THE ECONOMIC ROLE OF THE APPLE REFRIGERATION INDUSTRY IN LEBANON

BY

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To my family :

My father, Mansour,

my sisters, Mona and Bouchra,

and my brother, Bassam.

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Abstract

Throughout the war period in Lebanon, the apple refrigeration industry suffered from destruction and disorganization. After the war, the reconstruction plans did not include this industry. Therefore, a chaotic construction of small non-developed refrigerators took place in different regions based on the financial interests of the owners. Further, the quality of results in apple refrigeration was and continues to be a conflicting issue between the owners of the refrigerators and their clients. This study provides a survey and an evaluation of apple refrigeration and focuses on the gaps and shortcomings in its functions. It proposes to measure the capacity and demand of apple refrigeration, and then compare them among various regions in Lebanon. The differences shown suggest either an increase in the refrigeration capacity in specific regions and / or change in the functional use of the refrigerators where there are idle capacities.

(82 pages)

CHAPTER ONE

APPLE REFRIGERATION

History and Scope of the Industry

Refrigeration as an art had been known for thousands of years. There are references to the use of ice cellars in an ancient Chinese collection of poems, Shi ching, in 1000 B.C.. The Greeks and Romans have insulated snow cellars with grass, earth, and manure in which they stored tightly compressed snow. The Indians, Egyptians, and Esthonians have chilled water and even produced ice by placing water in shallow, porous clay vessels, then leaving these overnight in holes in the ground. Also, east Indians have put in water certain salts, such as sodium nitrate, to lower its temperature in the fourth century A.D. (Jordan, 1956, p.3).

Refrigeration by Natural Ice :

Frederic Tudor started the first large-scale commercial venture in the refrigeration field in 1806, by shipping a cargo of 130 tons of cake ice to Martinique, West Indies. Frederic lost money in the shipment since ice was unknown in Martinique and no storage facilities were available for its preservation. Later on, by the construction of ice houses at different harbors, and by the use of pine sawdust as an insulation during the transportation of his ice cargoes, he turned his idea into an extremely profitable business which has changed the lives and habits of people throughout the world. By 1864, he was shipping to 53 ports in various countries. And by 1880, the methods he had used were replaced by the manufacture of artificial ice (Jordan, 1956, p.3).

Refrigeration in the Nineteenth Century :

In 1790, Thomas Harris and John long patented the first refrigeration machine in Great Britain. Few years later, the American Jacob Perkins patented a machine, which used ether as refrigerant, working with a hand-operated compressor. In 1860, Dr. James Harrisson made the world's first installation of refrigerating equipment using sulfuric ether in a brewery. At the beginning of the 1890s, compressors were driven by steam, the operating speed of large units was within 50 rpm, and it had a huge size. Besides, absorption refrigeration systems were widely used using ammonia as refrigerant (Jordan, 1956, p.8).

Refrigeration in the Twentieth Century :

The Refrigerating Machinery Association was formed in 1903 and the American Society of Refrigerating Engineers in 1904. In 1905, Gardner patented his famous multiple effect compressor, in which the refrigerant gas from two different evaporators at different pressures could be drawn in and compressed in a single cylinder. By 1904, New York stock Exchange was air conditioned by 450-ton cooling system. Compressor speeds had been raised to between 100 and 300 rpm by 1911. Refrigeration became widely used in the oil- refining industry. Even as late as 1919, various members of the American Society of Refrigeration concluded that household units had few if any possibilities. 1937 was the peak production year of the refrigeration and air conditioning industry (Jordan, 1956, p.13). In the middle part of the century, refrigeration became a giant and rapidly expanding industry. This rapid growth was the result of several factors. First, the development of precision manufacturing methods enabled the production of smaller and more efficient equipment. Second, the development of "safe" refrigerants and the invention of the fractional horsepower electric motor enabled the production of small refrigerating units which are commonly used as domestic refrigerators and freezers, small air conditioners, and commercial fixture (Dossat, 1961, p.121).

Few people are acquainted with the crucial role that refrigeration has played in the development of highly technical societies which are also dependent upon technical refrigeration for their very existence. For instance, mechanical refrigeration made the preservation of food possible in sufficient quantities to feed the growing urban population. Besides, the heat of the summer months makes too many buildings untenable without air conditioners and refrigerating equipment (Dossat, 1961, p.121).

Moreover, mechanical refrigeration enabled the construction of roads and tunnels and the sinking of foundations and mining shafts through and across unstable ground formations. With mechanical refrigeration, the production of plastics, synthetic rubber, and many other raw and useful materials became possible. It helped the bakers to get more loaves of bread from a barrel of flour and the textile and paper manufacturers to speed up their machines and get more production (Dossat, 1961, p.121). Besides, there are many applications of refrigeration in the medical profession such as the treatment of some physical ailments, and cold anesthesia etc... (Jordan, 1956, p.14).

Refrigeration in Lebanon:

In Lebanon the apple refrigeration industry is still disordered and chaotic. It witnessed the destruction of many refrigerators - of huge size - in the years of war, and the unplanned construction of small ones afterwards. There are no existing studies or plans regarding refrigeration education, capacity and demand, and regional distribution of apple refrigeration in order to organize and evolve this refrigeration sector. This study defines the foundations of apple refrigeration, and sheds the light on the requirements of the development of this industry.

Permit Situation: In order to have a permit for a refrigerator the following documents should be presented to the health administrations in the province:

1)a construction permit if the building is under construction, or the execution maps signed by the engineer and the Engineering Union, if the building is not constructed yet. 2) a document that justifies the occupation of the building, rent or ownership document etc. . 3) photocopy of the identity card if a person is applying for the permit, or of the business record if an establishment is applying. 4) a land - surveying certificate for the lot from the Art Office. 5) two copies of detailed maps showing interior divisions, equipment distribution, and the disposal of sewage, scale 1/100. 6) two copies of the cite map showing the location of the building in the lot scale 1/10000. 7) habitation permit or building accomplishment for building done before 1964.

Then a tax due should be paid for the third class - 300,000 l.l. - for the second class - 400,000 l.l. - for the first class -500,000 l.l. After that, a statement for publication should be sent to the municipality that publish it for fifteen days for the third and second class, and for thirty days for the first class. After the publication period, the health inspector comes to the place for inspection, then the permit is given (Ministry of health).

Classifications and Applications

There are five general categories of refrigeration applications: (1) domestic refrigeration, (2) commercial refrigeration, (3) industrial refrigeration, (4) marine and transportation refrigeration, (5) and air conditioning (Dossat, 1961, p.122).

Domestic Refrigeration:

Domestic refrigeration occupies a considerable part of the refrigeration industry although its primary concerns are household refrigerators and home freezers. The number of domestic units is very big, while they are usually small in size with horsepower ratings between 1/20 and 1/2 hp, and are of the hermetically sealed type.

Commercial Refrigeration:

Commercial refrigeration satisfies the need of retail stores, restaurants, hotels and institutions for refrigerated fixtures designed for the strong, displaying, processing, and dispensing of perishable commodities of all types.

Industrial Refrigeration:

Industrial refrigeration is differentiated from the commercial refrigeration by two criteria : industrial applications are larger in size, and they require an attendant on duty, usually a licensed operating engineer. Industrial applications include: ice plants, large food packing plants (meat, fish, poultry, frozen foods, etc...) industrial plants, such as refineries, chemical plants, rubber plants, and construction industry.

Marine and Transportation Refrigeration:

Marine applications are refrigeration aboard marine vessels such as refrigeration for fishing boats, for vessels transporting perishable cargo and for the ships' stores on vessels of all kinds. Transportation refrigeration refers to the refrigerating equipment applied to trucks and airplanes for transportation overlong distance and to refrigerated railway cars.

Air Conditioning:

Its application involves conditioning not only the space temperature in a designated area but also the humidity and air motion, along with filtering and cleaning of the air. Comfort and industrial air conditioning are the two applications of this category. Typical installations of comfort air conditioning are in houses, schools, and offices where the function is the conditioning of air for human comfort. However, the applications of industrial air conditioning are unlimited both in number and variety. Some of these are : control the moisture content of the hydroscopic materials, govern the rate of chemical and biochemical reactions, provide clean filtered air which is often essential to trouble-free operation and to the production of quality products .

Food Preservation

The most common application of mechanical refrigeration is the preservation of perishable commodities particularly foodstuff. Through history, man had discovered and developed many methods of food preservations as drying, smoking, pickling, and salting before he knew the causes of food spoilage. Furthermore, the keeping qualities of food preserved by such methods are definitely limited as to time. Later, during Napoleon time, the invention of microscope and subsequent discovery of microorganisms as a major cause of food spoilage were behind the development of canning in France. Nicolas Appert won great acclaim for his discovery and was awarded 12000 francs by Napoleon in 1809 (Jordan, 1956, p. 468). Canning enabled food preservation of all kind, in large quantities and for long period of time; however, it had the disadvantage that food must be heat-sterilized which usually make the flavor differ greatly from the original fresh one. This raises the need for refrigeration which is the only mean of preserving food in its original fresh state. However, this principal advantage requires that the refrigerating process starts directly after harvesting or killing and stops only when food is to be consumed. Food preservation depends upon a number of factors such as the type of product, the length of time the product is to be preserved, the usage of the product and many others. There is no one best method of food preservation for all cases. Some cases necessitate the use of several methods simultaneously to obtain the desired results.

Deterioration and Spoilage:

The preservation of food is concerned with preventing or retarding deterioration and spoilage; therefore, it is indispensable in the study of refrigeration to know the causes of deterioration and spoilage. In most cases the modifications of complex organic substances present in the cell tissue of perishable products cause deterioration and spoilage after harvesting or killing. These modifications are provoked by two categories of agents: enzymes and microorganisms (Collin, 1975, p.13). The enzymes are internal agents inherent in all organic materials, whereas microorganisms are external agents which grow in and on the surface of the foodstuff (Dossat, 1961, p.124). Either agent is capable of spoiling perishable food; however in most cases, both agents are involved. Therefore, adequate reservation of perishables requires effective control over the activity of these spoilage agents.

Enzymes : Enzymes are chemical substances of organic nature that provoke chemical reactions in living and dead cells (Collin, 1975, p.13). "They help carry on various living activities of the cell such as respiration, digestion, reproduction and they play an important part in the digestive processes of animals including man" (Dossat, 1961, p.124). Enzymes are catabolic - agents of constructive metabolism - as well as anabolic - agents of destructive metabolism - and responsible of the fermentation and purification process. However, enzymes are affected by the conditions of the surrounding area particularly temperature, degree of acidity or alkalinity, humidity, light and level of oxygen. Enzymes are eliminated by high temperatures starting from 80°C ; on the other hand, low temperature, around O°C, reduce only their activity. Free oxygen motivates enzymic actions which decrease as oxygen supply diminishes. High humidity facilitates enzymic actions. Light has a sterilizing effect over enzymes. As for acidity or alkalinity, enzymes requiring acid surroundings are destroyed by alkalinity and vice versa.

Micro Organisms : Microorganisms are microscopic plants and animals of which only three concerns food preservation : (1) bacteria, (2) yeast, (3) molds (Dossat, 1961, p.125). They grow in and on the surface of perishable foods causing complex chemical alterations in the food substance that renders it unfit for consumption. Microorganisms secrete enzymes that attack the organic materials resulting in undesirable alterations in the taste, odor, and appearance of the food. Microorganisms are agents of fermentation, putrefaction and decay. They are not only indispensable to the life cycle, but also dangerous causing poisoning by secreting toxins. Despite their useful and necessary functions, they are spoilage agents and their activity must be either eliminated or effectively controlled for adequate preservation of foodstuff. High temperatures are effective in the destruction of microorganisms.

Preservation by Refrigeration

The use of low temperature in refrigeration retards the activity of spoilage agents and provides a mean of preserving perishables in their original fresh state for varying periods of time (Collin, 1975, p.14), (Dossat, 1961, p.129). The degree of low temperature required for adequate preservation varies with the type of product and with the length of time the product is to be kept in storage. As opposed to animal products which are non living food substances, fruit and vegetables are living substances and their life give protection against microbial invasion. The life of vegetables and fruits continues even after harvesting through utilization of food substances previously stored and supplied by growing plants. The activity of the natural enzymes such as oxidation and hydrolysis are controlled by refrigeration under low temperature (IIR, 1974, p.54).

Composition of Fruits and Vegetables:

Fresh fruits and vegetables consist mainly of water which is lost from them by evaporation. This loss leads to wilting, and good storage is the result of maintenance of conditions for minimum water loss from the produce (Ashrae handbook, 1985, p.31.7).

Carbohydrates are the most constituent of the structural framework and stored materials in fruits and vegetables. Its content can range from 2 percent of fresh weight to over 30 percent in starchy vegetables. Most of the carbohydrate is present as sugar – up to 23 percent of fresh weight in ripe fruits (IRR, 1974, p.37).

The protein content in most fruits and vegetables is Low - less than 1 percent of the fresh weight - however, functionally they are extremely important. They include the full complement of enzymes essentially involved in metabolism during growth. maturation, ripening and post behavior of the living produce.

Besides, they are components of the nuclear and cytoplasmic structures which take part in determining and maintaining cellules organization. Like the protein, the lipids of fruit and vegetables - except avocado and olive - are largely confined to the cytoplasmic layers in which they are especially associated with the structure and function of membranes. Their content rarely exceeds 1 percent of the fresh weight. Lipid and lipid-like materials – cutin and uberin - are particularly prominent in the cuticle, epidermis and corky layer protecting the surface of the fruits and vegetables physically, and from water loss (IRR, 1974, p.37).

Free amino acids and related simple nitrogenous compounds often account for half the total content of nitrogen and always occur in association with the proteins. Many organic acids are formed in plant tissues during the course of their metabolism.

Therefore, fruits and vegetables are normally acid in reaction with a pH of 2-4. Citric and malic acids are the most common and abundant acids in fruits and vegetables - citric in citrus fruits and malic in apples. The acid content of fruits usually falls during maturation and ripening (IIR, 1974, p.38).

Three main groups are responsible for the natural coloring in fruits and vegetables: the chlorophylls - green - which play an important role in photosynthesis, the carotenoids - yellow, orange or orange-red - which consist of carotene which is of important nutritive value as it yields vitamin A when included in the diet and the flavonoids or anthocyanins - red, blue, or purple. Some flavonoids are oxidised by phenoloxidases. Chlorogenic acid occurs widely and is the main substrate involved in the enzymic oxidative browning of damaged tissue of such as that of apple, peach and potato when exposed to air (IIR, 1974, p.38).

The mineral content in fruits and vegetables varies from 0.1% in some varieties of yam to as much as 4.4 % in kohlrabi. Potassium is the most abundant individual mineral. Calcium which is associated with the cell wall is the next in importance. Phosphorus is a constituent of cytoplasmic and nuclear proteins and plays an important part in the metabolism of carbohydrates and the transfer of energy, while magnesium is a constituent of the chlorophyll molecule. The mineral elements affect not only the quality of fruits and vegetables but also post behavior and storage life. For example, the Ca/Mg ratio has strong influence on the bitter pit of apples (IIR, 1974, p.38).

Last but not least, the characteristic flavor of fruits is due to the presence of volatile which are largely oxygenated compounds such as esters, alcohols, acids, aldeydes, and ketones. These volatiles have a limited range in vegetable. Fruits and vegetables supply ascorbic acid - vitamin C - β-carotene - pro-vitamins A - B vitamins especially folic acid, and mineral elements especially calcium and iron necessary in the daily diet. Through adequate refrigeration fruits and vegetables can maintain their vitamin supply for varying period of time.

Refrigerated Storage :

It may be grouped into three general categories : (1) short-term or temporary storage, (2) long term storage, and (3) frozen storage (IRR, 1976, p.158). For short and long term storage, the product is chilled and stored at low temperature above the freezing point, approximately O°C. On the other hand, freezing requires a rapid reduction of temperature below the freezing point between - 12°C and - 25°C (- 18°C being most frequently used). Short-term storage is usually associated with retail establishment where turnover ranges from one day to almost 3 weeks. Long term storage is an application of commercial storage warehouses with maximum storage periods of eight months for durable products such as onions and apples. The period of refrigerated storage depends upon two criteria: type of the product and condition of the product on entering storage (Collin, 1975, p.140).

Storage Condition : The nature of the product, the length of time the product is to be held in storage and whether the product is packaged or unpackaged are necessary criteria for optimum storage conditioning whether it is short or long term. Usually, recommended storage conditions for short term are more flexible than those required for long-term storage.

A list of storage conditions for various fruits is shown in table 1 (Dossat, 1961. p.453). These data are necessary for high level product quality.

Table 1 : Preservations Conditions From Carrier Design Data. Reproduced by permission of Carrier Corporation.

Fruits	Type of storage	Temperature °C	Max. Storage period	Humidity %	Max. Air motion Ft./min
Apples	short	1.6 to 4.5		87	90
	long	-1 to 0	4-8 month		60
Avocados	short	4.5 to 11.6		85 – 90	90
	long	2.7 to 11.6	10 days	85 – 90	90
Grapes	short	1.6 to 4.5		80 – 85	90
	long	-0.5 to 0	3 - 8 weeks	80 – 85	90
Lemons	short	12.7 to 15.5		85 – 90	90
	long	12.7 to 15.5	1 - 4 month	85 – 90	90
Oranges	short	4.5 to 7.2		85 – 90	90
	long	0 to 1.1	8 - 10 weeks	85 – 90	90
Pears	short	1.6 to 4.5		85 – 90	60
	long	-1.6 to -0.5	1-7 months	85 – 90	60
Peaches	short	1.6 to 4.5		80 – 85	60
	long	-0.5 to 0.5	2-4 weeks	80 – 85	60

Storage Temperature : Table 1 shows that the optimum storage temperature for most products is slightly above the freezing point of the product . Vegetables and fruits stored at temperatures above or below their critical storage temperatures are susceptible to cold storage diseases and this lower product quality and shorten storage life. The best storage temperature for apples is O°C to -1°C, some varieties are subject to soft scald and soggy breakdown when temperature gets below -2°C, others break at temperature below -2.5°C, and others develop internal browning when stored below -4.5°C. As for vegetables, onions tend to sprout at temperatures above O°C, and Irish potatoes tend to become sweet at storage temperatures below - 4.5°C (IIR, 1974, p.53) , (Moras, 1977, p.178).

Transpiration, Humidity and Air-motion : The storage of vegetables and fruits recommends close control of the space temperatures as well as the space humidity and air motion. One cause of deterioration of these products - unpackaged - is the loss of moisture from the surface of the product by evaporation into the surrounding air. This desiccation or dehydration is accompanied by shriveling and wilting; as a result, the product is subject to great loss in both weight and vitamins content. Desiccation takes place whenever the vapor pressure of the product is greater than the vapor pressure of the surrounding air. The rate of moisture loss from the product is proportional to the difference in the vapor and to the amount of exposed product surface (IRR. 1974, p.55). The difference in vapor pressure between the product and the air is primarily a function of the relative humidity and the velocity of the air in the storage space. A greater rate of moisture loss from the product is a result of greater vapor pressure differential caused by lower relative humidity and higher air velocity. Unfortunately, ideal conditions for preventing dehydration of the product such as 100% relative humidity and stagnate air are in contrast with the necessities for adequate refrigeration. Therefore, space humidity must be maintained around 90 to 95% and air velocities must be sufficient to provide adequate air circulation (Collin, 1975, p.138), (IIR, 1974, p.56).

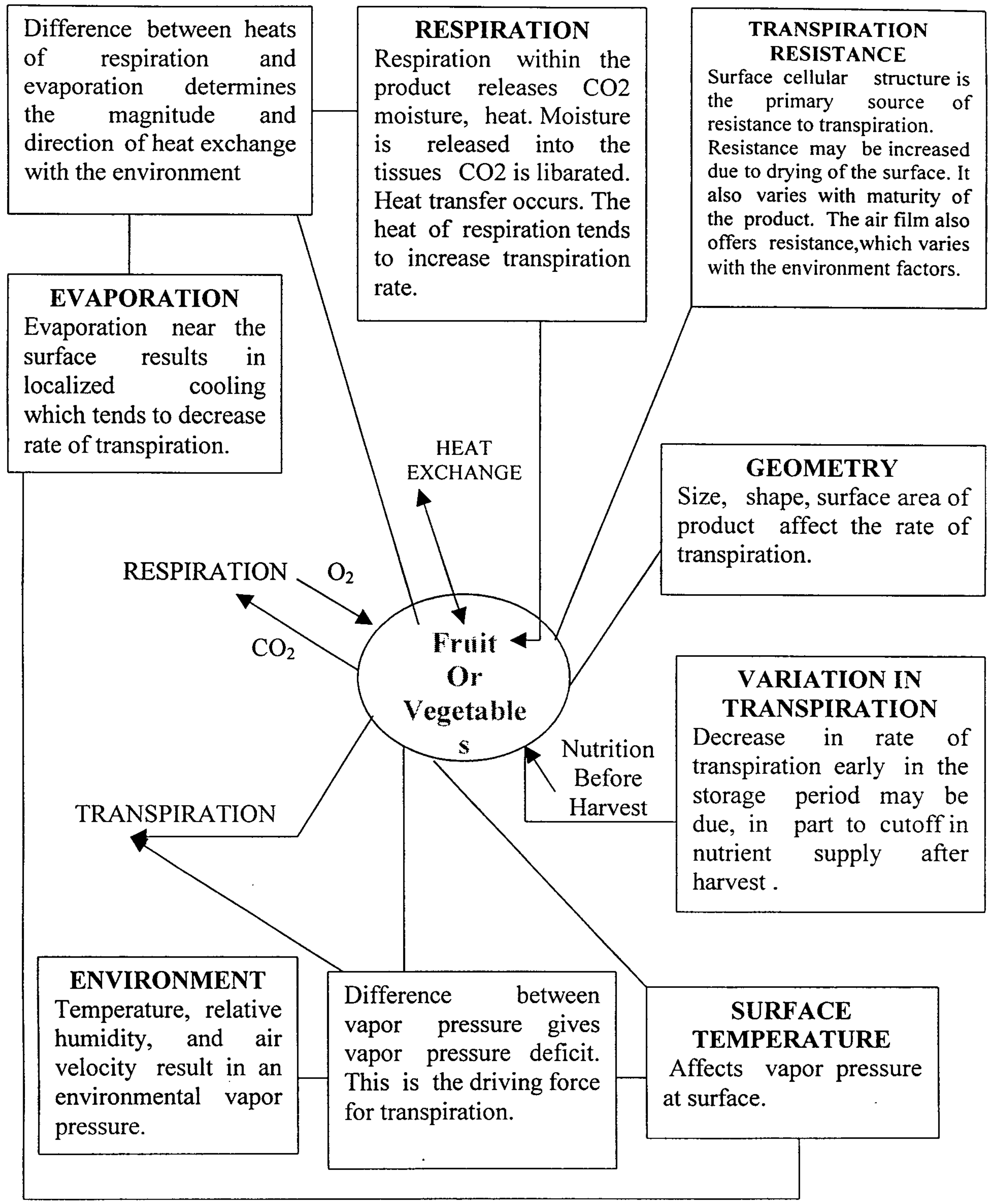

Figure 1 : Transpiration Cycle . Ashrae Hand Book , 1985, p.31.7
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Respiration and Maturity Product : like any living creature, fruits and vegetables need oxygen for survival. Respiration within these products releases CO2 moisture and heat. Heat transfer occurs when moisture is released into the tissues and CO2 is liberated (Collin, 1975, p.137). This tends to increase transpiration rate (Ashrae Hand Book, 1985,p.31.7).

Table 2 shows the heat transfer by respiration of the fruit in Kcal/T/24h (Collin, p.138).

Table 2:Heat transfer by respiration of the fruit in Kcal / T/ 24 H (IF commission IV)

	Heat transfer by respiration of the fruit in Kcal/T/24h					
Fruit	**0 °C**	**2 °C**	**5 °C**	**10 °C**	**15 °C**	**20 °C**
Apples	110-220	220-280	280-430	420-640	570-1200	900-1500
Pears	160-220	220-460	360-850	480-1150	1700-2600	2000-4500
Grapes	100-200	240-350	340-500	490-750	740-1000	1000-1600
Lemons	120-200	150-270	220-400	350-670	490-970	640-1200
Oranges	100-220	130-260	220-390	430-720	750-1150	1390-1420
Perches	260-390	360-450	520-840	1300-1900	1800-2700	2900-3750
Straw-berries	700-960	830-1300	900-1900	1800-3600	2700-5000	3600-6200

Besides, the emission of "ethylene" from mature fruits stimulates rapid maturity in immature ones. In the atmosphere, the level of CO2 and O2 has also an effect on maturity of fruits. As for apples, maturity will be slow when the level of CO2 increase and the level of O2 decrease to a certain level where fruit can still survive. Another factor that affects maturity and storage life of the fruit is its condition on entering storage. Fruits should be harvested before reaching full maturity, if not, their storage life will be extremely short even under best storage conditions. The same applies for damaged fruits especially if the skin has been broken, so natural protection against microbial invasion has also been lost (Moras, 1977, p.178). Since fruits begin to deteriorate very quickly after harvesting, it is recommended that refrigeration measures be taken immediately.

Weight Loss and Shrinkage:

Water content in fresh fruit and vegetable is as high as 95 % of total weight (Moras, 1977, p.170). Apples of types Golden and Starking have a water content between 55% and 60% of total weight (panhwar, 1970, p.89). The crucial part of quality maintenance during storage and marketing is the retention of the original high water content which is lost by evaporation resulting in loss of saleable weight and fresh appearance. A loss of 5 % produces visible shrinkage and a significant reduction in quality (IIR, 1974, p.56). The cooling of warm fruit is associated with a weight loss managing from 0.25 to 0.75 percent (IRR, 1973, p.99). And, this loss continues during storage at a rate depending on the nature of the fruit and storage condition and can easily be limited to 0.5 % per month (IRR, 1970, p.287). Weight losses of 4 to 5 % are common in the long storage of apples and pears. Table 3 shows weight losses of some fruit during storage.

Table 3: Weight loss of fruits during refrigerated storage by Ms Scupin (Collin,1975, p.137)

	Weight loss of fruits during refrigerated storage by Ms Scupin			
Fruit	**Conversation period**	**temperature ° C**	**Relative humidity**	**% weight loss**
Apples	6 to 8 months	- 0.5 to 0.5	0.90	3 to 4
Pears	4 to 6 months	- 0.5 to 0.5	0.90	3 to 6
Peaches	1 to 1.5 months	-1	0.90	8 to 12
Strawberries	3 weeks	+1	0.90	1

Excessive shrinkage is due to: 1) immaturity of the fruit, 2) delay before storage, 3) picking the fruit when hot and placing very hot fruit in the cool store, 4) high storage temperature e.g. hot spots in the room against a north wall or an uninsulated floor, 5) low humidity due to insufficient insulation or insufficient coil surface, 6) slow cooling, and 7) excessive air circulation (IIR, 1974, p.99).

An increase in relative humidity is absolutely necessary when increasing the rate of air circulation in order to avoid increased wilting.

In California, Allen and Pentzer found that, doubling the rate of air movement increased weight loss by about one-third, with apples and pears stored at 5°C , which was equivalent to the effect of a 5 percent drop in relative humidity (IIR, 1974, p.99). However, quick cooling and uniform storage temperatures necessitate good air circulation.

In England, Mann has experienced the effects of varying temperatures in different positions in a cool store on the weight loss from apples when stored at a normal 5°C and 88 % relative humidity. Weight loss varied by a factor of 2 with a variation in temperature of 2°C. Fruit packaged in dry wooden boxes and cartons experienced increased shrinkaged since these packages absorb moisture most of which comes from fruit. The equilibrium in moisture content of wood is about 21 % in a cool store at 0°C and 90 % relative humidity. An initial dry 4 kg box going into such a store at a moisture content of 10 % would absorb 500 g of water, which is equivalent to 2-2.5 % weight loss from 20 kg of fruit. Therfore, it is necessary to wet dry boxes before cool-storing fruit in them (IRR, 1974, p.99). This problem of wooden boxes is scarcely found since apple producers uses plastic boxes nowadays. However, they still package apples for export in carton boxes and store it for a period of time that ranges from 1 still 30 days before transporting them to the imported countries. Besides, transportations are also refrigerated and consume time which ranges from 2 to 20 days - sometimes more due to borders and political problems.

Before storing warm fruit, wetting and treating it with a scald inhibiting dip or spray, has great impact on reducing weight loss from the fruit during cooling. In hot dry weather, it is a good practice to leave the hot fruit picked later in the day - out in the open overnight - to cool by a combination of evaporative cooling and radiation cooling - if the might sky is clear - and store it next morning. Besides, fruit that arrive hot to the store should be waited overnight, and those picked early in the morning should be stored directly before it warms up (IRR, 1974, p.99).

To sum, low weight losses and shrinkage necessitate fast cooling, uniform low temperature, and high humidities in the store.

Treatment of the Produce

Apples belong to the less perishable fruits. They are suitable for long range storage. However, their storage life depends on two conditions : Pre-harvest variables and post-harvest variables.

The pre-harvest variables are : The type of orchard and the method of soil maintenance, plant grafting, climatic conditions during the growth and repining of the produce, and maturity and picking (IIR, 1973, p.187).

The post-harvest variables : packing, grading and sizing, careful handling, loading, stacking, skin coatings, types of storage stores (IIR, 1973, p.182).

Pre Harvest Treatment:

Type of orchard and method of soil maintenance : Highly cultivated and fertilized orchards produce apples of higher dimensions, higher concentration of total sugar and ascorbic acid and lower preservation capacity than those produced by the conventional type of orchards. For example, Jonathan apples from highly cultivated orchards had lost 25.9 percent in total - weight loss + beginning of putrefaction + putrefied produce - while those from the conventional type of orchards presented a total loss of 10.3 percent (IRR, 1973, p.188). Besides, highly cultivated orchards produce apples with higher tendency to internal breakdown than other.

Moreover, any condition leading to an unbalanced situation between the nutritional position of the plant and the quantity of fruit on the tree results in fruit with a lower keeping quality. However, this does not mean that apples produced on weak rootstocks or originated from trees which have a high nitrogen supply always present a shorter storage life (IRR, 1973, p.182).

Apples originated from trees with high potassium supply usually present a more favorable sugar-acid ratio and a better taste. And the relation between potassium, calcium and magnesium in the leaves and fruits leads to great susceptibility to physiological disorders such as better pit.

Greener color apples come in association with high nitrogen content which does not necessarily present a less tasty fruit, unless the fruit flesh remain in the green state.

Plant grafting : In orchards laid out on sandy soil, three grafting experiments were carried out. The best storage qualities were obtained with Jonathan trees treated with MM104 grafts and starking delicious treated with MM104 and MM109 grafts (IIR, 1973, p.187).

Climate conditions : The conservation capacity of apples had not correlated with the average temperature and the summation of the atmospheric pressure of the growth and maturity period of the fruit. However, this conservation capacity is widely influenced by the climatic conditions of the growth and maturity period of the two last months of the fruit especially that of August. The experiments showed that the daily average temperature higher than 20-25°C lasting more than three weeks associated with low atmospheric pressure had reduced the conservation capacity of apples and favored the apparition of senescence. On the other hand, atmospheric pressure (higher than 100 mm) favored the apparition of spots during refrigeration (IRR, 1973, p.191).

Maturity and picking : When apples reache the last slow stage of growth they are physiologically mature and develop the ability to ripen normally after picking. However, they are commercially mature when they develop sufficient durable characteristics to make them edible. Many practical tests are available to indicate the stage of maturity and optimum picking time since it has strong influence on the keepability, but all have limitations (IRR, 1974, p.40). No one of these : color of the skin, time from blossoming, ease of detachment from the spur, firmness measured by a pressure test, amount of starch and respiration activity test, is by itself a reliable basis for forecasting the storage life or the ripening behavior of the fruit (IRR, 1973, p.184).

Bruises, skin breaks and stem punctures which are the results of rough and careless handling in the orchard or in the packaging house, may be overlooked at the time, but result in premature break down or fungal infections in storage. Stems that are torn off the fruit may easily result in decay of the fruit as a result of mould infection. Pickers must take great care in handling the fruit as little as possible and the packaging material should be near at hand. Picking is done by hand in Lebanon, despite the striking advances in mechanical harvesting in the industrial countries. Besides, they widely use the bulk bins handled by fork trucks instead of the smaller field boxes used in Lebanon in order to reduce bruising and damage of the fruit (IRR, 1973, p.184).

Post Harvest Treatments :

Packing : before packing the produce, grading for quality is a necessary activity. Fruit that is not marketable should not be picked and others with a good keeping quality can be graded on quality and sized before storage and packed later. This process in not done in Lebanon for many reasons such as producers can not find sufficient time to grad and size before storing the produce, and they prefer to store it at the same condition as it was picked for economic reasons. However, substantard fruit should be eliminated during picking for not to use storage space for low quality produce (IRR, 1973, p.184).

Grading and Sizing : Not all fruit is fit for storage, some has better keeping quality than others. Therefore, selecting and sorting are almost unevitable. There is a possibility of grading on quality and sizing during the first part of the storage period - two months - and returning the apples to cold store without any difficulties arising. Sizing, when done before storage, permits the elimination of culls. and the separation of fruit into smaller and larger sizes. The larger fruits are less keepable than the smaller ones, particularly with respect to break down, and should be marketed earlier. Grading and sizing allow more economy in the use of cold storage volume and a quick respond to market demands. The grading process, when done after storage must take care of fruits, which have been stored for a long period and that have condensated moisture on the skin since it results in skin discoloration. Experience has shown that on the average, 15 percent of cool store space in apple and pear stores are saved by presorting (IIR, 1974, p.95).

Careful handling : Rough handling increase the amount of damaged fruit which has to be discarded. It also reduces storage life since broken skins lead to fungal infections and increase rotting during storage. Besides, bruises not only induce breakdown but also increase the respiration rate of the fruit, thus reducing its life (Index 1, p.2).

Hydrohandling of fruit in bulk bins is a successful requirement for long storage. This pre-storage treatment provides washing and cleaning of the fruit in water with optional aid - when necessary - of fungicide to control rotting; a hormone-type chemical such as gibberellic acid to assist in slowing the ageing process, or a special inhibitor such as diphenylamine which inhibits storage scald of apples and pears. Washing is another treatment that reduces shrinkage and gives the produce a shiny look (IRR, 1973, p.184), (IRR, 1974, p.95), (Index 1, p.9).

Loading : Before any fruit is placed in the storage room it should be well cooled down. Cooling will be slow, the life of the fruit reduced and shrinkaged increased if the daily loading - entry of warm fruit - exceeds the 10 percent of the capacity of the room. Besides, warm fruit should not be close-stacked directly and its cooling can be improved by using a portable fan placed in front of the stack, suction side to the fruit, to draw air through it.

Stacking : The matter of staking requires economy of space, adequate and uniform air circulation, and accessibility to different produce. It is bad practice to over fill a room, as it results in poor temperature control in different parts of the stack. Therefore a poor out-turn of a proportion of the fruit. For good cooling and good temperature control staking should meet the following requirements (IRR, 1974, p.96):

1) The stack should be placed at 8cm away from outer walls and 10-12 cm away from a

hot wall exposed to the sun - this will ensure that heat coming in though the walls will all be carried away to the coils by air moving freely between the stack and the wall without warming nearby fruit, 2) There should be a clear air space of not less than 20 cm between overhead coil drip trays and the top of the stack. This to ensure uniform cooling. And the full depth of the space in front of a forced draught cooler should be kept clear for a distance of 2 meters out from it to allow it to function properly and to avoid freezing fruit, 3) There should be an air plenum of about 8 centimeters between the floor and the stack. Single boxes should be placed in rows running in the direction of airflow, and or pallets with pallet-base bearers parallel to the direction of airflow. This condition is absolutely essential in a non-insulated floor, 4) There must be small vertical air paths within the stack not less than 1 centimeter wide between adjacent packages.

Skin Coating : the application of artificial coatings to the skin of the fruit ensure the control of internal gas concentrations so adding to the natural resistance of the skin. This application " waxing " has a considerable potential to increase storage life. However, it adds a fixed resistance that is independent of temperature. The respiration rate and therefore the effect of the added skin resistance are dependent on temperature. Thus a coating effective and safe at 0°C can cause the development of damaging internal levels of $CO2$ or $O2$, or both, at 20°C. And vice versa a satisfactory coating at higher temperature would be ineffectual in cool storage (IIR, 1974, p.55). However, waxing ensures the control of the water evaporation and consequent shrinkage. Without adversely affecting respiration over a wide range of temperatures, suitable coatings can reduce weight loss - water loss - by as much as 50 %. The degree of weight loss reduction that can be safely obtained depends on the nature and thickness of the coating, the temperature and the nature of the produce (IRR, 1974, p.56).

Types of Stores : For larger storage life of the fruit, prompt cooling is essential and any delay between picking and cooling shortens storage life. Apples held at about 20°C age seven to ten time as rapidly as those held at 0°C. Moreover, very tight packaging material, too close stacking, and inadequate refrigeration capacity may result in too slow cooling.

There is a differenciation between refrigerated storage - normal atmosphere - and controlled atmosphere storage. In the latter, special apparatus are installed to maintain a desirable low oxygen atmosphere and carbon dioxide absorption and fruit volatile absorption such as ethylene. C.A storage is constructed with tightly sealed rooms designed for extended marketing season and higher quality of the fruit (IRR, 1979, p.306).

Storage Disorders in Apples and Pears

Disorders that shows up in apples and pears during or after storage may originate from preharvest time or may start in the store and may be of a parasitic charcaters or physiological one (IIR, 1973, p.196).

Preharvest Conditions :

Fruit Russeting : the original bright colour of the affected area of the fruit turns darker, during storage, and becomes more noticeable. Moulds very often covers the affected parts, and increase losses in fruit attractiveness, weight and shrivelling. Orchard climatics are the cause of this form of fruit russeting. Besides, phytosanitation with sprays of hard crop protectors may lead to further russeting (IIR, 1968, p.137).

Scald caused by phytosanitary sprays : The kind of weather in autumn and the ripeness of the fruit to harvest time are responsible of this scald which becomes visible during storage after 4 or 5 months. This scald is caused by the manifold applications of unsuitable fungicides.

Parasitic Disorders : The correct use of fungicides which are generally applied before picking and on the trees themselves controlls the growth of storage moulds. Other way of control is the discinfection of storage rooms and packing cases. Lowering the temperature and air humidity in controlled atmosphere stores may delay the growth of moulds (collin, 1975, p.152).

Penicillium Decay : This mold which has several forms can be found nearly every where, on fruit, on cases and can be airborn in cold stores. This infection originates where there is skin injury caused by picking and sorting. The growth of this mold can not be sufficiently delayed by lowering storage temperature to 0°C or relative humidity to 75%. For this rot not to take place fruit should not be bruised or broken in the skin, and thorough disinfection of cases and storage rooms is essential (IIR 1974, p.57).

Monilia Decay : This decay originates in post-harvest lots which are not immediately put in cold storage and where skin is broken by attacks of insects or birds.

Gloeosporium Decay : This decay is responsible up to 90 percent of losses from spoilage in cold stores. It occurs only after some months of cold storage and has the ability to grow at a temperature of 0°C, at one third of its maximum rate. Infection occurs in the lenticells during the growing period whilst the fruit is on the tree. Therefore, it can be controlled by spraying the trees with special fungicides. Controlled atmosphere is an indirect control of gloeosporium Decay (IIR, 1968, p.138).

Botrytis Decay : It is caused by fungus Botrytis Cinera which infects the fruit whilst they are on the trees. It invads the fruit through the calyx or stems. Even in cold rooms at -10°C, this decay may cause heavy losses especially in pears, since it spreads quickly and infects sound fruit in contact with infected ones (IIR, 1968, p.138). High humidity in storage rooms abets further Botrytis decay. Controlled atmosphere stores at 3% CO_2 concentration does not retard the development of Botrytis.

Scab during Storage : This scab is caused by the fungus Fusicladium dendriticum or F.pirinum which infects the fruit just prior to picking it. Therefore, careful control especially during the last weeks before picking can prevent scab formation during storage. Scab affects only the upper cell layers of the skin.

Agro-climatic Conditions:

Physiological disorders which are mostly due to agro-climatic conditions are :

Scald : There are many types of scald ; early scald, late scald, lenticell scald, and several forms of scald induced by chemical substances. Scald appears only after some months of storage and often not before the end of the storage period. Scald which attacks apples as well as pears becomes apparent just after the fruit is taken out of the store. "Deep scald" or "soft scald" takes the form of internal break down.

The symptom of early scald is a colour change in the skin on the shadowed side. This discoloration starts in the superficial layers of the skin before it penetrates into the deeper layers and changes to a darker brown colour. But, the pulp remains sound for a long time (Moras, 1977, p.181), (Scald, p,3).

The symptom of late scald which is a typical disorder of aged fruit, is a rapid browning of the pulp directly under the skin - Lenticell scald may be considered as another form of late scald.

Jonahan Spot : It also attacks other varieties of apples, this physiological disorder originates in aged fruit for genetic reasons. An indirect control of the appearance of spots is by storing in a controlled atmosphere with at least a 3% CO2 concentration.

Red Lenticell Spot : There is a possibility that certain fungicides may contribute to the generation of this disorder which appears only just prior to picking. Its real cause is not exactly known. However, the application of some sprays may prevent its appearance. Lots heavily affected by red lenticell spot may sometimes be also affected by gloeosporium decay (IIR, 1968, p.138).

Bitterpit : This disorder takes the appearance of slightly inset spots of 2 to 3mm of a dark green to brown colour (Moros, 1977, p.182). These pits lies in the pulp are groups of brown dead cells. It is caused by a disturbance in the balance between potassium, magnesium and calcium. To avoid bitterpit apples should be harvest at optimum maturity and stored immediately in cold rooms at 90% relative humidity. Apples susceptible to bitterpit should be sprayed with calcium salts (Bitterpit, P.3).

Low Temperature Breakdown : Golden delicious are susceptible to this disorder where one or more parts of the skin in combination with about 7mm of the underlying flesh take on a dark-brown colours. Products near the vicinity of the evaporators are mostly attacked by this disorder (IRR, 1968, p.140).

The effects of temperature on storage life are not uniform, small changes in temperature have greater effect at lower than at higher temperatures. The effects of low temperature damage vary from skin pitted or spotted, to flesh breakdown, becoming either soft, moist and brown, dry and discoloured. This leads to abnormal ripening and fungi attacks like gloeosporium (IIR, 1974, p.53).

Fruits and vegetables will freeze at temperature in the range -0.5°C to -3°C. Once frozen they are irreversibly damaged. The effect of damage depends not only on temperature but also on duration of freezing. Apples and pears if frozen for only a few hours of a day or two at a temperature close to their freezing point will usually recover when thawed gradually in a high humidity atmosphere at a temperature of 1 to 2°C. Therefore, to avoid this kind of problem direct control on the atmosphere temperature as well as the fruit flesh temperature is essential.

Chapter II

The Economic Aspects of Apple Refrigeration

Cold storage development in the Near Eastern countries was very limited in the 1960s. There was a big need in most countries to expand capacities for storage of imported food as meat, fish and poultry (IIR, 1966, p.281). Three quarters of the cold storage capacity was in Lebanon, which was capable of holding 90,000 tons of apples. This capacity was behind the big increase in apple production, which was directed towards the export market. For this reason, most of the stores have been situated in or near the two main ports of Beirut and Tripoli and were owned by private sectors especially apple exporters who have financial interest in cold stores.

Ownership, Management and Control

The relation between the storage function and other marketing functions is an important aspect in cold storage operations. In Lebanon, many apple exporters have built cold stores or have a financial interest in refrigeration. Many cold stores firms have been established without clear-cut objectives and have suffered various difficulties in the course of their operations. Better organization of cold storage operations is required, particularly with reference to the movement of goods to and in and out of the refrigerators. Other problems are cold storage chambers which are sometimes filled up so completely that proper cooling is no longer possible, and goods which are subject to damage by pressure are stocked so high, resulting in damage and deterioration. Besides, reliable data on operating costs are in general not available. Many cold stores are part of or linked up with other enterprises and operating costs of the different segments are not separated (IIR, 1966, p.284). Therefore, the introduction of technical control over cold storage operations and proper cost systems, and the establishments of productivity and efficiency standards are very much needed as well as important for the growth and development of the industry.

Prevention of Apple Wastage

Refrigeration preserves the original fresh quality of apples by controlling the climatic conditions as the temperature, relative humidity and air motion that limit and eliminate apple disorders originated from the development of microorganisms. Apple refrigeration has prevented losses that were largely exceeding an average figure of 20 to 30 percent between production and consumption (IIR, 1974, p.199). Furthermore, it enables the constitution of apple reserves that has many economic impacts. For instance, during the harvest period apples are abundant and the prices tend to lower dangerously, according to supply and demand, to a level where they are no longer remunerative to the producers. Therefore, producers and exporters intervene by stocking in cold storage excess quantities and then reintroducing them when market prices are satisfactory. In countries where the economy is liberal or centrally planned, this stabilization of markets plays a considerable role. This was applied in France at the beginning of the sixties with the superabundant production of meat (IIR, 1974, p. 201). Besides, this stock of apples can be shipped to international markets and the country can obtain hard currencies necessary to its economy. For instance, apple refrigeration enables the export of apples from Lebanon to Amman and Libya that do not accept apple till 4 to 5 months after the harvest in October.

The Cost of Refrigeration

In general, refrigeration is cheaper in temperate industrialized countries than in developing countries where the refrigeration construction industry is very often restricted to assembly (IIR, 1976, p.157). Refrigeration adds to the price of the refrigerated product; therefore, it must be applied with full knowledge of the cost of installation of equipment and sufficient thorough economic study. However, profitability may not intervene where refrigeration is indispensable for safeguarding a food product that is essential for the sustenance of the population (IIR, 1974, p.202).

Refrigeration Installations:

Installations involve three services: civil engineering, insulation and refrigerating machinery.

Civil Engineering : Economical construction must be the goal of civil engineering since the function of the building is that of a shelter and a screen. However, it must take into consideration some handling facilities that facilitate the operations and improve efficiency like the availability of a platform and palletisation.

The platform must have different heights depending on the height of the vehicles or it can take an average height, and be provided with dock leveling facilities where a leveling arrangement can allow the platform and the vehicle to correspond. It must have a minimum width of 6 meters in order to allow forklift truck drivers to pass each other taking goods to and from the vehicles without running the risk of accident. In all cases the platform must be under cover (IIR, 1976, p.20).

The adoption of palletisation must take into account : 1) a plan of dimensions considering spaces between pallets and along the length of walls, as walls as gangways with widths that are suitable for the type of fork lift trucks used, 2) the adoption of automatically operated sliding doors for the truck driver not to get off his vehicle to open and close the door, 3) the deletion of rows of pillars that would obstruct palletisation or positioning them in a way that minimizes spaces loss (IIR, 1976, p.22).

The floor must be made of reinforced concrete in a way to be able to hold a dynamic load of 1200 to 1500 Kg per wheel of fork lift truck, and a static load of 3000 to 5000 kg/m^2 (IIR, 1976, p.119). And, it should be insulated.

Insulation : In a climate like Lebanon, it is very essential to prevent direct insolation of the walls of a cold room, since the surface temperatures produced by insolation - 70°C and even higher - necessitate excessive thickness of insulation and some types of insulant like expanded polystyrene - widely used in Lebanon - do not withstand high temperatures. In order to reduce and even eliminate the shrinkage in polystyrene to marked alteration in temperatures, it is absolutely essential that this insulant be "aged" sufficiently before use and of high - density - not less than 20kg/m^3 (IIR, 1976, p.119).

The cost of insulants varies according to their nature and thickness. The economic thickness of insulants can be determined graphically or using the KD notion (IRR, 1974, p.203). The ordinates of the graph are : the annual amortization relative to the insulation and the annual electricity cost, both as a function of insulation thickness. The first curve increases and the second decreases with thickness. The first curve increases and the second decreases with the thickness.

The cumulative curve passes through a minimum, which indicates the economic thickness. The KD notion expresses the quantity of heat in kcal passing through one square meter of wall per hour where K represents the overall heat transfer coefficient of the wall, and D represents the widest temperature difference at any one part or other of the wall. D is equal to $\theta e - \theta i$, where θi represents the cold room interior temperature and θe represents the outside ambient temperature. In France, the product KD used is equal to 10 where as KD used where electricity is expensive has a value of 7 to 8.

Applying Insulation : When applying the insulation and the material is in sheet form, the minimum allowable quantity of adhesive within the joints must be used, and carefully overlap all joints by providing two layers of insulation; protect the insulant against shocks by using sheet materials (aluminum, galvanized steel etc.); and protect the insulant against moisture by vapor barrier (IIR, 1976, p.34).

Vapor Barrier: There are three forms of vapor barrier : 1) Watertight surfaces of preformed insulation panels (reinforced plastic materials, aluminum, galvanized steel, etc...), 2) membranes (metal sheets, laminated sheet and treated paper, felt and bitumen paper, plastic films or sheets, 3) surface preparation: fluid or semi fluid mastics with an asphalt - Widely used in Lebanon - resin or polymer base.

Whatever form of vapor barrier used, it must be incorporated on the warm side of the insulant to prevent ingress of moisture vapor, and it must be able to withstand expansion and contraction in all directions without creating any cracks for the entry of moisture vapor (IIR, 1976, p.32).

Insulated Doors : The temperature of the store and the insulated material, dictate the insulation thickness of the doors which varies between 5 cm and 20 cm. Polyurethane is commonly used for this purpose.

In order to prevent the introduction of atmospheric humidity into the cold rooms when the doors are opened, a double "push thought" door can be hanged behind the door made of thick transparent plastic sheet or a screen of thick cloth. The "air certain" is a more up-today and costly method consisting of a powerful fan above the door blowing a vertical wall of air down through a narrow vent (IIR, 1967, p. 120).

Refrigerating Machinery : Refrigeration by mechanical compression presents two systems; the central cooling plant, and the independent compressor units. Each system has its advantages and disadvantages.

The independent compressor units consist of one condensing unit per cold room especially for that of modest size - 300 m³ - and identical machine may be used. In developing countries, these machines are pre-assembled in factory and comprise the motor, compressor and condenser that is often air-cooled, with integral control gear, and are easy to service and install. In case of failure, one standard replacement unit is enough for a number of cold rooms.

The central cooling plant consists of a number of compressors grouped in a machine room. In developing countries, the stand by machinery should be available in sufficient quantities and all the compressors should be of the same type or have identical cylinders to facilitate repair (IIR, 1976, p.120). This system requires a technically qualified staff. It is advantageous to use the separate compressor units when all cold rooms are not permanently in use at the same time.

The cost of refrigerating machinery is approximately distributed as follows: the distribution equipment - evaporators, tubing - 50 to 60 %; compressors, 15 to 20%; condensers, 10 to 15 %; controls, electricity and assembly 15 to 20% (IIR, 1974, p.203).

Compressors : There are several types of refrigeration compressors out of which the reciprocating is the most popular type, after it, comes the centrifugal. The compressor is responsible for two functions. From the evaporator, the compressor draws the refrigerant vapor and then lowers the pressure of the refrigerant in it to the desired evaporating temperature. And, it raises the pressure of the refrigerant vapor in the condenser high enough so that the saturation temperature is higher than the temperature of the cooling medium used to cool the condenser and condense the refrigerant (Langely, 1986, p. 67).

When deciding on the capacity of compressors, it is necessary to evaluate the total heat load. The heat sources are (IIR, 1976, p.38), (IIR, 1973, p.100) : 1) field heat of produce and packaging material, 2) heat of respiration of the produce, 3) heat ingress through insulation of the walls, ceiling and floor, 4) heat entering the room through door openings and leakage, 6) heat produced by defrost, 7) cooling down time to storage temperature.

Condensers : The refrigerant vapor leaves the compressor, quite hot and ready to give up the heat it picked up in the evaporator along with the heat of compression, to a radiator like device known as condenser. The sensible heat must be removed by the high temperature and high - pressure refrigerant vapor, its temperature falls to the saturation point - condensing temperature - and the refrigerant vapor condenses to a liquid refrigerant (Langely, 1986, p.96).

Evaporators : There are several different shapes and styles of evaporators to fill specific needs. The evaporator is placed inside the area to be cooled since it performs the actual cooling by absorbing heat into the refrigeration system. The absorption of heat is a function of the evaporator tubes where the refrigerant flows while it vaporizes and absorbs heat (Langley, 1986, p.110).

Cost of Refrigerating Installations : The overall cost of the construction of cold stores is generally related to unit volume and can vary from 20 dollars per m^3 for a large cool store to 315 dollars per m^3 for small units for meat and fish storage (IIR, 1966, p.284). This cost depends upon the unitary volume of the cold room - the larger the room, the lower is the cost per unit volume, the height limit of the room being dependent of the stockage handling system - and the level of the temperature chosen (IIR, 1974, p.204). A case study that compared the unit cost of cold storage in Lebanon to that of Switzerland showed a cost of 20 dollars per m^3 in Lebanon against 40 dollars per m^3 in Switzerland. What made that difference were the thickness of insulation and the cost of manpower. The cost of local material and labor, imported equipment, and insulation are the factors influencing construction costs.

Operating Costs for Refrigerating Installations : The proportions of operating costs used in France are 30 to 35% amortization, 15 to 20% consumption, 30 to 35%

personnel, 10 to 15% general expenses and profits (IIR, 1974, p.204). Amortization includes the actual service life of installations and building and the interest and paying-off of capital. Consumption includes the energy - electricity and fuel - and the maintenance cost. The personnel cover all labors costs and are higher in small cold stores. The general expenses include taxes, insurance, etc. Since many cold stores are linked up with other enterprises there is no reliable data on operating costs and uniform book-keeping and accounting have seldom been introduced (IIR, 1966, p.284).

Controlled Atmosphere Storage

Controlled atmosphere storage is a combination of two simultaneous actions: refrigeration and precise control of the carbon dioxide and oxygen concentrations in the storage atmosphere. Controlled atmosphere was the produce of close cooperation between biologists and engineers (IIR, 1979, p.306).

History and Reasons:

Professor Berard published the results of the first scientific study of the effects of atmospheres on fruit ripening in France, 1821. He concluded that harvested fruits consume oxygen and give off Carbon dioxide and when placed in an atmosphere deprived of oxygen did not ripen till oxygen was restored.

Nyce built and operated a fruit store airtight in the late 1860'S in Cleveland. He designed his own system where rooms were cooled with ice and sealed after the fruit entry. Tons of apples were profitably stored; however, he experienced losses since he did not know that insufficient oxygen and excess carbon dioxide could injure fruit. Thus, his system was forgotten (IIR, 1974, p.103).

Drs Franklin Kiddand and Cyril West founded the real basis for the development of controlled atmosphere storage in England after World War I (IIR, 1973, p.43), (IIR, 1974, p.103). Before 1939, controlled atmosphere storage was commercialized only in England and continued to expand till it reached 73% of the total cooled storage space for apples and pears in 1973. The real success of controlled atmosphere was limited to the storage of apples and pears and was widely used in U. S. A. , France and Italy after the Second World War (IIR, 1973, p.43). However, few applications were made on peaches, mangoes, citrus and bananas (IIR, 1979, p.307).

After the Second World War, fruit production has much increased in many European countries as well as outside Europe. Consequently, the need for cold storage increased, and this stimulated the need for controlled atmosphere storage that extended the marketing period for some varieties such as Branley's, Cox's, Jonathan, Golden delicious and conference pears. It proved that controlled atmosphere storage prolong the storage time and give the fruit better marketing values. The fruit remained more turgescent, experienced less weight loss and storage diseases, and has a longer shelf life outside the cold stores. All this, enabled apples to yield higher prices and by time it became clear that higher returns were compensating higher costs for installing and running controlled atmosphere storage (IIR, 1973, p.44).

Other reasons are extending the works of the storekeeper and offering traders greater variation of fruits over a longer period. All these economical reasons are well understood by apple growers and traders.

Construction and Operation:

The natural respiration process of apples in a cool store sufficiently gas-tight reduces oxygen and increase carbon dioxide levels at a rate of 1% per day, till all oxygen is removed. Therefore, it's necessary to control the atmosphere and provide the exact levels of oxygen and carbon dioxide required by any variety of fruit (IIR, 1974, p.108).

Store Construction : The first barriers of successful controlled atmosphere storage were gas tightness and the control of the level of gas composition. The conventional construction consisted of a building constructed with masonry, steel or timber, and a combined gas-vapor barrier fixed between the framework and the insulation to the inside. This rendered the gas barrier inaccessible for reparation in case of leakage (IIR, 1974, p.108), and did not prevent moisture condensation in the insulation (IIR, 1973, p.46). This problem was overcome with the prefabricated panel construction that consisted of panels made from expanded polystyrene and thin metal sheet joined together with silicone rubber or other sealant to make the room gas-tight (IIR, 1974, p.108). Moreover, special construction developed by Lentz made the gas barrier readily accessible. This concept of the jacket room consists of providing a gas-tight lining inside a cool room with air space between the insulated walls and the living where cold air circulates to remove the heat. What differs the blanket type from the jacket is that the former does not require the floor to have air ducts below, a normal floor is used, thus lower cost of construction.

The plastic film rooms gained interest since 1957 and witnessed major developments (IIR, 1974, p.109): 1) the elimination of the need for skilled site works, complete prefabrication of the plastic room was done in the factory, 2) the use of a film which remained flexible at cool room temperatures, 3) the use of a plastic duct inside the room to distribute the internal atmosphere circulated by a fan etc...

Because of varying pressure differentials between the outside and inside due to changes in atmospheric pressure and even cycling of the refrigeration system rigid structure are prone to develop leaks, besides being difficult to seal. The solution to this problem in the jacket and blanket construction was the flexible plastic tent inside the insulated structure.

The complete internal lining of the room with foamed-in-place polyurethane applied with special gum enables successful conversion of existing cool stores to controlled atmosphere operation. It provides both insulation and a gas barrier and sufficient flexibility to avoid significant leaves that would otherwise occur in a rigged structure (IIR, 1974, p.110).

Store Equipment : Effective controlled atmosphere storage requires special means of control regarding oxygen burners, carbon dioxide absorbers, and measuring the temperature and relative humidity. The development of external generator that consumes much more rapidly the oxygen in the air than the respiration of the fruit enables artificial lowering of the oxygen level. The generator belongs to two different systems; the flushing system, which consists of a special burner that, produces a low oxygen atmosphere with the required carbon dioxide content to flush out the oxygen from the room. An atmosphere generator can produce the flushing gas or nitrogen can be used. And the recirculating system consisting of a generator that burns up the oxygen from the air in the room and the exhaust gas in is passed back to the room

(IIR, 1974, p.106). Besides, a carbon dioxide absorber is also required to absorb the excess carbon dioxide produced by the generator and by the respiration of the fruit.

In addition, long distance thermometers that can be read outside the room and automatic recording instruments for temperature, humidity, oxygen and carbon dioxide must be available (IIR, 1973, p.46).

Scrubbers : There are two types of scrubbers; those that remove carbon dioxide by chemical processes and are: the dry line scrubbers, Ethanolamine scrubber, and the potassium carbonate scrubber. And those that remove carbon dioxide by physical processes and are : Activated carbon scrubber, molecular seine scrubber, the selective diffusion scrubber, and the water scrubber (IIR, 1973, p.136).

Inert Gas Generators : These generators are used to reduce the oxygen level in controlled atmosphere stores. These generators work in three ways: either with ammonia, or by burning propane, butane or other gaseous fuel, or by adding nitrogen or carbon dioxide gas. These generators enabled : 1) the development of the atmosphere in a few days and reduce management problems regarding the development of the atmosphere, 2) the development of the atmosphere in a partially filled store, 3) the reestablishment of the atmosphere after opening the store either for the removal or addition of fruit or for carrying out a refrigeration repair, 4) Keeping on operation a controlled atmosphere room that suffers from major increase in the leakage rate of the room that will no longer permit an atmosphere to be maintained in the natural ways (IIR, 1973, p.136).

Automation : The way to control the controlled parameters like the temperature, relative humidity, and gas composition is the automatic control system that supervise the controlled variable and make the necessary adjustment when needed. Automation is not a goal but it fulfills the following goals: 1) balance of the capacity of the plant against the overall refrigeration load by intermittent running of the plant or by modulation of refrigerant mass flow by alterations to circuit conditions, 2) balance the operation circuit element by the compressor, condenser, and evaporator, 3) control scrubber and / or gas generator equipment, 4) shut-off the plant if unsafe conditions arise (IIR, 1973, p. 144).

There are a variety of functional ways for control systems, the simplest is the on off control. It is necessary to have the right air motion in the room at constant temperature since it provides basis for a constant relative humidity. Tolerable temperature variation is ± 0.5 °C. Temperature distribution depends on good design and stacking patterns and is one of the most difficult features to control.

The more sophisticated control systems use electrical sensing elements and electronic controllers, and the output of the controller is fed to a servo system to operate pneumatic or electric valves.

<u>Rate of oxygen reduction:</u>

The 21% oxygen present in the air must be reduced to below 5% with reduction of storage temperature, in order to reduce apple and pears rates of respiration. However, oxygen supply must not fall below a level of 2% for apple and pears in cool storage at temperatures between -1 to 1°C to prevent oxygen starvation leading to fermentation and breakdown (IIR, 1974, p.104). Moreover, oxygen reduction to less than 5% should be within specific period of time from closing the room. For instance, in some states of the U. S. A. legislation requires that oxygen reduction to less then 5% should be within 20 days of closing the room of apples. And, Macintosh variety kept better in 5% carbon dioxide and 3 percent oxygen when oxygen reduction took 14 days or less than when it took 20 days (IIR, 1974, p.107).

Rate of carbon dioxide reduction:

Normal air is composed of 79% nitrogen, 21% oxygen and 0.03% carbon dioxide and for each volume of oxygen consumed, equal volume of carbon dioxide is produced. Thus the percentages for oxygen and carbon dioxide remain about 21% and the nitrogen content does not change (IIR, 1973, p.120).

Small increases in the carbon dioxide concentration in the air of cold rooms produce more marked effects on respiration rate than small changes in the oxygen level. However, high concentrations as 10 percent will upset respiration and cause breakdowns in the apples and pears, which requires a 2 to 3 percent carbon dioxide. (IIR, 1974, p. 104). Increased level of carbon dioxide has a relatively greater effect than reduced oxygen level in retarding loss of acidity and potential flavor development of the fruit. Therefore, it was found that an atmosphere of 2 to 3 percent carbon dioxide with 2 to 3 percent oxygen is suitable for most variety of apples and pears at cool storage temperatures (IIR, 1974, p.106). The carbon dioxide production per volume that is expressed by kg of carbon dioxide per ton of produce per hour, multiplied by the number of tons per m^3 volume of the whole storage room can determine the capacity of the absorption equipment - scrubber (IIR, 1973, p.122). The oxygen consumption can be expressed in the same way.

Removal of Ethylene:

The ethylene can be removed by an external scrubber containing u.v. lamps through which pass the atmosphere of a store. The air is irradiated in the scrubber with u.v. light at wavelengths of 185 mm and 254 mm. The excited states of molecular oxygen, ozone and atomic oxygen are responsible for the decomposition of ethylene and other oxidizable volatile in the air (IIR, 1974, p.115).

Leakage and Respiration Rates:

In a reasonably tight room, the pull down time to establish the desired controlled atmosphere depends on the respiration rate of the produce in the store, the fullness of the store and the leakage rate of the store. The respiration rate is a function of the nature and the variety of the produce, the temperature of the cold room, and the gas composition of the atmosphere. There is a balance between a specific respiration rate and a limit in the leakage rate that permits a certain oxygen level to be reached in a specific time in a store filled with produce (IIR, 1973, p.122). The development of the atmosphere by the natural way depends mostly on the relative quantity of respiring fruit in a given storage volume. This means that in a room partially filled with fruit, it is impossible to develop an atmosphere by the natural way. The same applies for a store with high leakage rate. For both conditions, a gas generator must be utilized to develop the atmosphere and maintain it after it is developed. Air leakage is strongly influenced by the cooling operation, resulting in a decrease of water vapor content and a contraction of the air itself (IIR, 1973, p.124).

Repair of Leaks : Repairing a leaky controlled atmosphere room is not an easy task especially when the gas tight sheets are inaccessible for reparation. In order to localize the spot of air leaks, the room must be closed and have an under pressure of 0.10 mbar. Leaks are localized by the flickering of a candle flame, by whistling sound, or by means of a soap solution (IIR, 1973, p.132). After repair the room must be retested, and air leakage test should be done before each season.

The first air leakage test must be done after the construction of the cold room and the installation of gas seal to ensure that the controlled atmosphere room will operate satisfactorily. An acceptable test is a simple pressure test. The pressure inside the room is increased, using blower, then observing the time taken for the pressure to fall. The time taken for the pressure to fall to one-half of its initial value must be at least 10 min for a pressure in the range of 0 to 25 mm w. g. (IIR, 1974, p.114).

Measurement of Gas Composition:

There are many apparatus for gas measurement especially for oxygen and carbon dioxide measurement. However, the measurement of ethylene is seldom required and if needed is best achieved by gas chromatography (IIR, 1973, p.144). The measuring of carbon dioxide and more particularly oxygen is time consuming and requires great accuracy and care.

Measuring Carbon Dioxide : The Orsat apparatus is a standard instrument and simple to handle. It is based on volumetric measuring. The scale should read from 0 to 21% and accuracy is within 0.5%. The process requires that a given volume of gas mixture should be brought in contact with a potassium hydroxide solution that absorbs carbon dioxide. The change in water level indicates the volume of carbon dioxide absorbed (IIR, 1973, p.142).

The katherometer relies on the thermal conductivity of the gas and it is reliable to within 0.5%. Carbon dioxide has a larger conductivity than nitrogen and oxygen.

The interferometer is a very useful portable apparatus. It is based on the principal that the refractive index for each gas is different.

The infra-red analyzer is based on the principle that gases absorb infra-red radiation of specific wavelengths. It can be used for remote reading and it is the only commercial measuring system which is suitable for differential analysis (IIR, 1973, p.144).

Measuring Oxygen : The Orsat apparatus is also used for measuring oxygen. After the absorption of carbon dioxide, a given volume of gas mixture is mixed with alkaline pyrogallol solution. This process is comparable to the carbon dioxide determination. There is also the catalytic transformation of oxygen into carbon dioxide where the carbon dioxide is measured by the change in thermal conductivity of the gas mixture. In addition to these methods, there are the polarographic electrode and the raramagretic analyzer that is easy to handle.

<u>Requirements for Successful Controlled Atmosphere Storage:</u>

a) The product should be of a variety suited for controlled atmosphere storage and of good keeping quality : Some variety of apples and pears react better than others in modified atmosphere due to the presence of determined concentration of carbon dioxide and oxygen. In addition, it is of no economic benefit to refrigerate low-grade quality, which will not keep well (IIR, 1973, p.44).

b) Gastightness : The controlled atmosphere store should be perfectly gastight. In the past storekeepers were not fully conscious of the necessity of gastighness;

consequently, they encountered many failure in the process of gas concentration controls, thus, resulting in major product losses. The gas tight layer has to comply with strict requirements and for this reason it must be accessible for inspection and repair (IIR, 1973, p.124).

c) Loading and withdrawal of products : Loading a controlled atmosphere room for apples and pears should be accomplished within 5 days. This to enable the gas composition to be built up after that within 2 to 3 weeks, depending on conditions and the concentrations required. As for the unloading process, it should not last longer than 3 to 4 weeks and the fruit exposed to normal air (IIR, 1974, p.44).

d) Gas concentration supervision : The narrower the range for carbon dioxide and oxygen concentrations is maintained the better storage conditions are available. The gas concentrations within the produce itself are the deciding factor and not that in the air (IIR, 1973, p.45). Therefore, special watch should be kept on the gas concentrations and regular measurements should be carried out and recorded. Records should be kept as a protection means against unwarranted claims and also to correct conditions before they become serious and to gain experience in the operation of the storage (IIR, 1973, p.138).

e) Regular product quality control : Samples should be withdrawn from the room and inspected for internal quality, even though the produce is stored in a sealed room which cannot be entered easily. Due to the reduced respiration and evaporation the produce may end up with an outside appearance of high quality; however, suffering from internal browning or off-flavor (IIR, 1973, p.45).

f) Over-storage : There is a tendency to over-store apples and pears with long term storage varieties. Product should not be held for too long. Product kept for very long periods has very little in reserve when exposed to higher environmental temperatures. It has good appearance at the moment of unloading but will disappoint the consumer at the time of eating.

g) Safety precautions : People should not be allowed to enter the room without an oxygen mask since there is a shortage of oxygen in controlled atmosphere rooms. Doors should always remain locked and personnel should never enter such a room on their own.

Conventional Storage versus Controlled Atmosphere:

The basis of comparison of the two types of refrigerated storage is that the controlled atmosphere is a progression of the common form of cold storage. It is proven that the establishment of a controlled atmosphere storage is more economical and its rentability for apples and pears has been verified by calculations in numerous cases (IIR, 1968, p.115).

Controlled Atmosphere Storage in the Province Region of France : In 1968, the province area grouped 22 co-operative fruit packing stations, twenty of the stations were equipped with conventional cold rooms - 100,000m^3 - and 9 of which had controlled atmosphere facilities - 20, m^3. Out of the 73,000 tons of total fruit production, 33000 tons of apples and 13,000 tons of pears were handled in this station. The produce of apples handled was of the type golden and starking apples; 85% and 15% respectively. The results should that on an overall average, weight losses were found to be of order of 0.6 to 0.8% per month under controlled atmosphere storage conditions and 1.2 under normal cold room conditions. Average storage temperatures were around 1.5°C (IIR, 1968, p.129).

Controlled Atmosphere Storage in the Netherlands : Comparative experiments were made in the Netherlands on 4 varieties of apples between conventional refrigerated storage and controlled atmosphere. The elements of comparison were percentage weigh loss, percentage losses through shrinkage, losses through deterioration of quality and mould infection and rot. All the elements of comparison showed the advantages of controlled atmosphere on the conventional storage since losses were much less under controlled atmosphere (IIR, 1968, p.111).

The Cold Store and its Customer

A part from the basic essential service of cold store that is to store goods - apples - under refrigerated conditions, it may also offer other services to its customers - producers or traders - such as product packaging, distribution, sales, etc. Both a legal and commercial aspects regulate this link between the customer and the store.

Legal Aspect:

The agreement between the cold store and the customer is governed by a contract whereby goods belonging to third party are received, looked after and returned afterwards. The customer is the depositor and the cold store operator is the depositary. The depositor uses a room or part of it and is granted the service of cold treatment of goods and ancillary services - hiring of labor etc. However, in some cases, the customer lets a room, the operator fixes the turns of lease and no longer renders any particular service (IIR, 1976, p.130).

Standard Contract : Since the refrigeration contract shows much specific character, it is preferable that its terms be clearly defined and communicated to the customers. In many countries, operators have induced the authorities to promulgate rules of trade which constitute a standard contract (IIR, 1976, p.132). Where there are no rules of trade, the basis of the refrigeration contract should be founded on the internal rules including essential provisions. And, where rules of trade exist, it may be supplemented by internal rules.

The contract define the mental obligations of the two parties, the cold store operator and the customer, which comprise: 1) a professional obligation on the cold store to perform its service, 2) a financial obligation on the customer to pay.

The customer obligation is clear and does not require much explanation while the store obligation is subject to discussion.

Obligation in Respect of Results : The cold store operator is obliged to deliver the goods entrusted to him in a best condition as when he received them. His commitment dictates perfect preservation of the goods in their original condition. If he failed in his commitment, he is liable. Any time any damage became evident makes the operator liable legally. Proving that he did not make any mistakes may discharge him of his liability. However, this will be very difficult to prove (IIR, 1976, p.132).

Obligation in Respect of Facilities : The obligation of the cold store operator dictates taking all measures, using all facilities to keep the goods in good condition and satisfy the customer. If the operator had not given proof of sufficient care and the customer were to prove that the facilities had been neglected then he would be liable.

Supplying proof of damage to the goods does not convict the operator. If goods have deteriorated in spite of the good use of facilities, the cold store operator is not liable (IIR, 1976, p.132). It is the customer's liability to lay down the conditions for the refrigeration treatment, estimate the duration thereof, and check the condition of the goods during storage. However, in practice, this non-liability in principle of cold store is not taken literally. Since he is a specialist, the operator has a commercial obligation to render a service with all its ancillary services, and after all he has a marketing interest in satisfactory out comes.

Internal Rules : They are necessary to clarify mental obligations and should be made known to all concerned especially to customers. Publication of these rules is also important; extracts of the main clauses should be typed on the storage notes, trade documents etc. They should also be posted up in places accessible by the customers, and handed out to new customers. They include: 1) times and conditions of customers access to premises, 2) provisions with regard to safety of goods and persons, 3) conditions of handling and weighing of the goods, 4) special cases - complete rooms rented, handling by customer, etc. , 5) insurance of risks with regard to the goods.

<u>Commercial Aspect</u>:

The commercial liability of the cold store operator is more extensive and of a more decisive nature than his legal liability. Produces are entrusted to him, he has to fulfil his obligations by rendering adequate service and delivering the goods when asked to do so. Some of his standard series of operations are : receipt of goods, storage service, delivery of goods, stocks accounting, setting rates and insurance of the goods.

Receipt of Goods : The first step in carrying out the refrigeration contract is checking the quantity and quality of the produce when entering the cold store. Insufficient checking and / or inaccurate quantity and quality identification may lead to disputes and conflicts later on. Moreover, the deliverer of the produce is often a carrier or a supplier of the customer and not the customer himself, thus checking is an important part of the cold store services.

Quantity checking requires counting the boxes or pallets and weighing them and comparing the results to the quantities advised. When discrepancies exists, it should be pointed out to the carrier, written on the storage note and confirmed to the customer later (IIR, 1976, p.136).

Quality checking necessitates inspecting conditions of the packs and the produce and comparing it to advised ones. The produce must be rejected if it shows signs of deterioration or inadequate for refrigeration or package in a way unsuitable for stacking.

Each time the cold store receives goods, the operator sends to the depositor a receipt indicating quantity and quality. This storage note must also indicate all observations made during checking the produce, operations to be carried out and the declared value of the product when the cold store insures the good. This note constitutes the basis of the refrigeration contract (IIR, 1976, p.138).

Storage Service : When receiving the produce, it should be stacked in the refrigerated rooms, as soon as possible, and divided into lots where a label is fixed, showing the batch number, date of entry etc, for easy identification. In order to avoid time consuming search, a card plan must be drawn for each room locating each pallet and identifying the customer to whom it belongs.

Another necessary step in carrying out the refrigeration contract is the inspection of goods. Although the customer should check his produce during storage - visiting hours and other facilities should be pointed out to him - this does not save the qualified staff in the cold store from carrying out their obligations. Checking must be permanent for example, varieties of apples and pears must be checked once a week in prolonged storage, unless they are almost ripe or unless some abnormal development - storage diseases etc. - have been noted.

During checking, different parcel should be checked each time at different places in the room. When abnormal development is observed more careful inspection is required. It is preferable to keep the customer in formed about the observations made when inspecting his produce refrigerated (IIR, 1976, p.140).

Delivery of Goods : This is the last phase of the contract, when the produce is delivered to the customer or to a person designated by him - carrier, buyer etc. The quality of the produce delivered must be cross-checked by the cold store staff and the person taking delivery in order to avoid dispute. The customer must sign a written order in the store in order for the operator to deliver the produce for anybody designated by the customer. The operator has to check the parcels and conform it with the storage note upon delivery, then draws up a delivery note identifying the references and quantities of the produce. This note constitutes a discharge to the operator and must be signed by the customer or his representative (IIR, 1976, p.140).

Stock Accounting : Stock accounting serves the purpose of the movement of the produce and identifying each parcel without any ambiguity. It serves the customer by supplying him by receipt for each movement of the produce - storage note, delivery note, keeping stocks per parcel permanently up-to-date, and replying to any requests for information and to any claims. It helps the internal operators to locate each batch in the cold store, to check and compare the accounting and physical inventories. It enables the management of the cold store to keep statistics needed for law declaration or for other commercial organization, and to supply the basic data for analytical accounting of the prime costs (IIR, 1976, p.142).

Setting Rates : The setting of rates is a decision of the cold store, official regulation or professional agreements. However, there are independent factors that take part in the final decision such as the prime cost, the supply of cold storage facilities, trade considerations of the stored produce, and the competition and certain local factors.

Insurance of the Produce : During refrigeration, the customer has entrusted his produce to the cold store that takes custody of it. This produce which has a value well above the value of the store is subject to risk of deterioration or even destruction due to unforeseeable causes. These causes are the fire, leakage of refrigerant, machine breakdown, theft of the goods etc. Therefore, it is necessary to clearly define the nature of the risks covered, and the respective liabilities of the store and the customer as regards cover of the risks incurred (IIR, 1976, p.148). The other types of insurance - buildings, plant, operating losses, etc - only concerns the cold stores.

Any accident, that may defect the produce, can start litigation between the depositor and the depository. In this situation, either the insurer applies a forfeiture of cover or indemnifies the customer if the calamities are covered.

In order to simplify the insurance procedures and economize, the cold store holds an insurance policy covering all the produce on the premises and embracing all the risks. This insurance involves only the insurer and the cold store regardless of the number of the customer.

There is also the adjustability clause that enables the insurer to modify the sum assured at any time provided it does not exceed the ceiling mention in the contract. The insurer usually fixes an average value of the produce each month, and at the end of the year the premium of insurance will be calculated according to the sums fixed by the insurer during the storage period.

Personnel Working in Cold Stores

Acceptance for working in cold stores demands high physical and mental standards since such work produces heat loss from the body and creates special effects on it. Therefore, to minimize these effects protective clothing and equipment are needed as well as heated rest rooms, hot beverages and hot showers after work.

Low Temperature Effects on the Human Body:

The numbness in the fingers and toes and the reduction in manual dexterity are the initial effects of exposure to low temperatures. The physical activity is one of the most important factors that help the body to maintain the temperature around 37°C.

The heat dissipated by a man, in W/min, varies according to his physical activity; hard work 9 to 12, moderate work 5 to 6, light work 3 to 4, at rest 1,5. Increased metabolism also helps to maintain the normal body temperature. Shivering increases the metabolism of the body; however, shivering results in a considerable drop in the working capacity (IIR, 1976, p.174). For every 1°C decreases in the deep body temperature the metabolism will decrease by 12% resulting in unsatisfactory physiological response. The human body will lose liquid through cold diuresis when its temperature falls. Therefore, working necessary medical examination before employment and properly uses all the precautionary measures provided by the cold store.

Protective clothing:

Working in the cold stores requires protective clothing with thermal protection relative to the temperature degree - thermal protection vary between 0°C, -10°C, -40°C etc.- tailored to the body and dimensioned to the work. The worker should wear the protective clothing on all parts of the body especially extremities such as hands, feet, and head. However, the needs and preferences of individuals vary. Good thermal protection should come in parallel with clothing that are neither too thick or too stiff, nor too heavy such that it hinders work or too tight such that it hinders internal air circulation or restrict blood circulation. And, since heavy perspiration should be avoided, clothing should be totally impervious to water vapor.

Working in cold stores requires three clothing layers: 1) the under clothes that regulate the "micro-climate" around the body. Thermal string vest are the most appropriate, 2) the middle layer - sweaters, pullovers, etc. - should be insulating and pervious to water vapor produced by perspiration, 3) the outer layer should be as wind tight and watertight and permeable as possible to avoid excessive perspiration (IIR, 1976, p.178).

Provisions for Personnel Welfare:

Psychologically, it is proven that it is better to allow some degree of freedom for personnel in selecting their protective clothing and working conditions. A well-lit room appears less cold than a darkened room, and draughts have a great influence on confort and must therefore be avoided. Besides, adequate lighting facilitates handling operations (IIR, 1976, p. 178).

Working in cold stores requires heated rest rooms for personnel to restore their physical and mental capacity and this contributes to improved physical performance. These rooms should be strategically located to enable easy access to workman during rest periods maintained at a temperature between 20°C and 27°C during winter, and furnished with confortable and easy to clean furniture (IIR, 1976, p.180).

Looker rooms should be available and divided into two parts, one for personal clothes and the other for working one.

Workmen should also have free access to hot beverages during winter and cold drinks in summer. Alcohol should be prohibited and smoking discouraged.

Chapter III

Capacity versus Demand for Apple Refrigeration

The apple refrigeration process extends the life of apples hence extends the period of product distribution and supply, reduces product losses, and stimulates apple agriculture. The marketing period of apples which is extended to eight months after the harvest enables apple producers and traders to sell their produce at good prices and seize higher price opportunities. Apple refrigeration answers the consumer's demand for fresh apples through a conservation that solved many problems such as microbial attacks, transpiration, vitamins and weight losses etc. Refrigeration reduces both qualitative and quantitative losses of apples. In addition, the increase in the production of apples in the 60's and 70's has induced the enlargement of cold storage spaces in Lebanon and vice versa.

Capacity of Apple Refrigeration Industry:

The capacity of this industry is not precisely known. During the war period, many refrigerators were completely ruined and owners did not found the opportunities to rebuild them, and others in Tripoli, Beirut and Bekaa became inadequate for operation. After that, this industry witnessed the birth of small refrigerators especially in Mount Lebanon with a holding capacity that did not exceed hundred thousand plastic boxes. These small refrigerators continue to be enlarged and multiplied without any study that may support its existence or advice not to enlarge them or build new ones.

The corner stone of the growth of any industry is knowing its capacity along with its demand to be able to manage both excess or shortage in supply and demand. It is important to determine the overall capacity of this industry and its regional capacity in order to manage its growth and answer those who want to enlarge their refrigerators and those who want to build new ones. Determining the overall capacity alone is not enough, it is necessary to determine also the regional capacity and its respective demand in order to solve the dilemma of enlarging their refrigerators. Most of the owners of apple refrigerators have the tendency of enlarging their refrigerators; this research may encourage or advice them to maintain the same capacity or change the functional use of their refrigerators of course depending on their region.

Demands for Apple Refrigeration:

Strategic plans for the future necessitates not only measuring the capacity of the industry, but also determining the demand for apple refrigeration. In order to control this industry and lead it to growth after its decline in the years of war, it is imperative to known the factors affecting its demand. Apples are one of the major agricultural exports of Lebanon (Ministry of agriculture, 1994) and this export relies on refrigeration which provides longer period of supply to foreign markets. Hence, apple refrigeration and exports are of crucial importance to the Lebanese economy and requires elaborate studies to maintain high standard and generate more returns.

The demand for apple refrigeration is the complement of the capacity of apple refrigeration in this research. Determining the seasonal demand for apple refrigeration and the factors affecting this demand is the first section of this objective. These factors are the total quantity of apple at harvest, the quantity of apple exported before refrigeration - during the harvest period, and the cost of refrigeration.

The second section consists of determining the regional demand for apple refrigeration per season. This may detect the need of increasing capacity in a region while decreasing it in another by changing the functional use of the refrigerator.

Chapter IV

Search for Capacity and Demand for Apple Refrigeration

The starting point in this search was in the packaging and refrigeration department of the Ministry of Agriculture where I was supplied with the lists of names of refrigerators, their capacities and the demand for refrigeration of apples for the seasons from1995 till 1998. These refrigerators were grouped according to five regions : Beirut and Mount Lebanon, the North, the Bekaa and Zahle, Bekaa al Gharbi, and the South region. After checking the capacities and demands, I found that these numbers were not accurate, and some refrigerators in the North and Mount Lebanon were not on these lists. Visiting and calling the refrigerators managers were not a good idea to detect the numbers, since almost nobody was ready to cooperate for many reasons. Some tended to decrease their numbers for tax purposes, others tended to increase their numbers thinking of donations, and others kept asking questions instead of giving answers. Therefore, detecting the numbers regarding capacities and demands relied on asking workers of the refrigerators, asking their neighbors, their clients being farmers and apple traders. All this has required a lot of visits to different regions and different people in order to eliminate any doubt about any number and to include every working refrigerator able to hold apples.

Capacity of Apple Refrigeration:

The lists from the Ministry of Agriculture provided the capacity of every refrigerator listed; however, these capacities were not accurate, and some refrigerators were not listed at all. That necessitated visiting and detecting the two most important regions - the North region, and Beirut and Mount Lebanon region - which have a holding capacity of 48% of the overall capacity and receive a demand of about 75% of the refrigerated quantity of apples per season. However, in these two regions, the area that produces apples count for 76% while the other three regions - South, Bekaa El Garbi, Bekaa and zahle region count only for 24% according to the statistic of the Ministry of Agriculture. Regarding the capacity of the refrigerators, the problem of accuracy of numbers, in the lists of the Ministry of Agriculture took place, because the information is not updated. Some refrigerators have changed their functional use, or have part of their refrigeration capacity that cannot run any more. And, some refrigerators are newly built and the Ministry does not know about their existence yet. However, the list of capacity was done for the purpose of giving donations and help for the refrigerators after the war; therefore, some numbers were inflated. On the other hand, some numbers were decreased because refrigerators tended to decrease their income taxes.

My investigation showed that Beirut and Mount Lebanon region has a capacity of 2,351,490 boxes of apple that counts for 28% of the total capacity. Two refrigerators have increased their capacities for the season 98 one in Faraya and the other in Mayrouba by 13,000 boxes and 15,000 boxes respectively. One refrigerator in Harajel is newly built with a capacity of 33,000 boxes and a will of enlarging this capacity for the next season.

The investigation in the North region showed a capacity of 1,746,500 boxes of apple that counts for 20% of the total capacity. Four refrigerators are newly built in Besharri with a capacity of 38,000 boxes.

According to the Ministry of Agriculture, Bekaa and Zahle, Bekaa El Gharbi and the South regions have refrigerators with a capacity of 2,675,000, 777,000 and 925,000 boxes of apples with percentages of total capacity 32%, 9%, and 11% respectively (regarding details see the appendices). The total capacity of the apple refrigerators in the five regions is 8,474,000 boxes.

Demand for Apple Refrigeration:

The search for the demand for apple refrigeration was made in parallel with the capacity and in the same way. However, I only detected the numbers of the seasons 97 and 98, since I could not rely on the memory of the workers, traders and clients of the refrigerators for more than one season backward.

In Beirut and Mount Lebanon region, the demand reached 1,569,000 and 1,427,000 boxes for 97 and 98 seasons with a percentage of the capacity 66.75 and 60.7% respectively.

In the North region, the demand was 1,250,000 and 856,500 boxes also for the seasons 97 and 98 reaching a percentage of the total capacity 71.6% and 49% respectively.

My investigations in these two regions showed that the data from the Ministry of Agriculture were less by 150,810 and 126,950 boxes from my results for the seasons 97 and 98 respectively. They were less by 5,4 and 5,6 %.

According to the data of the Ministry of Agriculture, the demand for the seasons 97 and 98 were in the Bekaa EL Gharbi region was 581,050 and 436,750 boxes with a percentage of the total capacity equal to 74.7%, and 56% respectively. In the Bekaa and Zahle region 136,000 and 200,000 boxes with a percentage of total capacity as low as 5% and 7,4% and in the South region 78,000 and 137,500 boxes relative to 8.4% and 14.85 of the total capacity (Regarding details see the appendices).

Refrigeration versus Production of Apples

The data from the Ministry of Agriculture showed the demands as follows: 1,760,000, 2,114,289, 3,242,572, 3,464,240 and 2,931,700 boxes for the seasons 94, 95, 96, 97 and 98 respectively. While the production of apples from seasons 92 till 97 were as follows: 145,403, 152,321, 119,692, 150,597, 152,508, and 147,992 tons equal to 6,608,566 , 6,922,989 , 5,440,000 , 6,844,633 , 6,931,488 , 6,726,236 boxes of apples, if each box weights 22kg. The total area that produces apples in Lebanon are 121,520 denum distributed as follows: 48,728 in the North region, 44,522 in Mount Lebanon, 21,612 in the Bekaa and 7,658 in the South region.

Increasing the production of apples will increase the demand for apple refrigeration, If exports before refrigeration are not increased. The percentages of quantity refrigerated over quantity produced shown in table 4 has increased from about 31% for the seasons 94 and 95 to about 50% for the seasons 96 and 97 since the expectations of increased exports - after refrigeration - were very high. The expectations were : The expectation of new market - Lybia - and the expectation of decreasing tariffs for the market of Egypt.

Table 4 : Refrigeration / production of apples. (Ministry of Agriculture).

Year	Quantity refrigerated	Quantity produced	% ref. / prod.
94	1,760,000	5,440,000	32 %
95	2,114,298	6,844,633	31 %
96	3,242,572	6,931,488	47 %
97	3,464,240	6,726,236	51 %

Apple Exports

The total crops of apples are distributed in the following way. Part is locally consumed, part is directly exported during the harvest period - August, September and October - and the residual part is refrigerated to be later on locally consumed and exported. Therefore, it is obvious that when exports - before refrigeration - increases, the refrigerated part decreases.

Apples are exported to Egypt, during the whole season, but they are subject to high tariffs, and prices are not encouraging during the harvest period. However, the Lebanese government signed an agreement with the Egyptian government in August 98, including canceling the tariffs on the exports of Lebanese apples starting from 1/1/99. But, its execution was delayed till mid April.

Lybia has been importing Lebanese apples for two seasons - including 98 - However, these imports started after the harvest period.

Jordan opens its doors the Lebanese apples for five months starting from mid February.

Lebanese apples are exported to the Gulf countries in small quantities because, they have small markets with high competition and low prices.

Table 5 : Exports during the harvest period.(Ministry of Agriculture).

year	August	September	October	Ttl/tons	Ttl/boxes	% exp./prod.
96	242	585	2746	3573	162,400	2.34
97	412	1988	4552	6952	316,000	4.69
98	607	2010	2780	5397	245,300	-

Cost of Refrigeration

The question of cost of refrigeration did not frighten the refrigerator managers especially when I asked it as a trader who wants to buy apples from the refrigerators' clients. The answer could not be other than 100% accurate. Besides, I also relied on the workers and clients of the refrigerators in these regards.

In the North region, the majority of the refrigerators charge the clients 2 to 3 dollars per box in a season that starts from mid September till June. While a few refrigerators charge their clients like they do in Mount Lebanon and Beirut, that is 1.5 to 1.7 dollars per box from September till the end of December - it depends on the quantity - and 10 to 13.5 cents each 10 days afterwards.

In the entire Bekaa region, the system charge is like that of the North, but it can be less in some cases, reaching 1.5 dollars per box in some instances. Many apple traders and exporters rent refrigerated rooms and sometimes the whole refrigerator for economical purposes. Besides, Many refrigerators also supply their clients empty boxes with of course extra charge that goes from 750 to 1000 Lebanese pounds.

Investigation also showed that the cost of refrigeration has not changed in the last five seasons, and is of little significance for the demand for apple refrigeration.

The Attitudes of the Refrigerators' Clients

I conducted many interviews with clients in the refrigerators who come to check the situation of their apples and see if they can sell them. I have chosen clients of the refrigerators that proved to be loaded to full capacity in Mount Lebanon and the North region. Also, I interviewed some owners and managers of refrigerators in these two regions who were ready to cooperate with me because they have business relations with my father who is an apple exporter and owner of a refrigerator in Zouk Mosbeh.

Most of the clients are skeptical about the quality result of refrigeration. They doubt the ability of the refrigerators' managers to provide effective service because they : 1) turn off the refrigerating machines to decrease electricity or fuel consumption, 2) lack knowledge especially concerning crucial issues like storage disorders and its detection and control, 3) practice wrong economy of space; stack badly and over fill the refrigerated rooms.

CHAPTER V

Matching Capacity with Demand for Apple Refrigeration

Lebanon has a total capacity of holding 8,474,000 boxes of apples in cold rooms while the largest demand for the last five seasons was 3,464,240 boxes in 97. At first glance, the answer seems obvious, no need to build new refrigerators or enlarge existing ones. However, the situation requires deep and close analysis studying each region and sub-region by itself.

Beirut and Mount Lebanon Region:

This region has a cold stores capacity of 2,351,490 boxes while the largest demand for apple refrigeration in the region for the last five seasons reached 66.7% of its capacity in the season 97. This means that each season this region will have at least 30% of its capacity unused. However, this unused capacity is not equally distributed among the refrigerators. Appendix A shows that the refrigerators on the coastal roads from Hazmieh passing by Dbayeh till Amchit, having numbers from one to eight have changed the functional uses of these spaces that were unused - where numbers hold two stars, means that part of the residual capacity or all of it is or are used to refrigerate products like cheese, beer, meat, fish or even produce ice. Adding to these eight refrigerators, that of El Dammour, Hammana, Bekfaya ...having numbers from 35 till 45. On the other hand, the refrigerators located on the road to the mountain in Kesrouan starting from Jounieh passing by Zouk Mosbeh, Ajaltoun, Bekaata, Mayrouba, Harajel, Faraya, Kfarzebien till Baskinta are always fully laoded with apple boxes with no empty space left. These refrigerators have numbers from 9 till 35 in appendix A. What is specific about these refrigerators is that no one of them has a capacity larger than 40,000 boxes. My investigation about these refrigerators and my interviews with their owners, managers, and/or clients gathered the following information.

First, most of the refrigerators of Faraya, Mayrouba, Kfarzebien and Baskinta are not built for being refrigerators rather than they were empty basment of houses for many years then turned to be refrigerators for economical purposes.

Second, what make them full each season is: 1) they are closer to the land and /or closer to the farmers' houses. This reduces time and money consuming in transportation of apple boxes and in the visits of the farmer to the refrigerator to check his harvest or try to sell it to traders and apple exporters. It also facilities the job of some farmers and apple traders who come to the refrigerator daily to pack some of their apples and prepare them for the whole sale markets. 2) Most of the refrigerators owners or managers either have friends and relatives who refrigerate their harvest each season, or are exporters or traders of apples who refrigerates their own products bought from the apple farmers. 3) These refrigerators are of small capacities; few clients can load them to full capacity.

Third, two refrigerators have increased their capacities for the season 98. The first was number 16 in Mayrouba who increased it by 15, 000 boxes and the second was number 18 in Faraya who increased it by 13, 000 boxes and both of them have loaded to full capacity.

Fourth, refrigerator number 20 is newly built in Harajel with a capacity of 33,000 boxes fully loaded for the season 98. While number 19 in Harajel which is marked with two stars on number 29, 000 boxes was also loaded to full capacity, but with 6, 000 boxes of pears in addition to the 29, 000 of apples.

Fifth, these refrigerators are younger then the others in Mount Lebanon and Beirut.

The North Region:

The apple refrigeration capacity of this region is 1,746,500 boxes, while the largest demand for apple refrigeration in the last five seasons has occupied only 71,6% of this capacity in the season 97. However, in appendix B, the refrigerators that have two stars on their demand numbers were loaded with pears. Knowing that the refrigerators of the North hold about 100,000 to 200,000 boxes of pears during the apple refrigeration season. In addition to that, Hedayed refrigerators in Mejdlaya, number 9, having a capacity of 227, 000 boxes has changed its functional use to be for freezing potatoes and making potato ships.

Appendix B also shows that the refrigerators of the coastal area -Tripoli, Mejdlaya - having numbers from 1 till 12 were not fully loaded while the others in the mountain - Besharri region - having numbers from 13 till 29 were.

The information I gathered from the refrigerators' owners, managers, and/ or clients proved the following. Besharri's refrigerators occupy the houses' basement of the owners who have financial interest in refrigeration. These refrigerators have very small capacities - maximum 23,000 boxes - which were fully loaded each season and will continue to be, for the same reasons of the refrigerators of Kesrouan. Most of Besharri's refrigerators are new in operation. Some are operating for the first season - refrigerators number 27, 28, 29 and 30 - and others for the second or third one.

Bekaa El Gharbi Region:

In Mashgara, the largest productive apple area of this region, there are eight refrigerators out of the fifteenth in Bekaa El Gharbi. The largest demand for apple refrigeration for the last five seasons was 74,7 % of 777, 000 boxes, the total capacity of apple refrigerators in the region. The concentration of the capacity of apple refrigerators in Mashgara is exactly matching the demand in the area (Appendix C).

Bekaa and Zahle Region:

This region has the largest capacity of refrigeration able to hold apples - 2,675,000 boxes. However, this capacity is not totally associated to apple, rather largely dedicated to the refrigeration of potatoes at the first place then grapes. Apples have occupied less then 10% of the capacity in the last five seasons (Appendix C).

The South Region:

The capacity of refrigeration in this region - 925, 000 boxes - is dedicated to the refrigeration of Lemon and oranges. Apples have only occupied a maximum of 14, 8 % in 98 (Appendix D).

Recommendations

Apple refrigeration capacity can be increased only in two sub-regions in Lebanon: In Besharri and in Kesrouan, for a simple reason that clients are demanding refrigerating space near to their farms as well as their houses. However, how much it could be increased depends on the quantity of apple produced in each sub- region. This quantity will be known as soon as the agricultural statistic in Lebanon ends.

However, this increase, if it occurs, will leave the coastal refrigerators in these two regions with more empty space, and urge them to think of changing the functional use of their refrigeration' space in light of the needs of the cities' markets around them.

Regarding the demand for apple refrigeration, it is directly affected by the total crops of apples and inversely affected by the exports of apples during the harvest period. Therefore, increasing the production of apples is of great benefit to the apple refrigeration industry. However, this can be done only by one way: increasing the exports of apples. Only increasing exports can induce the farmers to plant new farms since their crops will be largely demanded. Which gives them more returns. Increasing the exports should be a non-ending governmental task to make available foreign markets for the Lebanese apples with no tariffs in order for the apples' exporters, and farmers to benefit.

This is a ten-year plan, since apple trees newly planted need an average of 5 years to start its early years of production, and about 10 years to reach the beginning of maturity in production. However, this plan is inevitable if the Lebanese government decided to encourage one of its major agricultural exports, increase its production, and make the apple refrigeration industry prosper.

Regarding successful apple refrigeration it requires good equipment and good management. Chapter one and two shed the light not only on history and background of refrigeration, but also on these requirements. Since the quality of the fruit on the market and its acceptability, and the prices received for it, depend very much on the care with which the cool storage has been carried out. And because of steadily increasing costs of production and marketing, the future of the fruit industry must depend more and more on presenting better quality fruit to the consumer. The keys to success are quality control and controlled marketing.

Appendix A :

Beirut and Mount Lebanon	Capacity in Boxes	demand of 98	demand of 97
1-Abou Jaoude- Hazmieh	170,000	107,000	160,000
2-Cortas- El-Sid	165,000	**100,000	**90,000
3-Cortas-Zalka	300,000	**210,000	**200,000
4-Moris Shrabieh-Dbayeh	150,000	**70,000	**146,000
5-Naher Ibrahim	30,000	15,000	25,000
6-Almafrak-Amchit	70,000	45,000	45,000
7-Hawat and saliba- Jbeil	95,000	75,000	65,000
8-Establishment Samir Abou Khalil- Amchit	75,000	**55,000	66,000
9-La Cite-Jounieh	28,000	29,000	28,000
10-Taaouniet-Kartaba	42,000	39,500	40,500
11-Ajaltoun	35,000	35,000	35,000
12-Moukhtar-Bekaata	25,000	25,000	25,000
13-Elias Rizk-Bekaata	8,000	8,000	8,000
14-Fares Tabet- Zouk Mosbeh	35,000	35,000	35,000
15-Mansour Zgheib& Sons- Zouk Mosbeh	33,000	33,000	33,000
16-Yousseh Khalil-Mayrouba	40,000	40,000	*25,000
17-Naim Saleh Khalil-Mayrouba	12,000	12,000	12,000
18-Kaysar Moussa- Faraya	35,000	35,000	*17,000
19-Eljabal-Hrajel	36,000	**29000	37,800
20-Alsaoumaa	33,000	33,000	
21-Faraya-Elhadiss	22,000	22,000	22,000
22-Khalil Elias Khalil- Faraya	9,000	9,000	9,000
23-El-Arrab - Faraya	25,000	22,000	25,000
24-Rafic Mehanna- Kfrzebien	11,000	11,000	11,000
25-Eid Akiki- kfrzebien	10,000	10,000	10,000
26-Farid Akiki- kfrzebien	24,000	24,000	24,000
27-Efram Beaino-kfrzebien	25,000	25,000	25,000
28-Georges Haddad- Baskinta	15,000	15,000	15,000
29-Tanios Imad-Baskinta	40,000	40,000	40,000
30-Ghassan El Hajj-Baskinta	25,000	25,000	25,000
31-Sassine Jadaoun- Baskinta	25,000	25,000	25,000
32-Raymond El Moudaouar- Baskinta	8,000	8,000	8,000
33-Mansour Fayad- Baskinta	15,000	15,000	15,000
34-Samir Hamoud- Baskinta	5,000	5,000	5,000
35-Beyt Elkoukou- Bekfaya road	12,000	8,500	9,500
36-Bekfaya	50,000	4,500	21,450
37-Jean bsaybiss - Baskinta	20,000	20,000	20,000
38-El Damour	113,490	53,400	110,000
39-Falougha	50,000	36,000	39,000
40-Bekaata- El Shouf	200,000	0	0
41-Kfernibrigh	40,000	19,000	17,300
42-Helwani- Shewayfat	75000		
43-Kabih- Hammana	50000		
44-El Beail- Ain zhalta	25000		
45-Almaten- Ras Almaten	40000		
Sum=	2,351,490	1,427,900	1,569,500
% of ttl capacity =		60.7	66.7

Appendix B :

North region:

	Capacity in boxes	demand of 98	demand of 97
1-Oumar Ali Oumar- Bouhsas	265,000	115,000	220,000
2-El Ghandour & Nazim El Samad- Bouhsas	250,000	**115000	170,000
3-Hamad Saleh- El Bouhsas	50,000	30,000	40,000
4-EL Maarad- EL Mina	60000	25,000	30,000
5-Elias Shemi - Daher el ain	65,000	**45,000	**50,000
6-Mikael El Shemi- Aazmi - Tarablos	100,000	40,000	80,000
7-El Bissar- Zahiriya avenue	110,000	35,000	75,000
8-EL shamal- Zahiriya avenue	70,000	**50,000	65,000
9-Hedayed- Mijdlaya	227,000	0	120,000
10-Neyla Meaouad- Mejdlaya	50,000	40,000	45,000
11-El shekek- El Ayrounieh	70,000	30,000	30,000
12-Saad El Yammik -Mijdlaya	100,000	**62,000	**84,000
13-Aziz Elaam- Madaris avenue	60,000	60,000	60,000
14-El Sheikh Emile El Khoury- Besharri	15,000	10,000	15,000
15-Joseph Soukkar- Besharri	17,000	17,000	17,000
16-Nasir Soukkar- Becharri	10,000	10,000	10,000
17-El jebeih- Hasroun	23,000	23,000	23,000
18- El Arz	18,000	18,000	18,000
19-Rafic Keyrouz- Besharri	22,000	22,000	22,000
20-Malek tawk	9,000	9,000	9,000
21-Zarif Soukkar	6,000	6,000	6,000
22-Shehadeh Rahme	5,000	5,000	5,000
23-Saker-ElSamad-El kebbeh	70,000	**27,000	**20,000
24-Hanna Tawk	13,000	13,000	13,000
25-Youseph Tawk	18,000	18,000	18,000
26-George Soukkar	5,500	5,500	5,500
27-PierreTawk	7,500	7,500	
28-Nidal Tawk	7,000	7,000	
29-Assad tawk	6,500	6,500	
30-Toni Meskine	17,000	5,000	
Sum=	1,746,500	856,500	1,250,500
% of ttl capacity=		49	71.6

Appendix C :

Bekaa and Zahle region:

	capacity in boxes	demand of 98	demand of 97
1-Shtoura Elhadiss- Shtoura	515,000	0	0
2-Kab Elias	40,000	35,000	35,000
3-Hamoud and Hatoum- Kab Elias	25,000	20,000	25,000
4-Nimer El Kfoury- Kab Elias	35,000	25,000	25,000
5-Akram Soultan-Bar Elias	90,000	7,500	5,000
6-Marzouk Mansour- Bar Elias	300,000	0	0
7-Mhaysin- Bar Elias - Elmarge	65,000	0	0
8-Daghmoush-Bar Elias- Elmarge	85,000	65,000	0
9-Ali Atallah- Masnah road	150,000	0	0
10-Sadek Elsharbati- Masnah road	125,000	0	0
11-Naser Elgebali- Bar Elias	125,000	0	0
12- El kottan- Taanail	50,000	7,500	0
13-El Sheikh- Anjar	100,000	0	6,000
14-El Ghandour-Anjar	800,000	0	0
15-Besaibis- Zahle	120,000	0	0
16-El Foursol	25,000	15,000	15,000
17-Baalbek	25,000	25,000	25,000
Sum=	2,675,000	200,000	136,000
% of ttl capacity=		7.4	5

Bekaa EL Gharbi region:

	capacity in boxes	demand of 98	demand of 97
1-Kefraya	100,000	47,500	55,300
2-Kherbet Kanafar	150,000	48,500	15,000
3-Aytanit- Mashghara	30,000	25,000	32,500
4-Biz- Mashghara	57,000	43,750	56,250
5-Salim Abou Khalil - Mashghara	21,000	0	21,000
6-Shehade& Kousma- Mashghara	22,000	18,500	22,000
7-Soubeh- Mashbhara	32,000	24,500	29,500
8-Aida- Mashgara	25,000	15,500	21,000
9-Sharaf- Mashghara	110,000	87,500	110,000
10-Mehaidli- Mashghara	100,000	42,500	98,500
11-Keraoun El Hadis- Keraoun	20,000	18,000	20,000
12-Ali Madi - El Keraoun	20,000	15,500	17,500
13-Kamed El laouz	40,000	0	35,000
14-El Rayshouni	25,000	25,000	22,500
15-Sader	25,000	25,000	25,000
Sum=	777,000	436,750	581,050
% of ttl capacity =		56	74.4

Appendix D :

South region:

	capacity in boxes	demand of 98	demand of 97
1-Hariri company- El Ghasieih- Sayda	40,000	0	0
2-Zaatari company- El Ghasieih	500,000	0	8,000
3-Safa company - El Ghasieih	220,000	0	0
4-Jezin	25,000	25,000	25,000
5-Daou company for fruit	140,000	112,500	45,000
Sum=	925,000	137,500	78,000
% of ttl capacity=		14.8	8.4

References

Collin, Daniel. 1975. Industries agricoles et alimentaires. 13-18 p.

Collin, Daniel. 1975. Fruits et legumes des pays temperés. 135-157p.

Dossat, Roy J. 1961. Principles of refrigeration. 121-134 p.

Jordan and Prister. 1956. Refrigeration and air conditioning. Second edition. Prentice Hall, New Jersy. 3-21 p. 81-85 p. 264-265 p. 280-281 p. 468-469.

Langley C. Billy. 1986. Refrigeration and air conditioning. Prentice Hall, New Jersy. 67 p. 96 p.110 p.

Moras, P. And Jean-Francois Chapon. 1977. Entreposage et conservation des fruits et légume frais 173-183 p.

Panhwar. 1970. Effect of processing and storage on chemical composition and Organaleptics quality of apple juice. AUB. Beirut. 89p.

The American Society of heating, Refrigerating and Air-conditioning Engineers inc. 1987. Ashrae Handbook. HVAC systems and applications. Chapter 19.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers inc. 1985. Ashrae Handbook. Fundamentals. Chapter 31.

International Institute of Refrigeration. IIR. 1966. Le Froid dans les Pays Mediterranéen. 281-287p.

International Institute of Refrigeration. 1968. Controlled atmosphere, cold rooms storage of quick-frozen products. 93-103 p. 111-119 p.129-131 p.

International Institute of Refrigeration.1970. Weight losses in foodstuffs no:3. 278-287p.

International Institute of Refrigeration. 1973. Packing station for fruit and vegetables. 98-146 p. 182-186 p. 194-198 p.

International Institute of Refrigeration. 1973. Cooling and ripening of fruit in relation to quality. Paris, France. 43-47 p. 69-74 p. 75-83 p. 187-191 p.

International Institute of Refrigeration. 1974. Refrigeration applications to fish, fruit, and vegetables in south Asia. 37-57 p. 90-115 p. 199-210 p.

International Institute of Refrigeration. Guide to refrigerated storage. Paris. 18-60 p. 130-154 p. 174-180 p.

International Institute of Refrigeration. 1976. Refrigeration techniques in developing countries. 117-121 p. 157-161 p.

International Institute of Refrigeration. 1979. History of refrigeration throughout the world. J.C. Fidlek trans. France. 306-311 p.

Ministry of Agriculture, Packaging and Refrigeration department, unpublished Manuscript.

Mininstry of Health. Unpublised Manuscript.

Scald. //post harvest.uc davis.edu/disorders/apple/pdap sca.html. 1-3 p.

Bitterpit. //post harvest.uc davis.edu/disorders/apple/pdap bit.html. 1-3 p.

Index.1vice/bae/www/programs/extension/publicat/postharv/AG-413-1/index.html.1-13 p

http ://www. Psu.edu/courses/Materials/Hort 101- rna/postharvest.html. 1-7 p.