improved product handling. In addition, it will almost certainly result in a more efficient system and will almost certainly save you money. Every produce packer and shipper performs unnecessary handling steps and pays more workers than necessary. Reducing these inputs can save money and make your operation more profitable.

Table 1. Example of time and temperature evaluation.

Let's use strawberries as an example since they are being harvested at this time of year.

HANDLING STEP	***TIME***	***TEMP.***
1. Harvest	0:00	12
2. Place in tray	0:01	12
3. Stack trays	0:10	12
4. Stage trays in field	0:20	13
5. Carry trays to packing house	0:50	14
6. Move trays to sorters	1:20	14
7. Take tray off stack and place on sorting table	1:25	14
8. Pick up berry	1:30	15
9. Place berry in punnet	1:31	15
10.Place punnet in carton	1:33	15
11.Fill carton with punnets	1:45	15
12.Carry carton to pallet	1:55	15
13.Stack cartons	2:15	15
14.Move pallet to cooler	2:45	14
15.Arrange pallets for cooling	3:30	14
16.Cool berries	3:40	14
17.Remove from cooler	5:30	2
18.Place in reefer	5:35	3
19.Reefer leaves for airport	12:30	6
20.Reefer opened at airport	13:30	5
21.Boxes of berries unloaded from reefer	14:00	5
22.Boxes of berries stacked	14:10	5
23.Boxes of berries loaded into air cargo container	17:00	7
24.Container loaded on aircraft	22:00	11

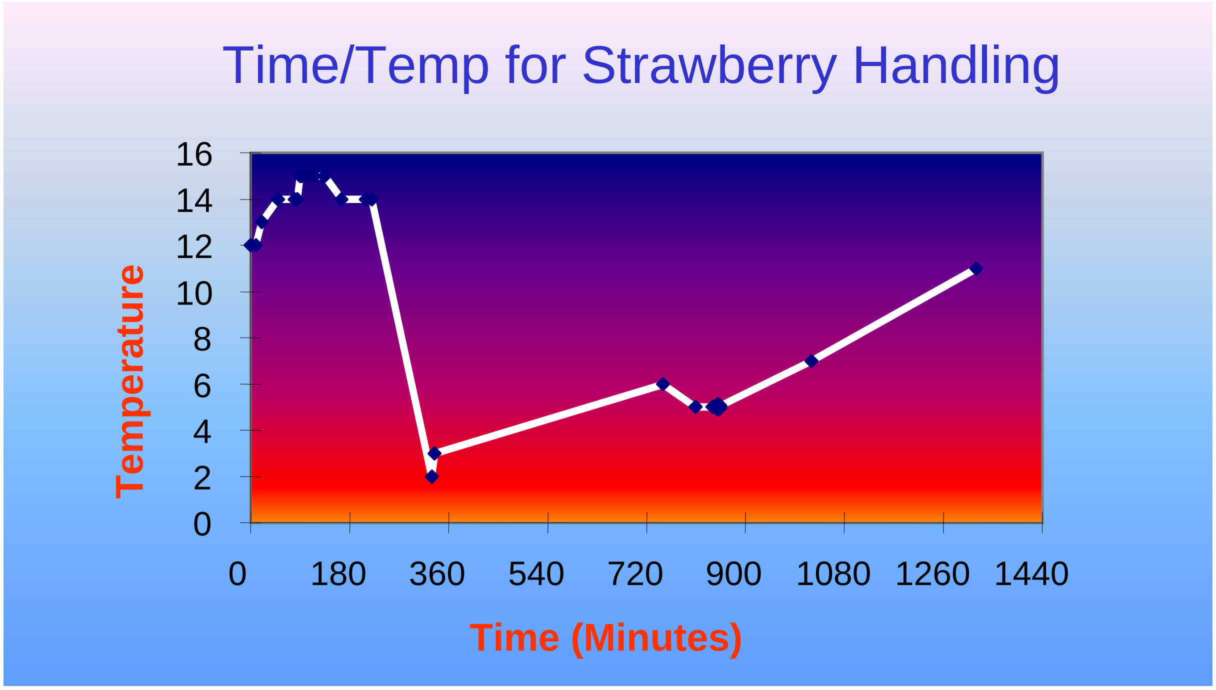


Figure 1. Graph of the results of a time and temperature analysis of strawberry handling.

The graph of this data clearly shows where product is warming, where product is waiting to be moved and where the problem areas are. For example, there are 15 operations requiring 220 minutes before the berries start to be cooled. What could be done to improve this? In this example, packing the berries in the field would eliminate seven handling steps and save two hours time before cooling. It would also save a great deal of money in labor, space and equipment and result in better quality berries with a longer postharvest life.

For field packing of strawberries, use small wheeled carts that can move between the rows of berries. Each cart holds a carton for packing berries. Each carton has its punnets already in it. The harvester picks a berry of the appropriate size and quality and places it directly into the punnet. This berry is then never touched again. When the punnets are full the carton goes to the cooler to be stacked on a pallet. When the pallets are full they are placed in front of the fan and cooled immediately.

Field packing of strawberries requires well trained harvesters. Train several crews. Each crew is instructed to pick only one quality class. Crews that pick Class 1 berries for export pick **only** Class 1 berries, every day. Crews that pick Class 4 or 5 for the local market pick only those classes. Thus, all classes are packed in the field in their appropriate container. Quality and consistency is improved because the crews become experts in recognizing their designated size and quality class.

This approach should be used for all of the commodities that you pack. It will save you money while improving the quality and shelf life of your products.

7. What is package "quality?"

How can we describe "package quality?" Quality is a relative term and will depend on the product handling system, the requirements of the market, the performance of the package and the price of the package. Thus, package quality will have many elements. Before it is possible to describe what constitutes "quality" in a package, it will first be necessary to describe the functions that a package must fulfill. The ability of the package to fulfill these functions will be the standard for determining quality.

A. Protection. The primary reason for using a package at all is to protect the contents of the package. In the case of fresh produce, it is usually necessary to protect the contents of the package from 1) injury due to compression, abrasion or impact, 2) extremes of temperature, 3) dirt, debris, insects and microorganisms, 4) moisture loss, 5) moisture accumulation, and 6) adulteration. In order to fulfill the function of protection, a package must have adequate strength, be of the proper size to prevent shifting of the contents, provide an adequate barrier to moisture loss or gain, and have a seal of adequate strength and durability.

B. Grades and Standards. Most markets have particular expectations for product quality and size. A package may facilitate sorting and grading by providing a unit for known quality and quantity. In this sense, a package should be designed to hold a particular size and amount of a given commodity. Furthermore, the package must meet the regulatory requirements of both the country of origin and the destination country in terms of size, color, and information provided by the package.

C. Transportation. Since produce must be transported to market, often over long distances, a package should be designed in such a way as to facilitate transportation. In the modern world this usually means that the package 1) adheres to international size standards, 2) can be stacked and palletized easily, and 3) has adequate strength to withstand the stresses of stacking and transporting.

D. Temperature Management. Temperature management is essential to delivering high quality produce to a distant market. The package design should facilitate temperature management by allowing adequate airflow in the proper directions, or by allowing sufficient cold water or ice to contact the product to effect rapid cooling. Furthermore, the package should retard rewarming if high temperatures are temporarily experienced during transportation and handling. The temperature management system may dictate the arrangement of ventilation holes, the resistance to moisture of the package, and the insulating qualities of the package as well as the stacking requirements during cooling and transportation. It is clear that the choice of a temperature management system will affect many aspects of packaging.

E. Materials. One must consider the suitability and availability of packaging materials. Which materials are available domestically? Which materials must be imported? What are the relative costs and availability's of different materials? What is the quality of available packaging materials? Are there multiple sources for the materials or is there only a single source? For example, you might determine that wooden boxes would be the most suitable package for a particular application. But the quality of wood actually available might be poor. Or there may be only a single source of wood for boxes and that source may be uncertain or unreliable. In this case, it might be wiser to use corrugated boxes if good quality corrugate is consistently available while wood is not. In this way, economic and supply factors might outweigh technical factors in the decision making process.

F. Assembly. Packages are most ideally stored flat so that they do not require excessive space. Such packages should be easily and rapidly assembled so that time and labor are minimized in their setup. Some packages are designed to be assembled, or partially assembled, by machine. Such considerations affect the package design.

G. Marketing. The appearance and specifications of the package can aid in marketing the product. An attractive box with the expected information and a respected label can sell faster and fetch a higher price than a less distinctive or poorly marked box. Since the object of business is to sell product, the value of an attractive box should not be overlooked.

H. Cost. In the real world, price is often the overriding consideration in all aspects of business. Packaging is no exception. A package should fulfill all of the specified requirements, but not more. Overdesign of a package can be as costly as underdesign. A box that must support an equivalent load of 200 kg should not be designed so that it supports 400 kg. This is wasteful of materials and costly. Boxes that are too expensive will not be used no matter how good they are, and all of the effort that went into their design and manufacture will therefore be wasted.

It is clear that there are many, often conflicting, requirements for a package. Any real package is a compromise among these different requirements. Consequently, package design requires thorough study of the product to be packaged and the handling system, thought about the different requirements for the package, knowledge of the economic, regulatory and marketing essentials, and imagination to combine all of the above factors in a satisfactory way.

8. How can we measure package quality?

The degree to which the package performs the above functions will determine the package "quality." How can we know how well the package performs those functions? **Measure them!** Take samples of several different packages supplied by different manufacturers. Pack your product in each of the boxes, place them all in the cooler and, using a thermometer and a watch, measure how long it takes for the temperature to be reduced to required levels. The box that allows most rapid cooling is the "best" box or the highest quality box with respect to cooling. Measure the compression strength of different boxes to determine which is the strongest. Do shipping tests of product in different boxes and measure quality, defects and injury when the product arrives at its market. Which box protects the product best? Color and design require more subjective decisions. After measuring and comparing the results for different boxes, it will become clear which is the "best." If no single box performs the best in all respects, compromises may have to be made. In addition, share the results of your studies with your package supplier. Or include the supplier in the test, so that he can improve his package design to better function in your handling system.

9. Package requirements and specifications

The design of produce packages must incorporate all of the considerations mentioned previously. As with all perishable products, every aspect of produce handling must be done correctly. If a single aspect of proper handling is neglected, the product quality can be lost. This is particularly important with packaging. By the time the produce is packaged, it has received a considerable investment in time, labor and energy. Its loss at this stage represents a much greater loss than if it were to be lost before harvest or earlier in the handling chain. Therefore, great care must be exercised in the design and use of a package. Although the package itself represents a significant cost, investment in packaging can often be the smartest place to put your money to protect an already considerable investment in the product.

Before package design or selection can begin, it is essential to define the specifications for the package. These will describe the performance, strength, size, durability, and other essential aspects of the package. In this way, it will be possible to objectively evaluate the suitability of a particular design for the application at hand.

A. Package Size. There are two major constraints on package size. These constraints are sometimes conflicting and a compromise must be found. First, the package must be large enough to hold the desired amount of product, but not so large that the product is able to move within the package and suffer abrasion injury. Second, the packages must be of a size that they fit efficiently into the transportation vehicle or vehicles.

The amount of product in each package is usually constrained by the requirements of the market. For example, it may be necessary to put 5 kg of product in each packaging unit. Once this requirement has been fixed, there are usually a small number of package sizes that will also load easily into the transportation vehicles. The trend in much of the world is to palletization of produce packages. Palletization facilitates loading and unloading, and results in standard units (hence the term unitization to refer to palletization) that can be handled easily all over the world. The agreed upon standard pallet size is 1000 x 1200 mm. There are many package sizes that will fit on such pallets, but several international organizations have recommended use of just a few of these sizes. The size options for packages that can be stacked on a standard pallet are given below in Table 2. The package size selected will be determined by the amount of product that must be accommodated and by the stacking pattern anticipated for the load.

Palletization of the load confers a number of benefits including reduced sorting, more efficient utilization of storage space because of higher stacking, a reduction in handling and consequent injury to the product, a reduction in labor and a reduction in distribution time. Assuming that the packages will be loaded on a standard pallet, then column (or modular) stacking or interlocking stacking are possible. Column stacking provides the greatest vertical load strength, while interlocking stacking provides greater lateral stability. To maximize the benefits of palletization, pallet loads should be established as soon as possible in the handling chain and remain unbroken as long as possible.

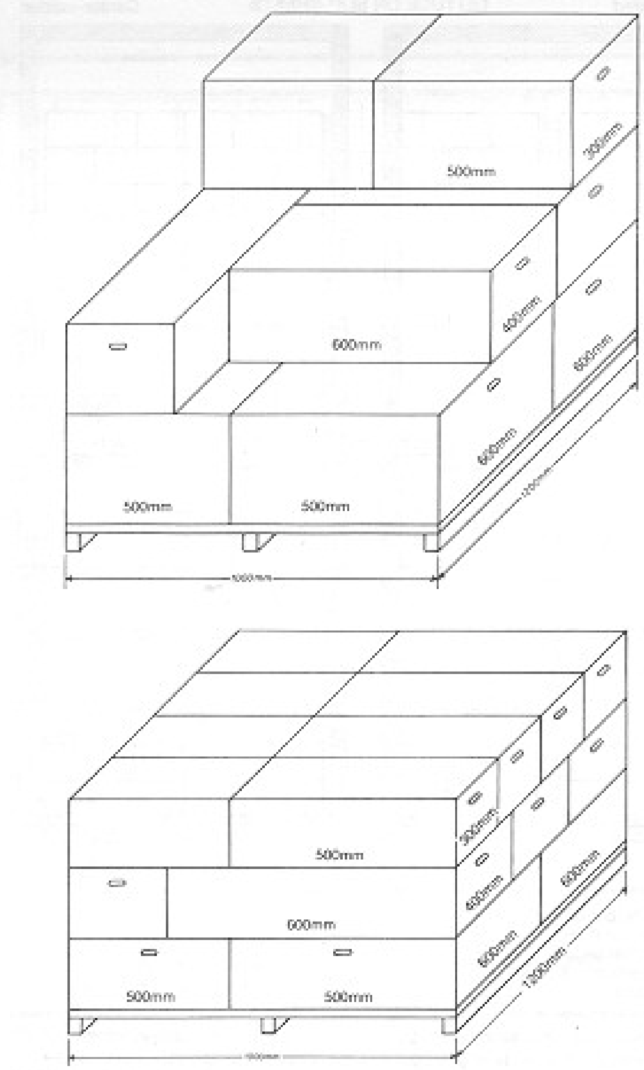
Table 2. Examples of Package Sizes (mm) For Stacking Patterns On A Standard Pallet.

600 x 500[A]	***600 x 400***[A,B]
600 x 333	600 x 266
600 x 250	600 x 200
520 x 240	500 x 400[A]
500 x 333	500 x 300[A,B]
500 x 200	433 x 333
400 x 400	400 x 333
400 x 300[A,B]	400 x 266
400 x 250	400 x 200
380 x 240	333 x 300
333 x 200	300 x 266
300 x 250	300 x 240
300 x 200	200 x 200

[A] Recommended by USDA: MUM (Modularization, Unitization and Metrication), USA.
[B] Recommended by OECD (Organisation for Economic Cooperation & Development), EEC.

B. Package Strength Requirements. A produce package must have the ability to withstand not just a heavy load of product inside and above, but also repeated loading and unloading (impact stress), high humidity conditions, vibration, impact, and heavy loads over long time periods. The choice of appropriate materials is very important to ensure that the package has the desired strength characteristics, and that the product is properly protected. Insufficient strength results in package collapse and resulting compression and abrasion injury which can cause loss of the product.

1. *Selection of Materials.* Many materials have been used for produce packages including wood, corrugated and polystyrene. Wood is the strongest of the three, but it is also heavy, relatively expensive, and inflexible. It is abrasive and can cause injury to sensitive commodities. Polystyrene is bulky, has poor heat exchange properties, and lacks strength. Corrugated is widely used worldwide due to its availability, versatility, light weight, strength, and price. However, corrugated can weaken in humid environments and, at its best, is not as strong as wood.



A MUM (Modular, Unitized, Metric) load.

a. Wooden Boxes. Wood for use in produce boxes must be inexpensive and easily worked. Poplar has been widely used for peeled boards due to its straight grain and ability to be cut in thin sections. Poplar is light wood which is an advantage during shipping. Pine wood has also been used for peeled boards but it is less appropriate than poplar for thin (less than 10mm) peeling. Pine is also heavier than poplar.

Wood used in package production should be well dried first to avoid cracking and growth of molds. Wooden boxes have been made from plywood, board and particle board. Plywood is usually made from birch wood. Since fastenings are the weakest part of a wooden box, care should be taken to ensure that all fastenings are sound. If difficulties in durability or strength occur with wooden boxes, wirebound crates can be used. Wirebound crates are more tolerant of variability in materials than are wooden boxes due to the many fastening points and reinforcing strength of the steel wire.

b. Corrugated Boxes. Many types of corrugated fiberboard (corrugated) have been used. For heavier loads (>10kg), double walled fiberboard may be used. The selection of raw materials for use in corrugated boxes is extremely important. The weight, or grammage, of the material is of no value unless the nature of the materials is also known as the strength properties of different types of paper vary widely.

Unbleached, virgin coniferous Kraft is considered the best material for the corrugated liner. It has high strength and stiffness properties and a low rate of moisture absorption. Materials based on recycled paper or hardwood fiber have poorer performance in high humidity environments and may result in strength reductions of 50% or more. Coating of the surfaces of the corrugated with wax or plastic material retards moisture absorption and, while useful, is not a substitute for using high quality materials. The best material for the fluting is semi-chemical deciduous paper, typically 112 to 127 grams per square meter. The use of poor quality fluting material can be compensated for by increasing the basis weight or grammage.

2. Calculation of Strength Requirements. The strength of wooden boxes fabricated from good quality materials is generally adequate for the protection of fresh produce. If boxes fail, it is because of poor quality wood materials, or poor quality fabrication. Polystyrene boxes generally lack adequate strength to protect fresh produce during lengthy journeys or under transportation conditions. Failure of the box is common with consequent loss or degrade of the produce. As corrugated boxes are the most commonly used produce containers in international commerce, and as their strength is variable and controllable, the rest of this discussion will concentrate on the calculation and design of corrugated box strength characteristics.

The quality of paperboard is largely determined by two measurements; *caliper* is a measurement of the thickness of the paperboard. Paper with a caliper greater than about 0.20mm is considered paperboard. Basis weight measures the grade of paperboard in grams per square meter. Paperboard of higher basis weight will tend to be stronger because it contains more fiber. Corrugate is made by laminating fluted paperboard between sheets of paperboard liner. This process confers great strength while using minimal materials. The strength of the corrugate depends on several parameters including the amplitude of the corrugate, the mean wavelength of the corrugate, and the thickness of the paperboard. For our purposes, we will concentrate on the overall thickness of the paperboard as it is most easily manipulated by the manufacturer, and changes in thickness alone will greatly affect overall strength.

For corrugated boxes fabricated with given materials, several factors will affect the total box strength. The vertical strength of a corrugated box (the direction that supports the greatest load) is called the Top-To-Bottom Compressive Force. It depends primarily on the paperboard caliper or thickness, the container perimeter (twice the length plus twice the width), and the Edgewise Compressive Strength of the corrugated. The edgewise compressive strength, in turn, is a function of the quality of the materials and the basis weight of the paperboard. It is possible to use values for these three parameters to estimate the top-to-bottom compressive strength of a box (See Appendix 1). However, several factors will cause the strength of the box under normal conditions to be less than the calculated strength. If boxes are not stacked so that the corners and edges are in exact alignment, the load will not rest on the strongest part of the box below. This, in effect, results in the box being able to support less weight than expected. When boxes absorb moisture in high humidity environments, they are weakened. Vibration and impact during loading and transportation will weaken corrugated boxes. In addition, bearing a load over a long period of time will further weaken a box. Therefore, when calculating the effective strength of a corrugated box, it is necessary to include correction factors to take into account the above strength reductions. Such factors are presented in Appendix 1 of this report. Appendix 1 provides a short summary of how to calculate corrugated box strength requirements as well as how to calculate expected strength of a box under specified conditions.

3. Ventilation. Providing proper and sufficient airflow around the packaged product is crucial to the maintenance of product quality. Airflow helps prevent the accumulation of condensed moisture which can promote decay. Adequate airflow also maintains proper temperature of the product. Even pre-cooled produce continues to produce heat through respiration. Airflow is necessary to remove this respiratory heat. Finally, ventilation is necessary to allow proper pre-cooling of the product to remove field heat.

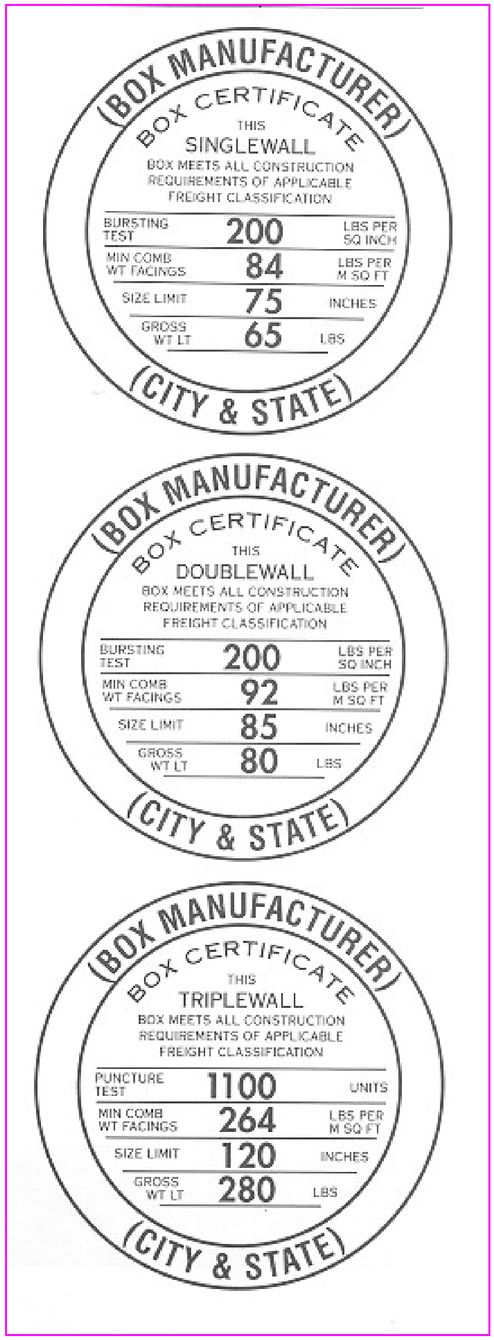
The general rule is that ventilation holes should represent approximately 5% of the surface area of the face of the box. Fewer large holes are preferable to many small holes. Holes should not be near the edges of the box, especially near the vertical edges which bear the greatest load and can be weakened by the proximity of ventilation holes. The spacing and placement of ventilation holes will be determined by the temperature management system employed. For room cooling (room cooling), holes should be evenly spaced around the sides of the box and away from the corners. To provide for forced air cooling, the ventilation holes should be on only the long sides of the box and may be near the upper edge of the box. In both cases, the ventilation holes should be placed so that they align from box to box and allow airflow through the entire load. Boxes suitable for top icing or hydrocooling must have top and bottom vents to allow for the vertical movement of ice or water. Boxes that will be shipped in maritime containers or overland reefers with bottom air delivery systems should also have top and bottom vents to allow for the vertical movement of cold air.

C. PACKAGE TESTING

Package testing should occur in several discrete stages of package development. 1) The theoretical basis of the package design should be evaluated for its suitability to the requirements that the package will actually face; 2) Packages should be tested in the laboratory during development to evaluate how they perform on a series of standard tests; 3) Storage and distribution field tests should be done; 4) Full scale commercial tests will provide the ultimate verification of the package performance. Because these tests become progressively more expensive and time consuming as the package moves from theory to lab to field to commercial use, it can save a great deal of money to detect package problems early on, rather than after the package is in commercial use.

A second goal of package testing is quality control. It is imperative that the user receive packages that will perform according to the claims of the manufacturer.

Package testing can detect problems early on in the development cycle and accelerate the development of better packages. Testing under controlled conditions, using standardized tests, allows comparison of different packages and selection of the best one for a given application.



A number of standard packaged tests have been devised to assess the strength and durability of cardboard boxes. They fall into a few main types: 1) Compression testing, 2) Vibration testing, 3) Shock or impact testing, and 4) Water absorption capacity. There are many different tests for these qualities, but the ISO (International Standard Organisation) tests are widely accepted.

Probably the most useful test for Egyptian manufacturers, to give the best indication of package performance, would be a carton compression test. In this test, a completed carton is placed be tween two horizontal metal plates. The carton is squeezed by the plates until the carton fails and the required force is recorded. The test must be performed under standard conditons of carton moisture content and must be repeated for several cartons from the same manufacturing run taken at different times during the day. The results of this test should be stamped on the bottom of the box so that they buyer knows how much strentgh to expect from that box.

D. Required Information

The European market requires certain label information to appear on every carton:

Country of origin
Name of the produce (i.e. strawberries, mangos)
Class of produce
The size or number of units in the carton for many commodities

The identity of the packer

10. Package management

How the produce package is used will largely determine is success and "quality." Oftentimes when packages collapse, the shipper blames the carton manufacturer and says that the packages were of poor quality. Most of the time the real problem is that they were not stacked properly on the pallet so that the corners and edges align. Consequently they were not able to confer strength as they were designed to do. Buying a stronger box is the expensive solution to the problem. Training workers to stack the boxes better and using boxes with interlocking tabs to ensure that they are aligned properly would solve the problem more cheaply.

A. Stacking

In order to utilize the strength of packages, they must be stacked properly. The main top to bottom strength of a package is conferred by the corners and secondarily by the horizontal edges. If the corners and edges of packages do not align with those of the package above, the strongest part of the package is not being used. The result will be package collapse. Often exporters or buyers will complain that boxes are not strong enough when the real problem is that they are not being properly stacked. Before paying extra money for a stronger box, learn to utilize the strength of the box through proper stacking.

Since the bottom boxes on a pallet bear the greatest load from above, the first two layers should be column stacked - that is the corners of the boxes in the bottom two layers should exactly align. For certain commodities, layers above the first two may be cross stacked - that is the long axis of one box is above the short axis of the box below. Cross stacking provides horizontal stability of the pallet load but provides less top to bottom strength.

B. Palletizing

Boxes of produce are most easily handled on pallets and most exported produce will probably be palletized. In that case, boxes need to conform to sizes that fit on pallets and fully utilize the space on the pallets.

Various kinds of techniques have been developed to aid stacking of boxes on pallets. Corner posts and side walls can be used to align boxes while they are being stacked on the pallet.

After the boxes have all been placed on the pallet, strapping may be placed around the pallet to provide lateral stability during transport. This ensures that the boxes stay aligned and reduces the chance of box collapse.

C. Temperature maintenance

Once the product has been precooled and stacked for transport, the boxes must allow continued access to cooled air to maintain the product temperature. In order to perform this function, there must be adequate ventilation holes on the boxes and those holes must be aligned from box to box so that the cooled air has access to the product, even in the center of the pallet.

For product sent on maritime containers with bottom air delivery systems, there need to be ventilation holes on the tops and bottoms of all boxes and those holes need to align during shipping. For shipment by land in top air delivery reefers, ventilation holes around all four sides of each box need to align.

D. Loading

Boxes should be loaded into containers, whether palletized or not, in straight stacks and in such a way that the cold air from the container can circulate through the boxes and cool the product. Different loading patterns are approporiate for top air and bottom air delivery containers and can be found in any of several transportation manuals. In very hot or cold conditions, the product should be center loaded, awat from the sidewalls which can transmit too much heat or cold. Center loaded product can be braced against the sidewalls using cardboard or polystyrene spaces.

11. Cleanliness and sanitation

There is a great concern in Europe and in the United States about the potential for fruits and vegetables to be sources of human pathogens. There have been several instances of people getting sick from eating fresh fruits and vegetables produced in several countries. The parasite *Cyclospora* on raspberries from Guatemala made many people sick in the United States. Apparently dirty water was used to mix and spray pesticides on the berries which transmitted the pathogen to the fruit. The result is that Guatemala is no longer able to export raspberries to the United States. A single producer was not careful about sanitation and it killed an entire export industry.

For this reason, it is very important that Egyptian growers, packers and exporters increase their awareness and attention to sanitation and food safety. Despite the best efforts of all involved, a food borne illness outbreak attributed to Egyptian produce could destroy the Egyptian export industry over night. This is a serious matter and at this time there is very little awareness of food safety in Egypt.

Although fresh produce is generally not a favorable environment for the growth of pathogenic microorganisms, produce can become contaminated through contact with infested irrigation water, animal manure, workers practicing poor hygiene or environmental contamination in packing houses or processing facilities. While many packinghouses are kept clean, cleanliness is not the same as sanitation. Sanitation requires that surfaces be cleaned and then treated with a sanitizer (chlorine and quartenary ammonium compounds are the most common). Sanitation requires that any water that contacts produce be potable and that workers who handle produce **always** wash their hands with soap after using the bathroom.

Fresh produce is food, often eaten without cooking to kill microorganisms. The basic principal of cleanliness is that if you and your family would not take your meals on a surface, fresh produce should not be on that surface. Similarly for corrugated cartons. They contact the produce and so should be clean. The facilities where they are manufactured should also be clean so that dirt is not transmitted to the produce.

12. Package design for Egyptian export commodities

Mango

Egyptian mangos are primarily exported to the Gulf states. These Egyptian varieties are very sweet but tend to be green rather than red colored and the fruit is fibrous so they may not be accepted in the European market. Mangos are often shipped in 4 kg boxes.

The primary consideration in mango packaging is to protect the fruit from mechanical damage. A key issue is that fruit of uniform size fit efficiently into the shipping boxes. Inserts may be used to cushion or separate the fruit. The boxes should have ventilation holes to allow cooling during transport, although mangos should not be cooled below 10-12C. The ventilation holes should be on all sides as well as the top and bottom of the box to allow cooling in trucks and in maritime containers.

The boxes need sufficient strength that they do not collapse when held in high humidity conditions. Since mangos are not forced-air cooled, there should be no ventilation holes on the edges of the box. If the boxes are stacked well, the corners and edges will bear the weight from above and give sufficient strength. If carton strength is not sufficient and cartons are collapsing, reinforced corners my be useful. Boxes need to by stacked carefully so that edges and corners align with boxes above and below. Otherwise the strength of the box will not be used well and the boxes will collapse.

Grape

Boxes need to accommodate either 5kg or 8.3 kg of grapes. The boxes are lined with perforated plastic to prevent moisture loss from the grapes. If grapes lose moisture, the rachis or stem becomes brown and the price of the grapes goes down. Grape bunches are typically placed in plastic sleeves as they are packed and the sleeves need to be suitable for 500 gms of grapes. The sleeves may have ventilation holes to allow air movement and prevent formation of condensation. The sleeves are placed in the grape box inside the perforated plastic liner to maintain moisture and SO_2 inside the box. A corrugated or other cushioning pad is often placed in the box first and the bags of grapes placed on it. A pad that emits SO_2 is placed on top of the grapes after packing and the box closed.

The box should have side ventilation for forced air cooling. Consequently, since the edges of the box will not be available to provide strength, the corners may be reinforced to make up for this. Tabs or stacking guides built into the box design are helpful to assure alignment of the boxes during stacking. The ventilation holes should align when the boxes are stacked on pallets.

Since grapes can be stored for more than a month at 0C, the boxes must be especially strong to avoid collapse due to absorption of moisture. Measurement of carton crush strength after exposure to high humidities will give the best indication of strength. The carton should be able to withstand a minimum of 45 days at 95% relative humidity with 19 layers of cartons on top.

Strawberry

The punnets currently used for packing strawberries in Egypt are not suitable for Egyptian handling practices. Punnets need to be vented on all four sides on the upper and lower part of each face to allow proper cooling of the berries. If the punnets are not adequately ventilated, as is the case with current punnets in Egypt, the cold forced air cools the punnet but not the berries. The warmer berries release moisture which condenses on the colder punnet resulting in drops of water which allow the growth of decay fungi. The punnets should also have top and bottom ventilation to allow for shipment within Europe in bottom air delivery trucks. The plastic pads that go in the bottom may not be necessary. If the bottom of the punnet has raised channels to allow condensate to stay away from the berries and the berries are packed carefully and handled gently the plastic pad may be unnecessary.

Strawberry punnets need to accommodate 500 gms going to the wholesale markets or 250 gms for those going to supermarkets. Current 250 gm punnets are too small for large berries and mixtures of large and small berries in the same punnet reduce their value in the European market. For exporters selling directly to supermarkets, it would be worth exporting the possibility of packing punnets in bins and sending them in that form. The punnets may have to be stronger than those currently in use. However, this strategy would dispense with corrugated containers completely, thus allowing far more strawberries to be packed into air cargo containers.

A strawberry carton is designed to be used with forced air cooling, which is a necessity for export strawberries. In forced air cooling, an air pressure differential caused cold air to be forced around the berries, thereby cooling them. Since the air is forced to move in only one direction, the ventilation opening on the box should direct the air in that direction only. The sides of the box in the long direction are cut away to allow air movement. There should also be ventilation holes on the bottom of the long sides to allow cold air access to the ventilation holes on the lower face of the punnets. The box must be deep enough to allow about a centimeter of space above each punnet so that the box above does not place weight directly on the punnet. The box should carry all of the weight. In this way the box and the punnet can work together to effect rapid and efficient cooling of the berries.

Because the sides of the box are cut away to allow air movement, those sides contribute relatively little to strength. Reinforcing the corners of the box, where most of the load is borne, will help strengthen the box. It is also very important that the boxes be stacked in very straight columns, both to effect rapid cooling and to utilize the strength of the carton in the most efficient way. In some cases, a cross piece is included dividing the box in two halves, thereby increasing the strength.

Melon

Egyptian Galia melons have the potential to be shipped to Europe by sea if they are harvested at the proper maturity and there is great uniformity of size, color and maturity among the fruit.

A melon box must prevent the melons from rubbing against each other. The delicate netting can be easily rubbed off resulting in excessive moisture loss through the injured skin. Loss of weight, shriveling and decay can result. Inserts or padding to hold the melons and restrain their motion during shipping are typically used.

For shipping by sea, the box needs vent holes in both the top and the bottom to allow access to cold air from the typical bottom air delivery systems in ships holds and maritime containers. The holes should align when the boxes are stacked. The inserts for pads that hold the melons must fit in the box in such a way that they do not occlude the ventilation holes. Ventilation holes in all four sides of the boxes are necessary to allow air access while in cold storage rooms or top air delivery trucks.

In the European market the preference is for the top of the box to be open or partially open so that it is easy to see the fruit. Reinforced corners are often used to confer additional strength to the carton. The box should be deep enough that the melons are not contacted by the box above so injury to the delicate fruit is avoided.

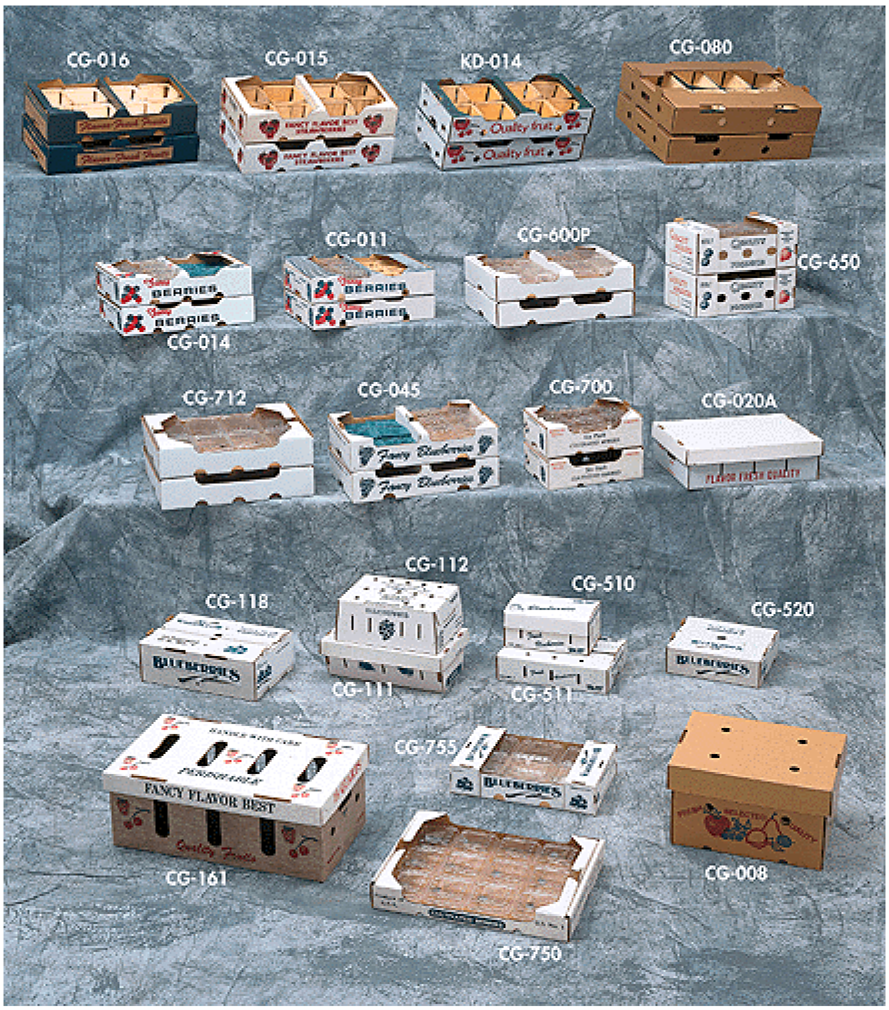
Melons going to supermarkets or individual buyers can be packed in bulk boxes, like apples, but pads must be included to prevent the fruit from rubbing against each other. Any such box must, of course, be acceptable to the buyer.

Green Beans

Beans are exported by air and many are being prepacked in 250 gm or 500 gm perforated plastic or mesh sleeves. There is increasing demand for topping and clipping of the beans on both ends. Take care that knives for clipping are very sharp and clean. Otherwise the beans will be damaged and they will decay during shipping. Typically beans are washed or hydrocooled to remove field heat and to rehydrate the beans. Beans are very sensitive to moisture loss and will be considered poor quality if they are dehydrated and limp. Beans are chilling sensitive and should not be held for significant periods below about 5-7C. Chilling damage is expressed as development of brown discoloration (russetting), sunken lesions and the early development of decay.

Cartons for beans need ventilation holes on all sides to allow the beans to be cooled during transit. Because beans lose moisture readily, bean boxes tend to absorb that moisture and can become weak. Boxes coated with water resistant plastic coatings may be useful to prevent this. If plastic coated boxes are not used, extra strength should be designed into the box to resist the weakening caused by moisture absorption. Many box designs are appropriate for beans and most are simple boxes with folding top closures.

Figure 2. Examples of some of the many strawberry box designs in commercial use.



APPENDIX 1: Determination of Package Strength Requirements[1]

1. Determine stacking pattern. This will be based on pallet size (generally 120cm x 100cm), package size, mass of each package when full, and depth of load (number of packages in the stack).

2. Calculate the static load on the bottom container due to the dead weight of the column above it.

3. Use a correction multiple for stacking misalignment because misalignment weakens the load. This is typically about 1.2 times. If the bottom rows are packed in an interlocking pattern, use a factor of 1.5.

4. Divide by a correction factor for the duration of travel because the load weakens over time. For a duration of 10 days, this factor should be about 0.65.

5. Divide by a correction factor for high humidity cold storage conditions because boxes are weaker when they are cold and wet. Assuming 25% RH and box moisture content of 6% under ambient conditions, and 85% RH and box moisture content of 16% in cold storage:

$$P_2/P_1 = 10^{3.01 \times 0.06}/10^{3.01 \times 0.16} = 0.50$$

[1] After ***Peleg, K. 1985. Produce Handling, Packaging and Distribution. AVI Pub. Co., Inc., Westport, CT***

6. Multiply by a safety factor for dynamic shock and vibration during loading and transit. A dynamic load safety factor of 1.5 is reasonable.

7. Write the total vertical strength requirements for the box.

8. Choose board configuration and calculate P_m, the edgewise compressive strength. In the absence of better information from the manufacturer, assume the following strengths:

A flute:	6.8-7.6 kg/cm
B flute:	5.2-7.3 kg/cm
C flute:	5.4-7.5 kg/cm

9. Estimate compression test force using McKee's formula as follows:

$$P = 5.87 P_m \sqrt{(hZ)}$$

where:
P = top to bottom compressive force.
Pm = edgewise compressive strength of the fiberboard.
h = board caliper.
Z = the container perimeter.

10. Compare the results of this calculation with the necessary compressive strength calculated above. If the two do not compare well, adjust the design of the carton appropriately.

Glossary of Packaging Terms

Abrasion or Vibration Injury: Caused by rubbing of the epidermis of the product against a harder surface such as the inside of the container, or against adjacent fruits or vegetables. Excessive vibration results in abrasion of the produce. Vibration injury will be exacerbated by transport: on vehicles with small wheels, on vehicles with poor or no shock absorbers, on poor roads or in incompletely filled containers.

Basis Weight: Measures the weight of fiber in cardboard in grams per square meter. Also called grammage.

Board Bursting Strength: The force necessary to puncture a sample of cardboard in a direction perpendicular to its axis, under specified conditions. Although widely used, the results of this test are not generally considered to correlate well with container strength under practical conditions.

Caliper: The thickness of a piece of cardboard or liner.

Carton Types:

Folder: Box consists of a single piece of fiberboard that can be set up without stitching, stapling or taping. Locking tabs, handles, display panels, etc., can be incorporated into the design.

Ready-Glued: Box consists of a single piece of fiberboard that is shipped flat and is ready to use by simply setting up.

Rigid: Two separate end pieces and a body. It requires stitching or similar operation before it can be used.

Slide: Several pieces of liners and sleeves sliding in different directions into each other.

Slotted: One piece of fiberboard with a stitched, taped, or glued manufacturers joint and top and bottom flaps. It is shipped flat, ready to use, and requires closing by using the flap provided.

Telescope: More than one piece of fiberboard, characterized by a lid, bottom, or both that telescopes over the body of the box.

Column Stacking: Stacking containers directly in columns so that the sides of each carton are directly above the sides of the container below it. This pattern results in the greatest stacking strength, but provides little stacking stability. Usually, the two bottom layers of a pallet load should be vertically stacked. The upper layers should be stacked in an interlocking pattern.

Compression Injury: Injuries to the produce caused by the product bearing a load, rather than the carton. This typically happens when cartons are overpacked with produce (causing bulging of the container), or when the vertical load strength of the carton is insufficient to support the product above. When this occurs, cartons collapse and compression injury results.

Compressive Force Versus Container Deflection Curve: See **Top-To-Bottom Compression Test**.

Conduction Type Cooling: The commodity cools through a gradient between the warm product and the colder air surrounding it. Movement of air is not involved.

Containers:

Box: Rigid container with closed faces.
Carton: A corrugated cardboard (fiberboard) box.
Crate: Rigid container of framed construction joined together with nails, bolts, or any equivalent fastening.
Tray: Shallow, unlidded container.

Creep: The response to a static load over a period of time. A box will gradually weaken under a certain load if the applied load is left for a sufficient period of time. This gradual weakening is referred to as creep.

Divider: Device made of various materials that separates the space within a container into two or more compartments, spaces, cells, or layers. Dividers may be plain, interlocking, scored, horizontal, vertical, or diagonal. Their primary purpose is to separate the articles, provide cushioning, or both.

Edgewise Compressive Strength: The edgewise tensile strength of a piece of corrugated cardboard or facing material. Beyond this limit, the material will bend and buckle. This is determined by the properties of the paper used in fabricating the cardboard (facing and corrugation as well as the quality of glue and gluing lines). This is measured by a standard "Edgewise Compressive Test."

Equilibrium Moisture Content: The percent moisture absorbed by a corrugated container under specified temperature and relative humidity conditions. At any given relative humidity, the equilibrium moisture content will be higher at lower temperature.

Facing: The paper material forming the faces of the corrugated paperboard. Also called the "sheeting."

Fiberboard: Corrugated cardboard.

Fluting: The corrugated inner lining of cardboard.

Full Telescopic Container (FTC): A corrugated box with a telescope top that slides on and extends all the way to the bottom of the carton.

Grammage: See **Basis Weight**.

Impact Injury: Injury to the produce due to a blow or impact. Such injuries result from dropping the container onto the floor, the truck, or the pallet.

Interior Tray: Type of interior packing made of corrugated or solid paperboard or other material, consisting of a sheet with four edges creased and turned up at right angles to support an object or to separate one surface from another.

Interlocking Stacking: This is a stacking pattern where each carton is offset relative to the carton beneath it. There are many types of interlocking patterns. These patterns lend stability to the stack, but provide less stacking strength than does column stacking.

Jumble Pack: Random, bulk filling of produce into a container.

Kraft Paper: Paperboard manufactured with two layers of paper. The primary layer consists of course but strong fibers. The secondary layer consists of more highly treated, smooth fibers to confer the smoothness required in cardboard boxes.

Liner: Generally any liner or nonadhering lining material that separates a product within a container from its basic walls; or, in cardboard, the stiff paper that holds the fluting.

Maximal Compressive Strength: The compressive force which causes the container to fail by creasing and buckling.

Pad: A corrugated or solid fiberboard sheet or other material used for extra protection or for separating tiers or layers of articles when packed for shipment.

Paperboard: The stiff, multilayer paper used to make cardboard.

Place Pack: Manually placing produce in a specific pattern into a container.

Puncture Injury: Injury to produce from a sharp object that penetrates the skin of the product. Such injury typically is caused by nails, wires, splinters, fingernails, forklifts, or rigid parts of other fruits or vegetables.

Pyramid Crate or Pyramid Carton: A container that forms the plinth of a pyramid in its vertical direction. Typically used to pack asparagus bunches in a vertical position to accommodate the increasing thickness of the stems toward the base.

Regular Slotted Containers (RSC): A corrugated box that may or may not have a top, but if it does, the top does not extend all the way to the bottom of the carton and thus does not contribute to top-to-bottom compressive strength.

Ring Crush Test: A test of the static tensile loading strength of a sample of a rolled strip of paper of specified dimensions under controlled conditions. This value relates the strength of the fabricating material to the edgewise compressive strength of the fabricated corrugated paperboard. Theoretically, the edgewise compressive strength of the paperboard should be equal to the combined ring crush values of the facing and the corrugating medium. It is therefore very important to the fiberboard manufacturer.

Slipsheet: A sheet of strong paper, cardboard, or plastic sometimes used in place of a pallet.

Stacking Pattern: The pattern in which boxes are stacked inside a truck, or on a pallet. The stacking pattern affects the load strength of the containers as well as the stability of the load. Also, a misalignment of boxes of 15-20 mm may reduce stacking strength by 50%.

Standards: Several international organizations have devised standards for produce package dimensions. Such standards are meant to facilitate unitization, and to streamline international trade of produce. The main organizations proposing standards are as follows:

> **ISO**. International Standard Organization.
> **OECD**. Organization for Economic Cooperation and Development.
> **USDA**. United States Department of Agriculture which has formulated the **MUM** standard (Modularization, Unitization and Metrication).

The first two groups have proposed European standards. The third has formulated American standards. All three groups advocate use of standard pallets 100cm x 120cm, with several standard box sizes. The standard European boxes are 60x40cm, 50x30cm, and 40x30cm. The American standards would allow, in addition, boxes of 60x50cm, and 50x40cm.

Static Strength: The strength of a container under a static or unmoving load. This includes the dead weight of the load on top of the container, strapping forces from strapping a pallet, and internal or outward static compression exerted by the product inside the box.

Top-To-Bottom Compression Test: Evaluates the stacking strength of cardboard boxes, rather than the strength of the components used in their manufacture. As such, it is very useful in evaluation of carton performance, although it is still not widely reported by box manufacturers. The main feature of such tests is a "Compressive Force Versus Container Deflection Curve." This curve represents angular deflection of the container under gradually increasing loads at a given temperature and relative humidity. Two points on such a curve are of critical importance: (1) Critical Deflection is the point at which unacceptable damage to the produce occurs. (2) Maximal (Yield) Compressive Force causes container collapse. Depending on the type of produce packed, containers without internal dividers typically have Critical Deflections of about 70% of Yield Compressive Force. Both points of the curve should be reported in the results of the test.

Unitized Containers: Containers stacked and stabilized on pallets and ready for shipping.

Wirebound Crate: A crate that is secured by wire that wraps around the crate. Typically used for beans, melons and other commodities. Allows maximum airflow and strength. infold a product for storage, shipment, or sale.