

# **COLD CHAIN MANAGEMENT OF FRUITS IN GHANA**

(A CASE STUDY OF THE PINEAPPLE SECTOR)

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON, IN PARTIAL  
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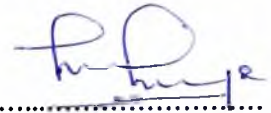
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**DECLARATION**

I, Roland Nii Ayi Quaye, do hereby declare my authority of this thesis titled “**Cold Chain Management of Fruits in Ghana, A case study of the Pineapple Industry**” and further wish to state that the research which led to this thesis was carried out by me at the Department of Crop Science. This research work has not in its entirety been presented for any degree be it in this University or elsewhere.



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This thesis has been submitted for examination with approval as supervisors.



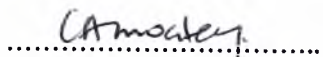
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## ABSTRACT

Ghana's Horticultural sector over recent years has seen tremendous growth and development with increasing demand for tropical fruits in Europe and the rest of the world. With the rise in competition among producing countries, it has become very important for the sector to be strengthened. Demand for quality produce by consumers in these developed countries has been a challenge to producers from developing countries like Ghana. For Ghana to compete favourably among its peers in the global market, quality parameters relevant to international markets like the cold chain and its management is of paramount importance to all the players in the sector.

This research therefore sought to catalogue the entire postharvest practices in the sector, find out the awareness and practice of cold chain management with the pineapple sector as a case study and find the best practices in the sector with regards to temperature, and other quality parameters which are of importance.



It was observed that, there was immense knowledge (100%) of the cold chain system among pineapple growers in the country and efforts were being made in practicing it. It was also found that growers were aware of GLOBALGAP, HACCP and many other sophisticated systems and do try their very best to abide by these regulations with different levels of compliance.

Finally with respect to cold chain temperature monitoring and management, the results showed that even though local growers have taken steps to acquire either complete or partial cold chain systems, little has been done to improve the management and monitoring of produce temperature, especially regarding produce in transit from the farm to the port.

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## ABBREVIATIONS AND ACRONYMS

<b>EU</b>	European Union
<b>EUREP</b>	Euro Retailer Produce Working Group
<b>FAGE</b>	Federation of Associations of Ghanaian Exporters
<b>FAO</b>	Food and Agriculture Organisation of the United Nations
<b>FASDEP</b>	Food and Agricultural Sector Development Policy
<b>FBO</b>	Farmer Based Organisations
<b>GAP</b>	Good Agricultural Practices
<b>GMP</b>	Good Manufacturing Practices
<b>HACCP</b>	Hazard Analysis and Critical Control Point
<b>ha</b>	Hectares
<b>HAG</b>	Horticultural Association of Ghana
<b>HEII</b>	Horticultural Export Industry Initiative
<b>MD2</b>	Maya Gold
<b>MoFA</b>	Ministry of Food and Agriculture
<b>NGO</b>	Non-Governmental Organization
<b>PFID-F&amp;V</b>	Partnerships for Food Industry Development - Fruits & Vegetables
<b>PPP</b>	Public Partnership Program
<b>SPEG</b>	Sea Pineapple Exporters of Ghana
<b>SWOT</b>	Strengths, Weaknesses, Opportunities and Threats

**USDA**

United States Department of Agriculture

**VEPEAG**

Vegetable Producers and Exporters Association of Ghana

## CHAPTER ONE

### 1.0 INTRODUCTION

#### 1.1 Background

Ghana's horticultural sector has become important in recent times. Horticultural exports are more than 250 percent of the level they were just some five years back when measured in dollar terms (MOFA, 2007). The stage is set for the sector's exports to rise sharply in the coming years. Ghana's location, climate and soil make it an ideal country to become Europe's next large supplier of horticultural products at a time when Europeans are turning to import to satisfy customers growing demand but natural geographic advantage alone will not make Ghana a major horticultural country (USAID, 2007a).

In the global market, even though people are concerned about the optimization and integration of supply chain management to deliver superior customer value at less cost (Christopher, 2005), there is a niche market of cold chain management (Verbic, 2006). Products with various requirements in temperature or humidity constitute diversified and complex cold chains (Ames, 2006). It is hard to maintain appropriate temperatures throughout a product's life, and negligence or mishandling in each link of the cold chain may undermine the quality of the temperature-controlled products (Meenke, 2006).

Fresh fruits are living products. After harvest they continue the process of respiration which produces carbon dioxide, water and heat. The heat produced by respiration results in warming of the produce unless it is actively kept cool e.g. by refrigeration. The rate of deterioration of the product is largely determined by the rate of respiration (Bartz and Brecht, 2002). Respiration needs to be slowed down to minimize product deterioration but respiration can never be completely stopped. The rate of respiration is temperature dependent (Gross *et al.*, 2002). Produce which is kept cool will have a low rate of respiration with limited heat production and low rate of deterioration. However, produce which is not actively cooled will gradually warm from the heat released during respiration, which will lead to increasing rates of respiration and deterioration as the produce continues to warm up. Different products have different rates of respiration. Those with higher rates are more highly perishable and temperature control is very

critical for these products. Even though a cold chain is not a priority for local fruits, it becomes a necessary adjunct to the development of horticultural exports. These crops must be cooled to the appropriate temperature and held in refrigeration at this same temperature from harvesting till the produce gets to the final consumer.

The Cold Chain is the management of produce temperature, from harvesting through to the consumer, to maintain the quality of the product (Beasley, 2002). Maintenance of the Cold Chain is the best way to minimize all forms of deterioration after harvesting. Good Cold Chain management results in the consumer receiving a product of “fresh” quality, leading to greater satisfaction and increased demand.

The export of fresh produce often involves long journey times and frequent handling. This makes effective Cold Chain management more difficult but even more essential to ensure the product offered for final sale retains maximum freshness. Maintaining the Cold Chain is the responsibility of everyone who handles fresh produce, from production to retail sale. A breakdown in temperature control at any stage will impact on the final quality.

## **1.2 Justification**

Significant quantities of horticultural crops are lost between harvest and consumption. The magnitude of these losses varies in accordance with the country and the commodity. In Ghana about 20-30% of production is lost due to the poor traditional post harvest management of food crops (MOFA, 2000). Losses of this magnitude have a positive effect on prices which in turn restrict access to food at the household level. In order to reduce these losses, postharvest technologies which delay senescence and which maintain quality must be applied. Existing technologies must be improved and alternative technologies must be sought.

Secondly, there is a growing market for tropical fruits in Europe and other parts of the world, particularly in the off-season. In a relatively short period of time, Ghana has been able to build up a substantial volume of exports of fruits. In 2009, the overall non- traditional export (NTE) with the horticultural sector leading, accounted for 12.4% of GDP raising more than

US\$1,215million (Afd, 2009).The perceived quality of Ghanaian fruits in Europe is lower, comparable to that of other countries. Improvement in quality is the starting point to achieve an increase in the volume purchased by European and even local buyers and this research seeks to bring out the alternatives to already existing practices.

Also, the fresh fruit industry in Ghana is highly fragmented, with thousands of farmers producing for sale to either local or export markets elsewhere in Africa or Europe. Although large-scale farmers in Ghana are conditioning to the GLOBAL GAP standard (and therefore achieving an acceptable level of quality conformance), the consistency of their products is questionable(USDA, 1983). Main factors causing inconsistency are the lack of an appropriate and integrated cold chain for fresh produce, poor handling of products, and low quality packaging. Successful cold chain management results in the end consumer receiving produce of a higher quality, leading to greater satisfaction and demand.

It is also worth mentioning that the problem of the cold chain lies in how to constitute an uninterrupted flow of a specific thermal profile throughout the product's life, from manufacturing, packaging, transit, storage and display (Beasley, 2002). It is time to work towards an optimal management system for the cold chain, and on the subject of how to utilize existing resources effectively to maintain various products' quality in the whole temperature-controlled chain, while minimizing the waste and cost from the supply chain point of view.

Finally, the concept of cold chain in Ghana is only introduced in a few papers over the past decade and research on the cold chain is limited. Most papers deal with the broad aspect of Postharvest without a vivid look at the whole cold chain. There is a gap to be filled in a systematic cold chain management perspective with the evaluation of variable elements and issues in the cold chain and best practices or standard operation systems of various cold chains need to be developed.

### **1.3 Objectives**

The objectives of the study were to;

- ✓ Assess the awareness and practice of cold chain management among farms in Ghana.
- ✓ Determine quality management practices and temperature variations along the chain.
- ✓ Determine best practices in Cold Chain management of fruits in Ghana

#### **1.4 Scope and limitations of the study**

The cold chain is involved in many industries such as food, pharmaceuticals, artwork, microchips, flowers, chemicals, etc but due to the nature of this particular research and its objectives, it has become relevant to limit the research to the pineapple sector. Also, even though the research area is Ghana, due to lack of resources, information, time and cooperation from farmers, limited data was collected (Three (3) regions and a limited number of farms were used).

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

#### 2.1 Fruits and Vegetables

Horticulture, which includes the production of fruits, vegetables, flowers, spices, medicinal and aromatic plants and plantation crops has emerged as a major economic activity in most parts of the world. The Asia-Pacific region alone contributes to more than 50% of the world's acreage under fruits and vegetables and produces a diversity of fruits such as apples, bananas, oranges, grapes and mangoes in addition to tropical and sub-tropical fruits such as pineapples, papayas, guavas, litchi and passion fruit.

Fruits and vegetables are not considered to be primary sources of carbohydrate, protein and fat. However, those with storage roots and tubers are rich in carbohydrate, particularly starch, in amounts comparable to the cereal crops, and can be used as staple foods. Leguminous vegetables supply as much as 14% protein, while dry seeds supply even more. The lipid content of most vegetables is less than 0.1%. Most fruits, vegetables and root crops are rich in minerals, carotene (Pro-vitamin A) and vitamin C, and are reasonably good sources of trace elements such as copper, manganese and zinc, which act as enzyme cofactors. Fruits and vegetables contribute approximately 91% of vitamin C, 48% of vitamin A, 27% of vitamin B6, 17% of niacin, 16% of magnesium, 19% of iron and 9% of calories to the human diet. Other important nutrients supplied by fruits and vegetables, include folacin, riboflavin, zinc, calcium, potassium and phosphorus (USDA, 1983). The nutrient content of fruits and vegetables varies in accordance with the fruit or vegetable variety, cultural practices, stage of maturity, postharvest handling and storage conditions. Natural physiological and biochemical activities in fruits and vegetables result in compositional changes following harvest.

Fruit and vegetable consumption has increased in response to growing health consciousness. Their consumption has been strongly linked to reduced risk of some forms of cancer, heart disease, stroke and other chronic diseases (Southon, 2000). Fruits and vegetables are sources of antioxidants which modify the metabolic activation and detoxification/disposal of carcinogens, or even influence processes that alter the course of tumor cell growth (Wargovich,

2000) Although antioxidant capacity varies greatly among fruits and vegetables, consumption of a variety of fruits and vegetables is preferred, over limiting fruit and vegetable consumption to those having the highest antioxidant capacity (Prior, 2000).

## **2.2 Causes of Post Harvest Loss in Horticultural Produce**

### **2.2.1 Biological and environmental causes**

Biological (internal) causes of deterioration include respiration rate, ethylene production and action, rates of compositional changes (associated with color, texture, flavor, and nutritive value), mechanical injuries, water stress, sprouting and rooting, physiological disorders, and pathological breakdown. The rate of biological deterioration depends on several environmental (external) factors, including temperature, relative humidity, air velocity, and atmospheric composition (concentrations of oxygen, carbon dioxide, and ethylene), and sanitation procedures (Bartz and Brecht, 2002).

Temperature affects many processes in Horticultural product and their environment (Kader, 2003). The rates of physiological process in the fruit, including respiration and ethylene evolution and action (as a ripening hormone), are temperature regulated, and are lowest just above the freezing point of the tissue. Thus the rates of fruit ripening and flesh softening, and the progression of senescent breakdown, are fruit temperature dependent; while the rates of water loss and fruit shrivel development (and cherry stem browning) result from vapor pressure differences between fruit and their environment, which are controlled by fruit temperature and the temperature, relative humidity and air velocity of the surrounding atmosphere. Temperature will also influence other causes of fruit deterioration. The rates of growth and spread of fruit rotting organisms are temperature regulated in the same way as the physiology of the fruit, though various fruit rotting fungi vary, in their temperature response patterns. The temperature regime will influence the development of temperature related injury symptoms in the fruit, whether high temperature injury, chilling injury (internal breakdown), or freezing injury.

Mechanical injuries are temperature influenced in two ways. First, temperature can affect fruit sensitivity to impact and vibration injuries. Second, low temperature following an injury will minimize its effects on the deterioration and physiological activity ( $\text{CO}_2$  and  $\text{C}_2\text{H}_4$  production) of the fruit as well as minimizing the rate of growth of microorganisms invading any resulting wounds.

### **2.2.2 Socio-economic factors**

Although the biological and environmental factors that contribute to postharvest losses are well understood and many technologies have been developed to reduce these losses, they have not been implemented due to one or more of the following socioeconomic factors (Kader, 2002).

#### **2.2.2.1 Inadequate marketing systems**

Growers can produce large quantities of good-quality fruits, ornamentals, and vegetables, but, if they do not have a dependable, fast, and equitable means of getting such commodities to the consumer, losses will be extensive. This problem exists in many locations within developing countries. It is accentuated by lack of communication between producers and receivers, and lack of market information.

Marketing cooperatives should be encouraged among producers of major commodities in important production areas. Such organizations are especially needed in developing countries because of the relatively small farm size. Advantages of marketing cooperatives include: providing central accumulation points for the harvested commodity, purchasing harvesting and packing supplies and materials in quantity, providing for proper preparation for market and storage when needed, facilitating transportation to the markets, and acting as a common selling unit for the members, coordinating the marketing program, and distributing profits equitably (World Bank Report, 1999).

Alternative distribution systems, such as direct selling to the consumer (roadside stands, produce markets in cities, local farmers' market in the countryside, etc.) should be encouraged. Production should be maintained as close to the major population centers as possible to minimize transportation costs.

Wholesale markets in most of the developing countries are in desperate need of improvement in terms of facilities and sanitation. These are overcrowded, unsanitary, and lack adequate facilities for loading, unloading, ripening, consumer packaging, and temporary storage. In several countries, there are plans to build better wholesale marketing facilities, but their implementation has been delayed more because of social and political than financial considerations.

#### **2.2.2.2 Inadequate transportation facilities**

In most developing countries, roads are not adequate for proper transport of horticultural crops. Also, transport vehicles and other modes, especially those suited for fresh horticultural perishables, are in short supply. This is true whether for local marketing or export to other countries. The majorities of producers have small holdings and cannot afford to own their own transport vehicles. In a few cases, marketing organizations and cooperatives have been able to acquire transport vehicles, but they cannot do much about poor road conditions (Gauraha, 1997).

#### **2.2.2.3 Government regulations and legislations**

The degree of governmental controls, especially on wholesale and retail prices of fresh fruits and vegetables, varies from one country to another. In many cases, price controls are counter-productive. Although intended for consumer protection, such regulations encourage fraud and provide no incentive for producing high-quality produce or for postharvest quality maintenance. On the other hand, regulations covering proper handling procedures and public health aspects (food safety issues) during marketing are, if enforced properly, very important to the consumer.

#### **2.2.2.4 Unavailability of needed tools and equipment**

Even if growers and handlers of fresh horticultural crops were convinced of the merits of using some special tools and/or equipment in harvesting and postharvest handling, they most likely will not be able to find them in the domestic market. This is true of harvesting aids; containers; equipment for cleaning, waxing, and packing; and cooling facilities. Most of the tools are neither manufactured locally nor imported in sufficient quantity to meet demand (FAO, 1980). Various governmental regulations in some countries do not permit direct importation by producers of their needs. It is imperative that the tools that will enable handlers to use recommended technology for a given situation be available for them to use. In many cases, such tools can be manufactured locally at much lower cost than those imported.

#### **2.2.2.5 Lack of information**

The human element in postharvest handling of horticultural commodities is extremely important. Most handlers involved directly in harvesting, packaging, transporting, and marketing in developing countries have limited or no appreciation for the need for, or how, to maintain quality. An effective and far-reaching educational (extension) program on these aspects is needed critically now and will continue to be essential in the future ([www.fao.org/inpho](http://www.fao.org/inpho)).

#### **2.2.2.6 Poor maintenance**

In many developing countries, some good facilities that were built a few years ago are currently “out of order” or not functioning properly because of lack of maintenance and unavailability of spare parts. This problem is especially true of public-sector facilities. Any new project should include in its plan adequate funds for maintenance to ensure its success and extended usefulness.

## **2.3 Postharvest operations for fruits**

### **2.3.1 Harvesting**

Quality cannot be improved after harvest, only maintained; therefore it is important to harvest fruits, vegetables, and flowers at the proper stage and size and at peak quality. Immature or over mature produce may not last as long in storage as that picked at proper maturity (Wilson, 1995).

Harvest should be completed during the coolest time of the day, which is usually in the early morning, and produce should be kept shaded in the field. Handle produce gently. Crops destined for storage should be as free as possible from skin breaks, bruises, spots, rots, decay, and other deterioration. Bruises and other mechanical damage not only affect appearance, but provide entrance to decay organisms as well.

Postharvest rots are more prevalent in fruits that are bruised or otherwise damaged. Mechanical damage also increases moisture loss. Damage can be prevented by training harvest labour to handle the crop gently; harvesting at proper maturity; harvesting dry whenever possible; handling each fruit or vegetable no more than necessary (field pack if possible); installing padding inside bulk bins; and avoiding over- or under-packing of containers (Wilson, 1995).

### **2.3.2 Transportation**

The harvested fruit is deposited in drawers and transported to the packing plant, where it is submerged in disinfectant in trays. Another alternative process consists of submerging the fruit completely in similar solution (with Triadimefon) this process is used especially to export to United States and Europe. The boxes used in the packing are revised to detect the presence of insects. The fruit is placed in boxes of 10 - 20 kg and, finally, put in pallets. The pallets, properly maintained in refrigeration chambers are loaded in the refrigerated containers. Each container has a capacity of 1500 boxes of 20 kg and/or 3000 approximately boxes of 10 kg. The refrigerated container is maintained at 7.5 - 8° C previous to export. Each container has a thermograph for the control and registration of the temperature while traveling as well as with the respective filters for the control of the ethylene. Is important to offer and use an

appropriate packing for the produce, for the cultivation and preparation of the fruit, because just with a safe and functional protection it can keep the quality of the product until arrival to the final market. The packing also helps to promote the fruit's sales because of the presentation, as well as the description of content and origin. The appropriate packing use for the product fulfills the following functions: to avoid the loss of aroma, to protect the product against the admission of flavors and disgusting scents, to offer a good period of conservation, to avoid the accumulation or loss of humidity, to protect the product against damages, to offer a space to print the relative necessary information about the product. A careful crop handling and postharvest contributes to the maintenance of the quality of the products. An important characteristic in this stage is that the boxes should have holes with lengthened form in all sides for the ventilation, because it allows a quick exit of the heat of the fruit. The packing measures for pineapples are not standardized, but are guided with the international packing norm for agricultural products according to the size. The product should be kept at temperature packing from 7 - 10° C, with a relative humidity of 90%. The fruits should be fixed inside the box, in order to avoid wounds in the shell and/or the crown (Isabellefruits, 2004).

### **2.3.3 Grading**

After pre-grading, washing, waxing, and fungicide treatment, the fruits are left to dry and then are graded for packing. Graders remove any fruit that shows signs of fresh mechanical damage or any of the conditions that qualify the fruit for rejection in the pre-grading stage. Remaining fruits are classified for packing based on size, stage of ripeness, and, if applicable, shape. Fruits of different shape may not be mixed in the same carton.

### **2.3.4 Packing**

The preferred method of packing is to place the fruit vertically on the base, and then to place dividers between the fruits to prevent rubbing against each other and movement. With some cartons, this is not possible and fruits are laid horizontally in alternating directions; where two

layers of fruit are packed, a layer of card is required between the layers: 6 counts - 1.75 kg fruit (3.8 lb), 12 count - 1.25 kg fruit (2.7 lb), 12 counts - 1.00 kg fruit (2.2 lb) and 20 counts - 0.75 kg fruit (1.6 lb)

Where sea-shipment is to be used, the fruit should be harvested on the day prior to shipment. Green fruit should be stored at 10°C, 85 to 95% relative humidity, and under these conditions, should have a storage life of two to three weeks. This will be dependent on the sugar content and the agronomic conditions during production, in addition to the handling and storage procedures. Where exports are made by air with fruit harvested at more advanced stages of maturity, pre-export storage can be used and the suitable storage temperature decreases to 7.5°C, 85 to 95% relative humidity. Potential postharvest losses in pineapples during air-transport are minimal if careful handling is employed. On sea-shipments and long term storage however, the fruit are more susceptible to post-harvest losses as a result of increased handling, control of temperature and disease incidence. Mechanical damage like bruising or puncturing caused by poor handling, dropping or abrasion, will result in localized areas of softening and development of secondary microbial infection (Foodmarketexchange, 2004).

### **2.3.5 Refrigeration**

Fruits are placed in an insulated room equipped with refrigeration units and forced air-cooling where fans pull cool air through pineapple packages. After storage the pineapple pallets are placed in refrigerated containers with fresh air supply or controlled atmosphere.

### **2.3.6 Storage of fruits**

The best storage environment for an individual fruit depends on its unique requirements for temperature, relative humidity, and ethylene exposure. Most compatibility charts for mixing products during postharvest handling divide fruits and vegetables into eight groups. In practice it

is very difficult to separate products into this many groups-very few wholesale or retail handling facilities, if any, have eight temperature-controlled rooms.

### **2.3.7 Transportation system**

Marketing and physical distribution of fresh produce inherently means moving the produce. The commodities are handled, either manually or mechanically, many times from harvest and through the distribution process before the consumer buys and prepares them to eat.

For domestic transportation the use of road vehicles offers substantial advantages of convenience, availability, flexibility permitting door-to-door delivery, and reasonable cost of transport. The use of road transportation for fresh produce is increasing and likely to increase in countries all over the world. Produce may be transported by pick-up, enclosed truck, open truck or refrigerated vehicle (Harrison, 1988).

For perishable products, however, the increased speed of handling and reduced transport costs that came with containerization were not enough. Ocean transport of cooled and frozen cargo received a substantial boost with development of mobile refrigerated cargo ships that lack this flexibility. Controlled atmosphere (CA) technologies allow operators to lower the respiration rate of produce by monitoring oxygen, carbon dioxide and nitrogen levels within a reefer. In this way, CA can slow down ripening, retard discoloration, and maintain freshness of pineapple. Although it is likely that container ships will dominate the perishable trade between North America, East Asia and Europe, conventional refrigerated vessels can serve many smaller ports, especially in the developing world, that are unable to handle large container vessels. Thus, in north-south trade and in certain niche markets, conventional refrigerated ships may have a brighter future, but even here, competition from container vessels is bound to increase as cost decline (OECD, 1999)

## 2.4 Ghana's Agriculture

Ghana has an area of about 240,000 km<sup>2</sup> with an estimated population of 24 million at an annual population growth rate of 2.7% (SRID, 2010). The population density is 85 persons per square meter. Land suitable for agriculture is about 13,629,000 or 57% of the total land area of Ghana (Asante, 2004). Land under cultivation in 2009 for the major crops was estimated at about 7.5 million hectares or 53.6% of total agricultural land. There is therefore no scarcity of agricultural land (MOFA 2009).

Ghana is well endowed with natural and human resources. The national nominal Gross Domestic Product (GDP) was GHC 21,746.8 million in 2009. Ghana is currently classified as a middle income country (World Bank Country Report, 2010). The economy depends to a great degree on primary production and exports, mainly cocoa (22.5%) minerals (36.6%) and timber (8.8%). Agriculture accounts for about 34.5% of the Gross Domestic Product in (MOFA 2009), 35.5% of foreign exchange earnings and directly employs 50.6% of the total labour force. The sector contributes 4.6 % of tax revenue and 4.3% of total revenue. The annual rainfall varies between 800 and 2400 mm generally decreasing from South to North and from West to East. Most lands are covered by poor fertility soils with poor physical properties with low organic matter content (GSS, 2009).

Ghana's overall performance in terms of agricultural production and productivity remains inadequate and Ghana has failed to make progress on the food security front. Average yields have remained stagnant. Commercial food imports and food aid constitute about 4.7% of food needs in the last fifteen years. The slow growth of agriculture is due to a combination of factors that reduce farmers' incentives to invest and produce. These include inappropriate policies, lack of technological change and poor basic infrastructure. Food security is defined as access by all people at all times to enough food for an active, healthy life.

## 2.4.1 Overview of the performance of Ghana's horticultural sector

### 2.4.1.1 Fruits

Fruits in Ghana are usually produced mainly for consumption. However, recently they are major contributors to non-traditional exports.

**Table 1: Estimated Yield of Fruits, 2009**

Crop	Average Yield (Mt/Ha)	Achievable Yield (Mt/Ha)
Pineapple	50.0	72.0
Pawpaw	45.0	75.0
Oranges	35.0	-
Mangoes	11.0	-

Source: MOFA (SRID, 2010)

Pineapple is mainly produced in the five regions of the country that is Central, Eastern, Western, Brong-Ahafo and Greater Accra. The export pull is producing a number of producers from the large-scale growers/exporters to the very small-scale commercial growers. The pineapple export industry is comprised of about 65 firms with three large producers' exporters accounting for over 40% of the exports. Many smallholders, some involved in out grower schemes, supply pineapples to medium to small exporters.

Table 2 presents estimation of the value of some of the non-traditional export fruits.

**Table 2: Value of Main Agricultural Non-Traditional Export(US S'000)**

Crop	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Pineapple	11853	13450	15520	14378	22069	13430	19086	13475	11842	10628
Pawpaw	161	993	864	737	1267	1081	937	1020	334	546
Banana	3695	3189	3250	227	209	489	10330	9965	12717	11590
Mangoes	118	78	70	108	164	135	83	998	522	235
Orange	249	126	672	329	94	3865	462	333	1647	875

Source: PPMED, MOFA

Supporting the large-scale growers with market linkages in the U.S and Europe for pineapples, pawpaw, banana, mangoes, can exert a further pull that can help increase the supply base. Table 15 presents exports of fruits from Ghana. The larger exporting enterprises are better able to tackle quality assurance systems mainly aiming for the Global GAP certification.

**Table 3: Fruits export from 2000 to 2009 (Mt)**

Crop	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
<b>Pineapple</b>	28512	34933	46391	45145	71805	46694	60751	40456	35134	3156
<b>Pawpaw</b>	1748	1792	1474	1917	3212	1912	3212	1194	968	891
<b>Banana</b>	3883	3251	3233	364	725	1117	44098	52069	69779	47613
<b>Oranges</b>	1242	1336	15213	4307	742	5846	6283	3674	10991	11028
<b>Mangoes</b>	268	232	126	234	376	407	182	824	858	435

Source: PPMED, MOFA

Production and marketing of banana in Ghana is not well developed. Volta River Estates Limited (VREL) is the only company that produces banana in commercial quantities (USAID, 2007). The company supplies the domestic, regional as well as the international markets. The export trend is on the increase.

Cashew is being supported by NGO's such as World Vision International, AMEX, ADRA, Ricerca, Cooprazione and TechnoServe and the crop has shown tremendous progress in both production and exports. The potential of the crop as a good, environmental friendly agro-forestry crop is tremendous. There is an on-going Cashew development project which seeks to double the present plantation of 18,000 ha to 36,000 ha.

The fresh orange market has been expanding recently particularly to the West African sub region. The market is highly seasonal and the producers are at the mercy of the few exporters. Citrus is a crop that is coming up in the Eastern and Central regions. An innovative area is to determine the factories capacity to cover the plantations in the area and develop a new facility for processing of the crop

Kola nuts are grown in the forest regions of Ghana. The domestic demand is limited by the fact that the Muslim population who constitute about 12% of the population mainly uses it. Kola is

therefore an export crop. The West African market is the biggest market for Ghana's fresh kola. Saudi Arabia is a major market for fresh Kola. The U.S and other European markets are for dry Kola. The export trend seems to be increasing; however supply is constrained by a number of factors, which are as follows,

- It is a buyer's market where traders determine prices.
- Fresh Kola cannot be transported by sea. Sub-Regional exports are by road and exports to Saudi Arabia from Nigeria are by air.
- Lack of standard prices and measures.
- The bulk of Ghana's export about 90% is channeled through Nigeria in transit to Saudi Arabia. Transit duties and countless barriers are physical and financial limitations.

#### 2.4.1.2 Vegetables

The cultivation of pepper is by about 50% of households operating a farm. The crop is harvested extensively in all the ecological zones. It is grown basically for domestic consumption and the marketable surplus is about 22% of annual production. The exports of pepper are increasing annually. There is the potential for export and paprika is the latest introduction.

**Table 4: Estimated Yield of Vegetable, 2009**

Crop	Average Yield (Mt/Ha)	Achievable Yield (Mt/Ha)
Pepper	6.5	32.3
Tomato	7.5	15.0
Garden Eggs	8.0	15.0

Source: GLSS 4 (¢b=¢billion)

Onion production is concentrated in the savannah and forest zones and the marketable surplus is about 80% of production. Ghana is a net importer of onions mainly from the Sahel region.

Conversely smaller quantities of onions are exported each year. The potential to increase production is in the upper east region.

Okra, Tomatoes and Garden eggs are also primarily concentrated in the forest and the savannah zones. Okras marketable surplus is about 34% of annual production. Okras exports have declined since 1997 however the potential to export more is still there. About 50% of tomatoes annual production is marketed and Ghana is a net importer of tomatoes. The imports are mainly processed products (puree, canned etc.) whilst Ghana exports fresh tomatoes. The fresh tomatoes exports have also declined since 1996. The marketable surplus for garden eggs is about 20% of the annual production. Garden eggs exports are on the ascendancy as shown in table 5.

**Table 5: Vegetable Exports From 1995 to 1999 (tonnes)**

<b>Crops/Year</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>
<b>Pepper</b>	121	732	1420	2088	2420	2819	5281	4687
<b>Onion</b>	-	29	25	75	39	58	46	58
<b>Okra</b>	-	44	392	38	56	64	67	65
<b>Tomatoes</b>	130	1814	817	534	471	2033	4539	4961
<b>Egg Plant</b>	-	513	1018	1184	1338	1080	1295	1512
<b>Tinda</b>	-	-	822	879	878	1126	1256	1137
<b>condiments</b>	1741	2319	625	495	389	980	988	1548

Source: PP MED, MOFA

## 2.4.2 History of the Cold Chain Practice in Ghana

There is a major difference between being a major player in European horticultural markets and being only an occasional shipper (USAID, 2007). Through Sea Pineapple Exporter of Ghana (SPEG's) efforts, Ghana's exporters have privileged access to two refrigerated vessels a week to Port venders in southern Europe, with a shipping time of ten to fifteen days (SPEG, 2009). Yet until recently, Ghana lacked any form of temperature-controlled supply chain for its horticultural products before arriving to the ships, making the distance from Ghana's interior to a European Supermarket shelf a long and risky one for perishable, high valued products and ultimately, the key limiting factor in Ghana's export growth. But this is changing rapidly: temperature-controlled pack houses are being constructed in Ghana's key horticultural districts, hundreds of kilometer of roads are being improved and expanded to shorten transport times to port and the construction of the Fruit Terminal (Shed 9) at the Tema Harbour has immensely improved the sector (MOFA, 2007).

Shed 9 which used to be a single store house where temperatures often exceed the heat outside is now a state of the art temperature controlled perishable goods facility with a capacity of up to three thousand (3,000) metric tonnes of flow-through per week to outbound vessels. Shed 9 has five (5) installed docks and eight independent temperature-controlled chambers which enables flexibility in the types of crops to be handled through the facility. The private sector has in recent years introduced temperature-controlled pack houses in the field. Currently most of SPEG's members and other association like the mango and pawpaw associations have access to cold facilities(SPEG, 2009).

Finally the HEII and its private sector partners have completed blueprints and contractor-tender specifications for the construction of a perishable Cargo center at the Kotoka International Airport. The center will combine an advanced temperature-controlled storage and aircraft loading facility with customs and phytosanitary inspection offices in the same building.

### **2.4.3 Institutional Support in the Sector**

The foundation of Ghana's emerging horticultural success story is Ghana's private sector-private farmers, companies and investors working to expand harvests, exports and product quality. As important as individual efforts has been to the sector's emerging success, the cooperative attitude these private entrepreneurs have brought to building the horticultural sector has been crucial in many years.

**SPEG** for instance took the challenge of coordinating sea-freight space to Europe. The Sea Pineapple Exporters of Ghana (SPEG), formed in 1994, has about 30 members who account for about half of the total exports to Europe. SPEG plays a role in facilitating cooperation among producer-exporters particularly in the area of shipping. At least two foreign owned processing companies (Blue Skies from the United Kingdom and Tongu Fruits from the Netherlands) export fresh cut pineapple and other fruits to extraordinarily demanding European buyers like Albert Heijn, Marks & Spencer and Sainsbury. First Catering is setting up processing facilities aiming to produce for high-end markets. Industry sources estimate that Ghana could increase its production and exports of pineapple four-fold in the medium term – from its current 30,000mt to 120,000mt – if the local business environment improved (World Bank, 2001).

**The Federation of Association of Ghanaian exporters (FAGE)** has worked with other stakeholders in the public-private research committees to coordinate efforts and focus resources. Throughout Ghana, hundreds of farmer-based organizations (FBO's) have been the vehicle for disseminating new techniques and plant materials.

Supporting these private efforts at every step are several institutions and programs that have emerged in recent years with the force squarely on developing on Ghana's horticulture effort. MoFA has been at the forefront of this development providing technology and strategic information support to developing the industry.

**The HDU** continues to work through MoFA's crop research service and its agric groups as technical training on good agricultural Practices and to undertake adaptive research and development for Ghana-specific horticultural production.

**The Ghana Export Promotion Council** has facilitated access to consulting services for horticultural entrepreneurs; this for instance helped in the creation of Ghana's first commercial papaya farm (GEPC, 2009)

**HEII** has been at the centre of many rapid developments in the Horticultural sector of the country. Currently they are supporting the sector with the following activities

- ✓ Development and spreading of elite planting materials to farmers
- ✓ Improving food safety and quality management
- ✓ The establishment of a definitive pesticide list for all fresh produce export crops
- ✓ International certification of Ghana Standard Board laboratory as an ISO 17025 accredited laboratory

Supporting the efforts of the sector are donor agencies, notable among them are the US Agency for International Development (USAID), the German Technical Cooperation's Market oriented Agricultural Programme (MOAP) and the EU's regional Pesticide Initiative are significantly contributing the sectors improvement.

#### **2.4.4 Quality and Standards in the Cold Chain**

The emergence of more rigorous international food quality standard for the past decade present challenges and opportunities for Ghana as a horticultural exporter and Ghana is proving it can meet the challenges and grab the opportunity.

European supermarkets differentiate themselves from their competitors by offering fresh produce and cannot afford to offer inferior produce of products that do not meet rigorous food-safety standard. These standard are based not on superficial preference of the retail shopper, but as become formalized as legal and commercial necessities as brand and food standard management. The leading organizing institution on the food safety front, based in Europe is the over decade-old GLOBAL GAP a private sector that sets voluntary standards for the certification of

agricultural products around the globe. Ghana is meeting these challenges, and then some. More than a year ago, the horticultural sector began efforts to comply with GLOBAL GAP under the “option 2” approach, whereby producer association acts as the vehicle for certification of its members.

Today more than 80 percent of Ghana pineapples are GLOBAL GAP certified. Over 30 companies produce directly for export with about 250 farms serving as out growers for larger exporters. In addition, most Ghanaian companies are now being trained to meet the Hazard Analysis and Critical Control Points (HACCP) standards adopted by U.S and European to ensure food safety. Yet Ghana’s horticultural industry wants to go beyond basic food safety compliance; the pineapple producers are working with Bureau Veritas Group an international respected company that performs inspection and certification services for exporters and importers worldwide, to ensure that all Ghana’s pineapple exports will be routinely inspected against 43 different quality attributes by the end of 2007, thus guaranteeing Ghana’s quality brand name.

Similarly, governments in Europe, North America, and other major importing regions set maximum residue levels (MRLs) pesticides and other potentially harmful chemicals. These requirements are applied to imported food products as well as those grown domestically. Here too, Ghana has moved rapidly to meet the MRL standards through monitoring and control before, during and after the production of the fruit or vegetable in question. At the front end, HEII and Ghana’s Environmental Protection Agency recently fast tracked the registration of 50 pesticides for use in agriculture on a good by good basis, and developed and published the definitive list acceptable pesticides for Ghana’s specific horticultural crops. This ensures that from the beginning, farm inputs do not violate the standards. On the farm itself, the private sector has implemented extensive training and monitoring programs to ensure MRL standards are maintained.

Finally, at the back end HEII and the Ghana Standard Board have upgraded the country’s monitoring of Horticultural exports by for example, providing the Pesticide Residue Lab with new, state of the art equipment and obtaining the labs certification as an ISO 17025 accredited laboratory.

## 2.5 Development of the Cold Chain

Fernie and Sparks (2004) explained that the cold chain has been evolving since the 1980s. In the past, a cold chain simply denoted single temperature warehouses and refrigerated vehicles. There was no awareness of integrating the supply chain links and as a result billions of dollars' worth of losses occurred every year (Beasley, 2002). Through technological development, cold stores (in Europe) or Refrigerated Warehouses (in US) have been built for handling temperature-controlled perishables. Apart from that, chambers for different temperature ranges and atmosphere requirements are equipped for professional handling for a wider range of product sets (Duiven and Binard, 2002). Further development of the perishables trade has led to the advanced transportation system (James *et al.*, 2006). It was also stated by Gac (2002) that by the end of 2002, there were at least one million refrigerated vehicles and four million refrigerated containers in use.

Management of the cold chain has also improved. Concerning “temperature disturbance” issues, distributors and retailers came to a consensus of not checking goods until they had been transferred into the temperature-controlled chambers at the store, which improved cold chain integrity. Retail products were delivered in plastic trays, on “dollies”, or on roll cages, which improved handling speed (Fernie and Sparks, 2004).

Another development of the cold chain occurred between the 1980s and 2000s when the ordering and replenishment cycle was shortened, and the ordering quantity largely shrunk (McKinnon and Campbell, 1998). Now there is no fresh stock held in the cold distribution center for more than one day and stock holding in frozen products has declined to less than 10 days (IGD, 2001).

Furthermore, a concept of “cold traceability” was introduced to trace groups of temperature-sensitive products like meat, fish, fruit and pharmaceuticals which are transported in different atmosphere requirements. Bogatajet *al.* (2005) present that this is enabled by some specific tools such as thermometers, RFID, and time-temperature integrators.

## 2.6 Cold Chain Management

The Cold Chain is the management of produce temperature, from harvesting through to the consumer, to maintain the quality of the product (Smith, 2005). Maintenance of the Cold Chain is the best way to minimize all forms of deterioration after harvesting, including

- ✓ Weight loss resulting in wilting and limpness
- ✓ Softening
- ✓ Bruising
- ✓ Unwanted ripening
- ✓ Colour changes
- ✓ Texture degradation
- ✓ Development of rots and moulds.

The cold chain has two main components, one for pre-cooling, and one for holding. Pre-cooling must be accomplished for most export horticultural products soon after harvest (SARDI, 2003). This can be done by means of forced air-cooling systems, hydro cooling, and vacuum cooling or through the use of package ice. The method used depends on the crop, the volume being pre-cooled and costs. Cold storage must be available while the product is awaiting transport. Good Cold Chain management results in the consumer receiving a product of “fresh” quality, leading to greater satisfaction and increased demand. The export of fresh produce often involves long journey times and frequent handling. This makes effective Cold Chain management more difficult but even more essential to ensure the product offered for final sale retains maximum freshness. Maintaining the Cold Chain is the responsibility of everyone who handles fresh produce, from production to retail sale (Smith, 2005). A breakdown in temperature control at any stage will impact on the final quality of the product, although the effect may not be visible until several days later. Without the cooperation of everyone involved in handling fresh produce, the consumer will not be able to enjoy the produce in the best possible condition.

## **2.7 Methods of Cooling**

### **2.7.1 Precooling**

Rapid cooling has been clearly shown to prolong the shelf life of freshly harvested produce. During busy harvest times it is important to have practical systems in place to minimize the amount of field heat accumulating in harvested fruit as well as having an efficient system for removing that heat at the cool store (SARDI 1999).

The key for all fresh produce is to minimize the time that the harvested produce is allowed to remain warm or even hot. Fresh produce is best harvested in the cool of the day and bins should be placed in the shade. Wrapping a bin or covering it with a tarpaulin and leaving it in the sun is not nearly as effective as putting the bin in the shade. Covers over bins can act like a greenhouse, trapping in heat from the product and making the problem worse. Some air circulation is necessary to avoid the build of respiratory heat. Ideally the produce should be taken to the cool room and cooled as quickly as possible.

#### **2.7.1.1 Method of Pre-cooling**

The rate fresh produce cools depends on several factors,

- The rate of heat transfer from the produce to the air or water used to cool it. (i.e. the faster cold air moves past the product the quicker the product cools).
- The difference in temperature between the produce and the cooling air or water (i.e. the greater the difference between the two the faster the product cools).
- The nature of the cooling medium. (i.e. cold water has a greater capacity to absorb heat than cold air).
- The nature of the produce which influences the rate heat is lost (i.e. leafy vegetables have a greater thermal conductivity than potatoes and so cool faster).

The rate a product cools is not constant. It starts cooling rapidly and then quickly slows down as the difference in temperature between the product and the cooling medium falls the rate of cooling slows down. So it takes longer for the product to cool the last 5°C than the first 5°C ([www.postharvest.com.au](http://www.postharvest.com.au)).

### **2.7.1.2 Room cooling**

This cooling method exposes produce to cold air in a refrigerated space. The main advantage of this system is cost as no extra equipment is required. However, room cooling is very slow. This method is best used for hold cold produce before marketing or for storing produce that can be cooled over several days.

### **2.7.1.3 Top icing**

This method has been used for many years. It is commonly applied to boxes of produce by placing a layer of crushed ice directly on top of the produce. The ice can be applied shortly after harvest so that pre-cooling can begin as soon as possible after harvest. Broccoli is often packaged this way, although not as commonly as it once was. There are some disadvantages with this method as the ice melts. The melting ice wets the produce and can make it more susceptible to disease, it also adds extra weight to the carton and can puddle in the bottom of cool rooms and trucks causing slippery areas and the water can also wet other

### **2.7.1.4 Forced-Air cooling**

Forced air cooling is where produce is cooled by placing the produce into a cold room and then arranging the airflow pattern so that it is directed through the crop. The heat given out from the surface of the crop is then carried away in the stream of cold air. This is a useful method for crops that need to be cooled rapidly after harvest such as stone fruit and strawberries.

### **2.7.1.5 Hydro Cooling**

Hydro Cooling cools produce by washing them with cold, moving water. Most hydro cooling is by cold water showering down over produce at about 20 liters per second per square meter. Hydro Cooling has the advantage over other pre-cooling methods in that it can help clean the produce. If this is the case then chlorine should also be added to the water to prevent the build up and transfer of spoilage pathogens. Hydro cooling suits such things as tomatoes, melons and leafy vegetables.

### **2.7.1.6 Vacuum cooling**

Vacuum cooling is useful for pre-cooling leaf crops such as lettuce. The produce is placed inside a chamber where the atmospheric pressure is reduced. At this new low pressure the water inside the produce boils and the product is cooled. There is some weight loss associated with this method but often the produce is misted with water before cooling to prevent any serious loss of quality. This is a very rapid method of Pre-cooling. The efficiency of different cooling methods is often compared using the half cooling time. This is the time that it takes for the product to be cooled half way between the start temperature and the final cool temperature. For example, if the product is at 20°C and you wish to cool it to 0 °C, then the half cooling time is the time it takes for the product to be cooled to 10 °C. It is convenient because it is during the most rapid stage of cooling. Comparing the half cooling time of different cooling methods is quite interesting (Table 6). Some research done in the 1960's compares the speed of cooling peaches by different methods (Guillou, 1960). Although this may seem like old research the principles still apply today.

**Table 6: Comparison of the half cooling times of different methods for cooling fresh peaches**

Cooling method	Half cooling time
Room cooling	6 hrs
Forced air cooling	1 hr
Hydro-cooling	15 mins

This example shows the relative efficiency of each cooling method. Room cooling is best for products that are either, already close to their optimum storage temperature or can be cooled over several days. Conventional refrigerated cool rooms, trucks or containers do not have the capacity to remove the field heat from harvested fresh produce at the rapid rates required for effective pre-cooling. Hydro cooling is the most rapid method of cooling in this example, but it does not suit every situation. Hydro cooling is commonly used to pre cool vegetables whose quality also depends on the amount of water loss and so hydro cooling ensures that these products do not dehydrate. Forced air cooling is useful for packed pallets and cartons of produce which can be stacked and cooled and then moved into the cool room for storage. Rapid cooling of fresh fruit and vegetables after harvest is the key to product quality. Placing warm fruit in a conventional refrigerated cool room is a slow and ineffective method of cooling fresh produce. It is therefore important to choose a method of pre-cooling which suits the needs of your crop.

## 2.8 Cold Chain Challenges

There are more risks existing in cold chain management because most of the perishables are of higher value and more vulnerable to temperature disturbances (Bogatajet *al.*, 2005). An ineffective cold chain causes spoilage (Litwak, 1999) and products may decay before sale. Even worse, products that is not noticeably spoiled or just starting to perish within their expiration date might undermine the business, because they are hard notice by retailers unless the consumers bring them back to claim. Take pre-cut salad, for example; the cut salad category is sensitive to temperature. The proper temperature to preserve the cut salad is in the range of 32-38°F. Below this temperature, the product freezes, above it, the product starts to decay (Litwak, 1999). An earlier investigation estimates that 10% of perishable food losses come from insufficient temperature control and physical damage, and the same investigation also indicates that up to 16% of food was wasted for reasons of cold chain breakage during distribution (Bin and Labuza, 1992). According to the cold chain characteristic, i.e. temperature-sensitive, the cold chain is as strong as its weakest link (Beasley, 2002). Any temperature disturbance can undermine the efforts of the whole chain (Meenke, 2006).

It is even more difficult in global cold chain management because there are more factors or complexities involved (Shister, 2004). Litwak (1999) argues that in order to reduce spoilage, the weak link in the cold chain must be identified. Hence, cold chain facilities, track-and-trace technologies, standard handling processes and synergy of the players at all levels of the cold chain are necessary. According to the high value of the perishables and the alarming loss in the cold chains, it is worthwhile to make efforts towards challenges and make continuous improvement in cold chain management (Coates, 2003).

## 2.9 Cold Chain Facilities

To maintain the temperature all the way from producers/manufacturers to the consumer end, specialised facilities and technologies are essential to constitute a robust cold chain. Salin and Nayga (2003) indicate that highways, ports, information infrastructures, reliable electric power systems, and laws and regulations are in the upper level which may determine the whole cold

chain environment in a country. These are established or enacted by government authorities and the development of these infrastructures is relevant to the development and economic power of a country. The refrigerated containers, cold storage facilities, and refrigerated vehicles are generally owned by carriers, public refrigerated warehouses (PRW), and trucking companies respectively. A small part of the facilities are owned by the shippers themselves. This is decided by the outsourcing strategy (Salin and Nayga, 2003). The cold chain facility is one of the factors which differentiates a firm and allows it to compete with other companies. This also determines the quality and performance of the cold chain. It is necessary for cold chain professionals to have a general understanding on how these facilities work to maintain an intact and cost-effective cold chain.

### **2.9.1 Refrigerated Vehicles**

Transport is an important link in the cold chain as temperature maintenance is critical in this link in order to preserve the quality, safety and shelf life of perishable food (Moureh and Flick, 2004). Therefore, cost, productivity and efficiency are three factors that need to be taken into account in the design of the refrigerated vehicle.

A refrigerated vehicle is always heavier than a conventional trailer, and it consumes more fuel to pull the extra weight. To enable the vehicle to operate with fuel economy and have more capacity, aluminum or other light weight material is used instead of steel. Dual tires are replaced by wide base single tires in order to save fuel and thermal insulation is designed according to the application requirement (Gelinias, 2007).

Cold plate is the central part that maintains the product in a specified temperature range. Traditionally, the cold plate in the refrigerated vehicle is powered by fuel. An advanced cold plate system is powered by electricity and can be recharged at night. A six to eight hour charge may power the cold plate for more than 12 hours with up to 48 hours of product protection time.

This innovative electricity powered cold plate system may save 80% fuel cost comparing with the traditional fuel-powered one. Additionally, it produces no diesel pollution (Gelinas, 2007). Bulkheads consist of compression-fit foam with a vinyl outer layer and are used to divide trailers into multi-temp zones. While the reefer is not fully loaded, a bulkhead can be adjusted to the utilized capacity to save fuel (Klie, 2005b). Demands for mixed loads of products require different storage temperatures and the trend of refrigerated transport is to use multi-compartmental vehicles (Kuo *et al.*, 2005; James *et al.*, 2006). Compartments are divided by movable or fixed insulated panels longitudinally. Half-width horizontal insulated bulkheads are used to partition off the lanes created by the panels (Anonymous, 2004). The advantage of using the multi-compartmental vehicle is flexibility and space-saving, but operating procedures are more complicated and this also affects costs. The cost of a multi-compartment temperature controlled vehicle is about £100,000 compared to around £30,000 for an ambient one (Ferne and Sparks, 2004). It must be pointed out that in Europe the specifications for refrigerated vehicles are covered by ATP3. There are standards for refrigerated equipment for the carriage of perishable foodstuffs (Estrada-Flores and Eddy, 2006). In addition, it is important to note that an ATP certificate is necessary if the road hauler transports perishable foodstuffs across an international boundary between countries that are signatories to the agreement (the Refrigerated Vehicle Test Centre, CRT, 2006).

## **2.9.2 Cold Store / Refrigerated Warehouse**

Cold stores (Europe) or refrigerated warehouse (US) are facilities for handling and storing perishables under controlled temperatures in order to maintain product quality (Duiven and Binard, 2002). A refrigerated warehouse is capital-intensive with high building and equipment costs, generally more than two times the cost of a conventional one (Sethi, 1999). Therefore, the challenge of designing cold storage facilities is to ensure accurate control of the environment under the lowest energy consumption (Merli, 1999). Facilities inside the refrigerated warehouse (e.g. racking system, refrigerated dock design, etc.) determine the operation efficiency and space usage factor in it.

### **2.9.3 Racking System**

The racking system in a refrigerated warehouse is generally designed into double-deep, push-back, or flow-through racking (Friedman, 1998a) because the perishable delivery trend is turning to smaller quantity and more frequent deliveries (Andelet *al.*, 1996). With the development of advanced technology, automated conveyors and AS/RS cranes with specialised bearings and lubricants are being equipped in the harsh environment to reduce manual operations affecting health issues and working efficiency (Andel, 2002). Vertical carousels can be refrigerated and they can be used to stage sensitive material, like pharmaceuticals. They are portable, space saving and cost-efficient (Andel, 2002).

### **2.9.4 Doors**

Flexible, high-speed, and taller doors, made from light material, which may facilitate handling speed, are used by many refrigerated warehouses (Friedman, 1997).

### **2.9.5 Docking equipment**

Vertical dock levelers are prevalent because they take up less space and are more efficient than horizontal levelers (Friedman, 1997).

### **2.9.6 Insulation Panels**

Steel panels with R factors and high density foam insulation in between are conventionally used, while superior materials are being developed to reduce insulation cost and enhance insulation effect (Friedman, 1998a).

### **2.9.7 Environment Control System**

Apart from temperature control, a desiccant dehumidification system is designed to remove the moisture from the air. The system promotes an optimal storage environment and a safer working environment. It also helps to prevent equipment from rusting in the vapour as well (Merli, 1999). From the aspect of capital investment, the cost of a temperature-controlled warehouse is about 2 to 2.5 times that of a conventional warehouse (Sethi, 1999).

### **2.9.8 Refrigerated Containers**

In the transport phase, temperature-controlled products are preserved in refrigerated containers. The development of mechanical refrigeration, controlled atmospheres (CA) and packaging provide solid technical support for international trade of various products under temperature-controlled conditions (James *et al.*, 2006). The refrigerated containers are insulated and equipped with refrigeration units in their structures. The units are powered by electricity from an external power supply either on board the ship or from a generator on vehicle. The container is connected to the ship's refrigerated system and temperature is easy to control. It is crucial to make sure the refrigeration unit is running all through the journey (James *et al.*, 2006).

Apart from temperature control, controlled atmosphere (CA) technology is designed to preserve the freshness of the postharvest during shipping. The system maintains a balanced atmosphere of oxygen and other gases such as nitrogen, to minimize respiration in postharvest. CA technology can also improve the control of insects in some commodities and prevent water loss and weight shrinkage (Sowinski, 1999). It is noteworthy that a refrigerated container cannot cool-down a product. The function of it is to maintain the current temperature of a product to ensure the product integrity (McGovern, 1998). In other words, it is important to ensure both the product and refrigerated container are at the right temperature before loading (James *et al.*, 2006).

## **2.10 The role of packaging in the cold chain**

Packaging plays a key role in protecting the product from contamination by external sources and from damage during its passage from the food producer to the consumer. The choice of packaging is dictated primarily by economic, technical and legislative factors. Also, a well-designed and consumer-appealing package will help to portray an image of high quality and responsible food production to the consumer.

The primary function of food packaging is to protect the food from external hazards. The package also ensures containment of the produce and also allows the producer to deliver the produce in known quantities. Recently the package serves as a marketing tool through which product information are communicated to the consumer. Packaging is a necessary element because the proper insulation materials can keep the temperature of the product as a cushion while they are in the weak links of the supply chain, for example, while the product is at airline hubs or in the loading/unloading stage (Light, 2003). Rigid polyurethane (PUR) foam has been used in the refrigeration industry for insulation for about 30 years. The advantages of PUR foam come from its good insulation properties as it is thinner than other insulation materials and it can form a sandwich structure with various facer materials. The new generation of PUR is CFC-free and recyclable (Ward, 1996). It is mentioned by Demharter (1998) that newly developed PUR foam may be applied between +130°C and -196°C. Vacuum insulated panel (VIP) technology is designed for solving the problems of longer shipping, and lowering packaging and shipping costs. With recyclable nonporous silica at the core, VIP has an insulation value 10 times that of expanded polystyrene and polyurethane materials (Jennings, 2003). Other types of cooling techniques involve dry ice, gel packs, insulated boxes and isotainers (Leys, 2003). Dry ice is a cost-effective method to maintain temperature in transit. However, it is only effective for short distance journeys (Curfs, 2003). Reusable insulated packaging is another method which is relatively cheap. However, it has the problem of reverse logistics and more administration work involved (Curfs, 2003).

## **2.11 Cold Chain Standards and Regulations**

### **2.11.1 GLOBAL GAP**

The objective of the GLOBAL GAP formally EUREP GAP, which consists of leading European food-retailers, is to raise standards for the production of fresh fruit and vegetables. In November 1997 the first draft protocol for Good Agricultural Practice was agreed to. This represented the first step toward integrated production. In September 1998 the GLOBAL GAP initiated pilot trial projects to verify the implementation of GLOBAL GAP in the field.

The draft protocol has been subject to numerous revisions. Representatives from around the globe and all stages of the food chain have been involved in the development of these protocols. In addition the views from stakeholders outside of the industry including consumer and environmental organizations and governments have helped shape the protocols. This wide consultation has produced a robust and challenging but nonetheless achievable protocol which farmers around the world can use to demonstrate compliance with Good Agricultural Practices.

Technically speaking GLOBAL GAP consists of a set of normative documents that are suitable for accreditation to internationally recognized certification criteria such as ISO Guide 65. In addition to the standard for the production of fresh fruit and vegetables, standards have been developed for flowers and ornamentals, integrated farm assurance, integrated aqua assurances and (green) coffee. The standards are widely available and are accessible through the GLOBAL GAP website: [www.GLOBALGAP.org](http://www.GLOBALGAP.org).

### **2.11.2 Scope of the Standard for the Production of Fresh Fruits and Vegetables**

The document sets out a framework for Good Agricultural Practice (GAP) on farms. This framework defines essential elements for the development of best-practices for the global production of horticultural products (e.g., fruits, vegetables, potatoes, salads, cut flowers and nursery stock). It defines the minimum standards acceptable to leading retail groups in Europe. Standards of individual retailers and those adopted by some growers may, however, exceed those

described. The document does not set out to provide prescriptive guidance on every method of agricultural production.

GLOBAL GAP members wish to recognize the significant progress made by many growers, grower groups, grower organizations, local schemes and national schemes in developing and implementing best-practice agricultural systems with the aim of minimizing adverse impact on the environment. GLOBAL GAP members also wish to encourage further work to improve growers' capability in this area, and in this respect this GAP framework, which defines the key elements of current agricultural best-practice, should be used as a benchmark to assess current practice, and provide guidance for further development. GAP is a means of incorporating Integrated Pest Management (IPM) and Integrated Crop Management (ICM) practices within the framework of commercial agricultural production. Adoption of IPM/ICM is regarded by GLOBAL GAP members as essential for the long-term improvement and sustainability of agricultural production. In response to the challenges posed by fast changing Crop Protection Product legislation, the GLOBAL GAP Technical and Standards Committee developed guidance notes to help farmers and growers to become more fully aware of the Maximum Residue Limits (MRLs) in operation in the markets where the product will be sold. The changes have been introduced so that growers develop awareness of the MRLs in operation in the countries where the product will be or is likely to be sold. It is important that growers can demonstrate that their produce meets the MRL requirements of these countries, particularly if the regimes are stricter than those in the country of production. GLOBAL GAP stresses the importance of residue screening and provides further re-assurance where the exact destination of the product is not known. GLOBAL GAP also produced a list of contacts where growers can find the most up-to-date information concerning MRLs. This will help growers to meet the challenges posed by legislative requirements. This list is available on the website of GLOBAL GAP. GLOBAL GAP supports the principles of and encourages the use of HACCP (Hazard Analysis Critical Control Points).

Website: [www.globalgap.org](http://www.globalgap.org)

### **2.11.3 Commitment**

It is essential that all organizations involved in the food production chain accept their share of the tasks and responsibilities to ensure that GAP is fully implemented and supported. If consumer confidence in fresh produce is to be maintained, such standards of Good Agricultural Practice must be adopted, and examples of poor practice must be eliminated from the industry. All growers must demonstrate their compliance with national or international law.

All growers should be able to demonstrate their commitment to:

- maintaining consumer confidence in food quality and safety;
- minimizing detrimental impact on the environment, whilst conserving nature and wildlife;
- reducing the use of agrochemicals;
- improving the efficiency of natural resource use; and
- Ensuring a responsible attitude towards worker health and safety.

### **2.11.4 Contents of the GLOBAL GAP Document**

The GLOBAL GAP document includes the following, with subsequent conditions:

Introduction

1. Traceability

2. Record Keeping and Internal Self-inspection

3. Varieties and Rootstocks

### **2.11.5 Certification of GLOBAL GAP**

Growers receive their GLOBAL GAP approval through independent auditing from a verification body that is approved by GLOBAL GAP. Documents included in the scheme include:

- “GLOBAL GAP General Regulations for Fruits and Vegetables,” explains the structure to certification to GLOBAL GAP standards for Fruits and Vegetables and the procedure that should be followed in order to obtain and maintain certification (GLOBAL GAP, 2004).
- GLOBAL GAP Document “Control Points and Compliance Criteria Protocol for Fruits & Vegetables” is the standard with which the farmer must comply and which gives specific details on how the farmer complies with each of the requirements of the scheme (GLOBAL GAP, 2004).
- GLOBAL GAP Checklist Fruits and Vegetables which forms the basis of the farmer external audit and which the farmer must use to fulfill the annual internal audit requirements (GLOBAL GAP, 2004).

### **2.12 Hazard Analysis Critical Control Point (HACCP)**

The Hazard Analysis Critical Control Point (HACCP) System was introduced in the United States (US) in 1971 by the Pillsbury Company in collaboration with the National Aeronautics and Space Administration (NASA) and the U.S. Army Natick Research & Development Laboratories. These agencies had the initial responsibility of designing and manufacturing food products and hardware which were to provide 100% assurance that either the food products would not be contaminated with pathogen, bacteria or viruses which could cause illness or that the equipment would function with zero defects.

After extensive evaluation, it was decided that the only way success could be achieved was by exercising control over the process and the workers, beginning as early as possible in the production system. This preventative system was perceived to offer the highest degree of

assurance that the products manufactured were safe as it negated the need for any further end product testing, and emphasis was placed on monitoring. The HACCP concept for food safety was developed on the basis of this approach.

### **2.12.1 HACCP Internationalization, Concept, Purpose, Implementation and Benefits**

The HACCP system has become the internationally recognized system for the management of food safety for all companies involved in the production, transformation, storage and distribution of food for human consumption. The *HACCP concept* involves the identification of specific hazards throughout the entire processing chain and focuses on preventative measures for their control to assure the quality and safety of the food. This includes analysis of raw material sources and usage, processing equipment, operating practices, packaging and storage, together with marketing and conditions for intended use. There is less reliance on the traditional system of end product testing and food safety is built into the product from conception through design and distribution. The *purpose of HACCP* can therefore be summarized as follows: “to identify potential problems which could occur in an operation, consider each and establish controls to minimize or prevent its occurrence”.

### **2.12.2 Implementation of a HACCP System**

The HACCP concept is based on 7 principles and 12 steps.

The CODEX Alimentarius describes 12 steps:

- Assemble the HACCP team
- Describe the product
- Identify the intended use
- Construct flow charts

- On-site verification of flow chart
- List all hazards associated with each step and list preventive measures
- Apply HACCP decision on each hazard
- Establish target levels and tolerances for each CCP
- Establish a monitoring system for each CCP
- Establish corrective actions
- Verification of the system
- Establish record keeping and documentation

(Note: Point 6 up to and including 12 are the so-called 7 principles of the HACCP process.)

### **2.12.3 Benefits of a HACCP System**

Some benefits of the HACCP-concept for general purposes and for food inspection include:

- The system is preventive, pro active, systematic, scientific and cost effective;
- It is a management tool;
- The system is internationally acknowledged (FAO/WHO);
- The system is applicable throughout the food chain;
- The system leads to increased awareness and subsequent greater involvement and commitment of employees;

- The official control based on HACCP-programs is more efficient than traditional inspection or end product-testing alone. Hence, health protection of consumers is enhanced;
- Harmonization of food inspection practices at an international level;
- Facilitation of Regulatory/Customer inspection;
- It leads to greater confidence in product safety;
- The system takes a preventive approach; reduction of rework and losses are achieved. Subsequently reduction of cost is achieved.

Website: [www.fda.gov](http://www.fda.gov)

#### **2.12.4 Certification of HACCP**

Different countries apply different criteria for auditing and assessing implemented HACCP systems. A guideline titled: Guidance on Regulatory Assessment of HACCP, was jointly published by FAO and WHO. This document was the output of an FAO/WHO Consultation on the Role of Government Agencies in Assessing HACCP, convened in Geneva in June 1998.

Standards have been established in a number of countries on the basis of these guidelines. Certification is carried out by a company accredited by the Board of Accreditation. A successful audit will result in a certificate. The certificate is not guaranteed for a life time.

Repeat audits by the same certifying body will be carried out at 3-year intervals, following which a new application must be made for certification. Certification is not a legal requirement; it can be pursued owing to company policy or can be requested by wholesale companies.

Differences in the requirements of individual countries lead to differences in the level of HACCP systems. HACCP requirements and HACCP criteria differ greatly across countries. Experience acquired on HACCP implementation differs substantially given the different levels of experience and knowledge of auditors. Various levels of certified HACCP systems therefore exist.

**Websites:** [www.iso.org](http://www.iso.org)

## CHAPTER THREE

### 3.0 Methodology

The research was conducted to determine the nature, practice and management of cold chain in the horticultural sector with primary focus on the pineapple industry in Ghana. It took place in three regions of the country (Central, Greater Accra and Eastern Regions) within the period of June 2009 to May 2010. In order to answer the research objective, the descriptive survey method was used as the research design and structured questionnaires were used as data collecting instruments. The purposive sampling method was used in the selection of the respondents for objective one (1) while the random sampling approach was used to select respondents for objectives two (2) and three (3). Selected respondents answered survey structured questionnaires and data gathered from this research instrument was then computed for interpretation. Along with primary data, secondary sources in the form of published articles and literature were used to support the survey results.

### 3.1 Research Design

The descriptive method of research was used for this study. To define the descriptive type of research, Creswell (1994) stated that the descriptive method of research is to gather information about the present existing condition. The emphasis is on describing rather than on judging or interpreting. The aim of descriptive research is to obtain an accurate profile of the people, events or situations. With this research type, it is essential that the researcher already has a clear view or picture of the phenomena being investigated before the data collection procedure is carried out.

This method of research was used to obtain first hand data from the respondents so as to formulate rational and sound conclusions and recommendations for the study.

### **3.2 Data Collection**

For this research, two types of data were gathered. These included primary and secondary data types. Primary data is the information collected for the specific purpose at hand. Primary data is collected in a way to reinforce secondary data if they are unavailable. On the other hand secondary data is the information that already exists somewhere, having been collected for another purpose. The primary data were derived from the answers the respondents gave during the survey process. They included temperatures at various locations within the farm, pH of water for washing fruits, % Total Soluble Solid (Brix), chlorine water concentration and waxing. The secondary data on the other hand, were obtained from published documents and literature that were relevant to the research topic and area.

With the use of the survey questionnaire and published literatures, this study took on the combined quantitative and qualitative approach of research. Quantitative data collection methods are centred on the quantification of relationships between variables. Quantitative data-gathering instruments establish relationship between measured variables. Contrary to the quantitative method, qualitative approach generates verbal information rather than numerical values (Patton, 1990). Instead of using statistical analysis, the qualitative approach utilizes content or holistic analysis; to explain and comprehend the research findings, inductive and not deductive reasoning is used.

By means of employing this combined approach, the research brought together the advantages of both quantitative and qualitative approaches and overcome their limitations.

The reliability of secondary data collected was assessed by using the check list as suggested by Morgan (2007),

- ✓ Was an explicit account of the theoretical framework given?
- ✓ Was there a succinct statement of objectives or research questions?
- ✓ How was the sample chosen? Was it adequate?
- ✓ Was there a clear description of data collection methods? Were they appropriate?
- ✓ How did the research move from the raw data to an analysis and interpretation of the meaning and significance of it?
- ✓ Were the findings relevant to policy/practice? Did they provide guidance for future research?

### **3.3 Objective one**

The first objective was to assess the awareness and practice of cold chain management among farms in Ghana.

#### **3.3.1 Sampling Procedure and Size**

The purposive method of sampling was used for this objective due to the nature of the cold chain practice in the country. Purposive sampling selects information rich cases for in-depth study. Size and specific cases depend on the study purpose (Webster, 1985). Purposive sampling is very

useful in situations where a quick targeted sample is needed and where sampling for proportionality is not the primary concern. With a purposive sample, you are likely to get the opinions of your target population, but you are also likely to overweight subgroups in your population that are more readily accessible. The participants qualified for the sample selection based on the following:

- Frequency of Production
- Ability to serve both the local and foreign markets with much emphasis on export
- Consistency of production and
- Scale of labour force and Production

This qualification ensured that the respondents understood the nature of the research and its relevance to the sector ensuring the best response during the survey. Forty four (44) members of the Sea Pineapple Exporters of Ghana (SPEG) out of the estimated sixty (60) were sampled.

A SWOT analysis was conducted at the end of the survey to ascertain the practice of cold chain management in the country.

### **3.3.2 Method of data collection**

A structured questionnaire was used as the main data-gathering instrument for this objective (See Appendix 22). The questionnaire was divided into two main sections: a Background/Production section and a Postharvest section. It had both closed and open ended questions making it easy for respondents to answer and achieve the research objective. The questionnaire was first pre tested for its validity. The respondents as well as their answers were however not part of the actual

study process and were only used for testing purposes. The questionnaires were administered to the respondents personally, by the email system and through the telephone.

### **3.4 Objective Two**

This objective involved the determination of the quality management practices and temperature variations along the postharvest chain.

#### **3.4.1 Sampling Procedure and Size**

Simple random sampling was done for the sample selection. This sampling method was conducted where each member of a population has an equal opportunity to become part of the sample. As all members of the population have an equal chance of becoming a research participant, this is said to be the most efficient sampling procedure. In order to conduct this sampling strategy, the researcher defined the population first, listed down all the members of the population and then selected members to make the sample. The lottery sampling or the fish bowl technique was employed. This method involves the selection of the sample at random from the sampling frame through the use of random number tables (Saunders et al., 2003). Numbers were assigned for each respondent in the master list. These numbers were written on pieces of paper and drawn from a box; the process was repeated until the sample size was reached. Four (4) farms out of the initial forty four (44) farms were selected for this stage of the research. The sample size was due to cost and time allocated for the research.

### **3.4.2 Method of data collection**

Specific analysis was conducted for this objective. The following analysis conducted answered the questions posed by the objective;

### **3.4.3 Farm gate analysis**

This analysis took place at the following locations within the farms and involved the use of thermometers to measure the temperature of the fruit.

- ✓ **Point of harvest:** Fruits were selected at each of the farms visited at random and their temperature taken on the field with the help of a hand thermometer. The temperature was recorded and their averages were calculated for results.

### **3.4.4 Pack house analysis**

These analyses took place at the pack houses of the various farms visited.

#### **3.4.4.1 Pack house temperature**

Fruits were randomly selected in the holding room and the hand thermometer was used to measure the temperature within the room. The averages were calculated for results

#### **3.4.4.2 Test of %Brix**

The Brix test was done by selecting fruits from the middle section of three (3) different pallets selected at random. Each fruit was then divided into three equal halves and juice from sliced

samples approximately 3 cm thick closest to the bottom was placed onto the hand refractometer and % Brix recorded. A refractometer is an optical device that takes advantage of the fact that light passing through a liquid bends or refracts.

#### **3.4.4.3 Average pH of water from different farms**

This test involved the measurement of the pH of the water used in washing the fruits. A pH kit was used to take the measurement every hour and the averaged readings were presented in tables. A pH meter is an electronic instrument used to measure the pH (acidity or alkalinity) of a liquid. A typical pH meter consists of a special measuring probe (a glass electrode) connected to an electronic meter that measures and displays the pH reading.

#### **3.4.4.4 The Chlorine Test**

The chlorine test was done with the aid of a chlorine test kit. Water was fetched from the pool containing the water used in cleaning the fruits every hour to find out the level of chlorine. A change in colour on the kit represents a change in the concentration of Chlorine.

#### **3.4.5 Transportation analysis**

This stage of the analysis involved the use of data loggers which were placed at vantage places within the transport system. The data loggers were used to measure the temperature of the transportation system over time during the period of transport. The data logger was placed in a pallet within the van on the farm. The duration from all the four farms was about 3 to 4 hours from the point of exit. The logger was taken out of the van at the point of exit and the results were presented in the form of graphs and tables.

### **3.4.5.1 Data loggers**

Data loggers are mobile recorders which travel with the produce in the truck and record the temperature and relative humidity in their local memory during transport. For this research, loggers were set to record the temperature within the trucks from the time of departure and during transportation at a pre-determined time interval of fifteen minutes (15). Once the truck arrived at the port, the sensors were taken out and the information stored on its central database was analysed. The data were presented in a graph which was printed from the system.

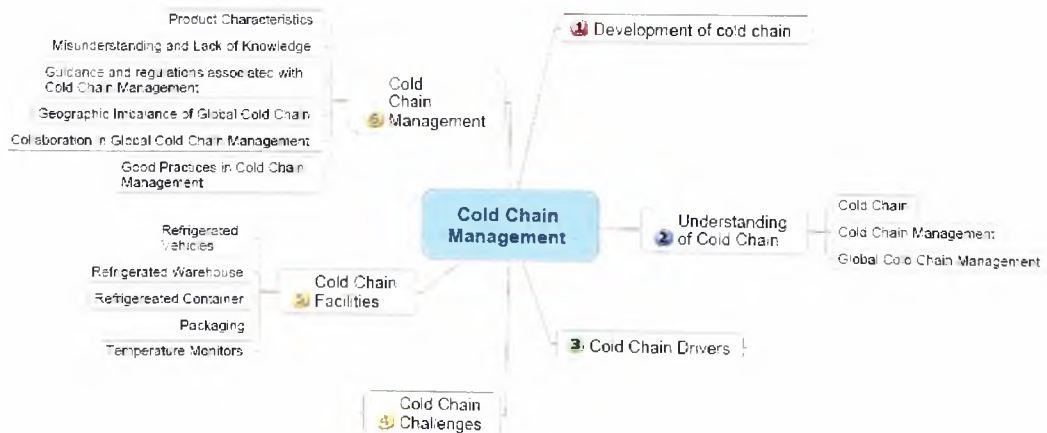
### **3.4.6 The data collected**

- ✓ Product Maturity
- ✓ Temperature at Harvest
- ✓ Transport to packing shed temperature
- ✓ Temperature and Relative humidity in the Pack House
- ✓ Temperature during Pre-cooling on arrival
- ✓ Time interval from shed to retail
- ✓ Total Soluble Solids (brix) by a hand refractometer
- ✓ pH Test by the pH meter
- ✓ Chlorine Test by the Chlorine Test kit

### 3.5 Objective Three

This section addressed the third objective of the thesis, which was to determine best practices in Cold Chain Management of fruits in Ghana. The observational approach was used for this objective and findings were compared to literature. Observational research was carried out by looking at what practices occur on the various farms that were chosen for the research. The results from this method supported the data collected through secondary research. Observational research is the gathering of primary data by observing relevant people, actions, practices and situations (Salant, 1994).

Detailed variables related to cold chain management were observed, reviewed and evaluated starting from the facilities and equipment involved in the cold chain to key elements that determined cold chain management performance and the quality of the products distributed. The thematic review framework is illustrated in Figure 1.



**Figure 1: Thematic Review Framework of Cold Chain Management**

### **3.6 Data Processing and Analysis**

After gathering all the completed questionnaires from the respondents, total responses for each item were obtained and tabulated. The data was then fed into Statistical Package for the Social Sciences (SPSS) and Excel and the results were presented as tables, graphs and charts.

## CHAPTER FOUR

### 4.0 Results

#### 4.1.0 Results for Objective One

##### 4.1.1 Status of pineapple fruit growers

It was observed that out of forty four (44) fruit farmers that were interviewed, thirty seven (37) were still in production representing 84% and only seven (7) were not in current production representing 16% as shown in figure 2.

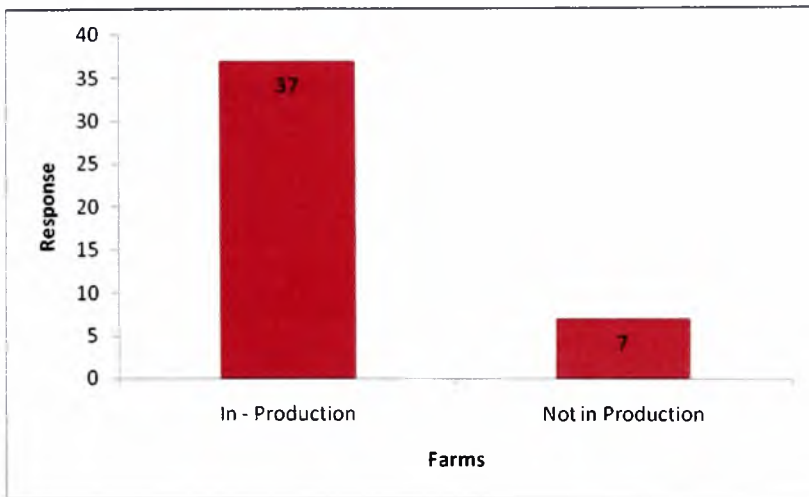
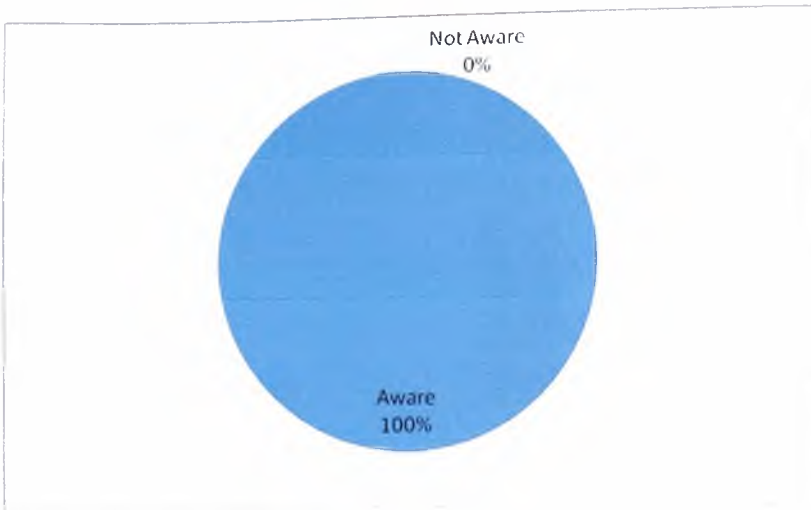


Figure 2: Status of pineapple growers

##### 4.1.2 Awareness of Cold Chain Management

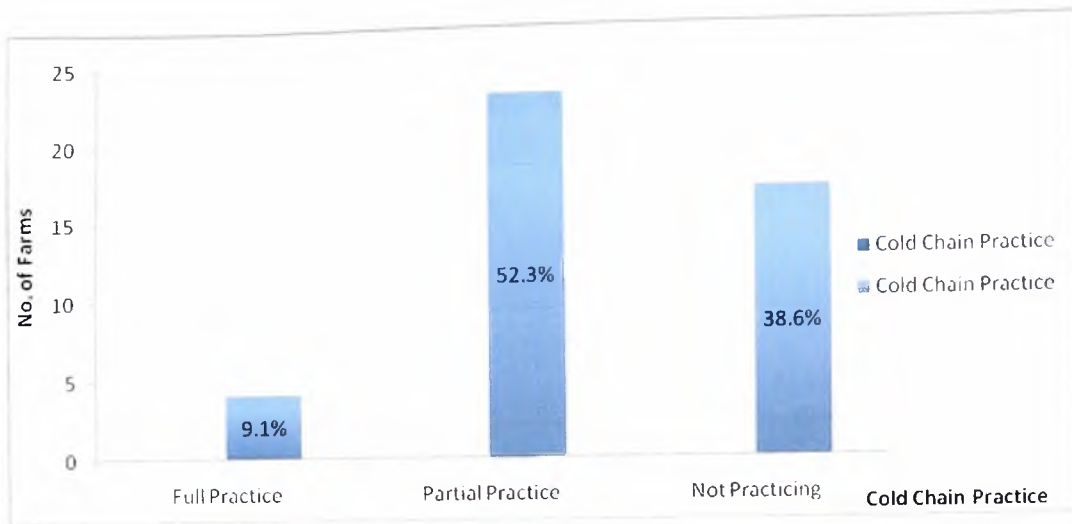
From the survey to find out about the awareness and knowledge about cold chain management and practices by farmers in Ghana, the results as shown in Figure 3 indicated that all the forty four (44) pineapple farms interviewed knew about the practice of cold chain representing 100%.



**Figure 3: Awareness of Cold Chain Practices in Ghana**

### **4.1.3 Cold Chain Practice in Ghana**

From a total of forty four (44) producers that were interviewed, only four (4) representing 9.1% were practicing the complete cold chain system as shown in figure 4. Seventeen (17) representing 38.6% of the farms interviewed were not practicing the system and did not even have cold chain facilities. The majority of 23 farmers representing 52.3% of fruit producers used the cold chain system partially (either had one cold room that served a multi-purpose task of holding and cooling or used refrigerated containers or reefers for transportation)



**Figure 4: Extent of Cold Chain Practice in Ghana**

## 4.2 SWOT Analysis of the sector

A SWOT analysis was conducted to find out the strength, weakness, opportunities and threats within the sector. It involved the use of a discussion guide to obtain information from all the stakeholders in the sector.

### 4.2.1 Strengths

There has been a great deal of support by the government to the sector over the years especially in the construction of a state of the art fruit terminal at the Tema port and a similar one at the Kotoka International Airport. Existing associations (VEPEAG, SPEG, HAG) already perform tasks like arranging vessels, providing export channel of regular fresh tropical fruits to UK and EU and searching for customers on behalf of all members. These roles could however be expanded. There is a strong co-operation between all the associations in the sector leading to flexibility in the operation of all the farms. There has also been a great improvement in the infrastructure and research within the sector. These include laboratory facilities for MRL testing,

quality assurance certification and improvement in the knowledge on grades, standards and codes of practice (like GLOBAL GAP). Finally, there is ongoing research for strengthening the domestic supply chain (e.g. World Bank, KIEM) and a PSOM program and EU program to expand commercial fruit production and trade.

#### **4.2.2 Weaknesses**

On the weak side, Ghanaian producers were few with relatively small export volumes. The access to credit facilities was minimal with very high interest rates (up to 50%/yr short term loans) in the few cases when they were available. There was also limited knowledge about the market and understanding of the end-user preferences. The local markets to absorb excesses from farms were few and underdeveloped. Finally the cold chain system was largely underdeveloped with little support from the packaging industry.

#### **4.2.3 Opportunities**

Aside the weakness observed, the horticultural sector has a promising future with growing market for fruits in the EU and UK. The location of Ghana makes it a lot easier for export to the European markets. There has been a strong partnership between stakeholders in the sector over the years and this is a sign of success. Unlike years ago, Ghanaians are realising the essence of quality and this has led to a constant development of the local market. There has been a substantial donor assistance available (AMEX, Techno Serve, USAID) in the field of capacity building, phytosanitary programs and standards & grading.

#### **4.2.4 Threats**

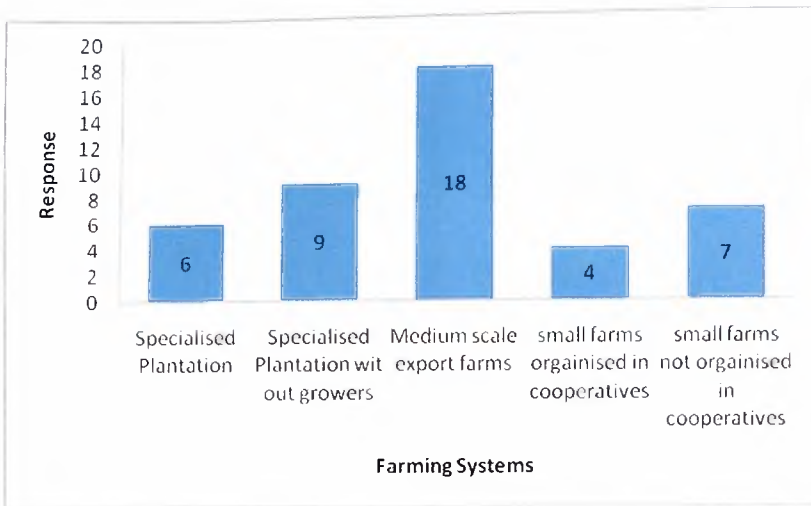
There is lots of competition in the horticultural world market. Ghana has to compete with countries like Costa Rica for the UK and EU markets. There is also the competition from other

produce and varieties that receive premium (MD2). It is also worth mentioning that the Ghanaian producers are at a disadvantaged position opposite to European buyers. The Ghanaian system is relationship based; it has multiple levels and faces an information gap. The buyers are a few large scale units who are specialized and well informed. Finally quality assurance systems are rapidly becoming more complicated

### **4.3 Results for Objective Two**

#### **4.3.1 Farming systems under practice**

On farming systems under practice, 14% of the farms visited practiced specialized plantation with no out growers. They were very large farms with large acreage and produce one crop for export. Twenty percent (20%) representing the second highest practiced specialized plantation with out growers as shown in Figure 5. They purchase fruits in addition to what they produce from small holder farms for export. Forty one percent (41%) of the farms were medium scale export farms with varieties of produce including pineapple, mangoes and pawpaw. Nine percent (9%) of the farms, with vegetable as predominant crop, were under the small farms in organized cooperative practice. They were made up of aggregated farms from the same location. Sixteenpercent (16%) of the farms practiced small scale export farms with farms ranging from 1acres to 10 acres.



**Figure 5: Farm Systems under Practice**

### 4.3.2 Harvesting and Field Operations

It was observed from the four farms (4) visited that pineapple fruits were harvested by hand into plastic crates and loaded on to tracks for transportation to the pack house. Most growers tried to harvest early in the day and reduce the time that harvested fruits are exposed to the sun but this was not always so since the farms, most of the time had to meet stringent deadlines and were therefore forced to harvest throughout the day. It was also observed that harvested fruits in crates were often left exposed to the sun as they await transportation to the packing house. The tracks for transporting the fruits had no cover to protect the fruits from the sun.

**Harvested fruits left in the sun (a)**



**Transport vehicles not shaded (b)**



**Washing and Cleaning (c)**



**Waxing (d)**



**Figure 6: Post harvest practices on the farm: Harvested fruits left in the sun (a), Transport vehicles not shaded (b), Washing and cleaning (c), Waxing (d)**

### 4.3.3 Washing and Cleaning

Wet dumping was usually used in the pack houses; i.e., fruit were unloaded into water. All the farms visited checked the pH and chlorine content of the water used for washing periodically using the pH meter and chlorine test kit respectively. The cleaning of fruits varied from using jet sprays that rotated and cleaned the fruit, to workers manually cleaning the fruit with soft brush. Out of the four (4) farms visited, two (2) sorted and waxed their fruits mechanically. On those farms fungicides were mixed with the wax and discharged onto the fruits mechanically. The remaining farms performed the process manually by dipping the fruits into wax and allowing them to drain; fungicide is then spread onto the fruits with a knap sack. The wax was replaced daily in all cases.

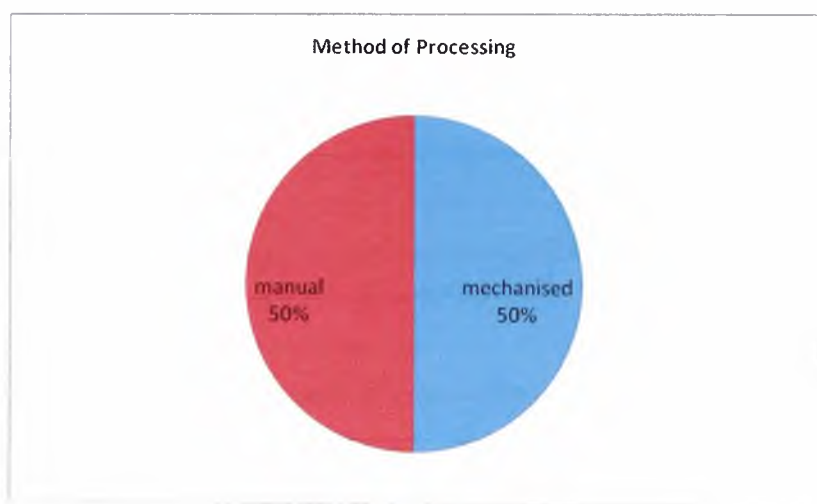


Figure 7: Method of washing and cleaning

### 4.3.4 Grading and Selection

The selection process was effective and common reasons for rejecting fruits included: color, protruding eyes, sunburn, malformations, crown size, insect damage, shading effects on color. Sanitary control measures were abundant: the use of boots, hairnets, and special coats was

noticed on two farms. It took fruit about 1-4 hours from the pack house until storage in cold rooms or cold containers depending on the types of mechanisms used (manual or mechanized)

#### **4.3.5 Packing and Packaging**

Sorting and packing took place under shade in all farms that were visited. All farms had fairly good facilities in the pack house, including benches for workers, padded grading tables, lights for working at night, fans, etc. Workers manually brushed ants off pineapples, weighed the fruit, sorted by color and rejected substandard fruits.

#### **4.3.6 Cooling and Holding**

Two kinds of the cold system were observed. Two (2) of the farms had both the cooling Chamber and the holding chamber while the other two (2) had only the cooling chamber. The chambers were set to specific temperature and relative humidity. All fruits were however placed in cold rooms or cold containers) on the farm. The farms that had one of the facilities used the facility for both cooling and holding fruits. Care was often taken to make sure temperatures never exceeded the limits that will cause chilling injury.

#### **4.3.7 Quality on the farm**

All the producers/exporters visited had an effective “Integrated Cold Chain” starting at the pack house level, and extending to the final market. While small producers load pallets directly into reefer containers at the pack house, large producers have either cooling facilities or air forced facilities to store produce before shipping. The “integrated cold chain” improves quality of produce and extends shelf life. Both small and large-scale producers/exporters had a good understanding of regulations and international standards. Farms visited were GLOBALGAP certified and Fair-trade certified. Growers were aware of maturity indices and used them to

determine when to harvest, e.g., pineapples are tested for °Brix (also known as % soluble solids content; or % total soluble solids) using a refractometer before ethephon is used to develop color for harvest. Farms had access to high quality planting material from existing associations. The industry relied on Research & Development to improve quality and maintain market share.

#### 4.4 Results for Objective Three

##### 4.4.1 Temperature, On Farm

Three (3) fruits were selected at random from three separate crates and their temperatures recorded. The averages of the three readings are presented in Table 7 below. The results revealed very high temperature readings which averaged between 35°C and 40°C.

**Table 7: Fruit temperature on the individual farms**

Average Temperatures				
Farms	A	B	C	D
	38.40	40.50	35.90	37.00

##### 4.4.2 Temperature at the Pack house

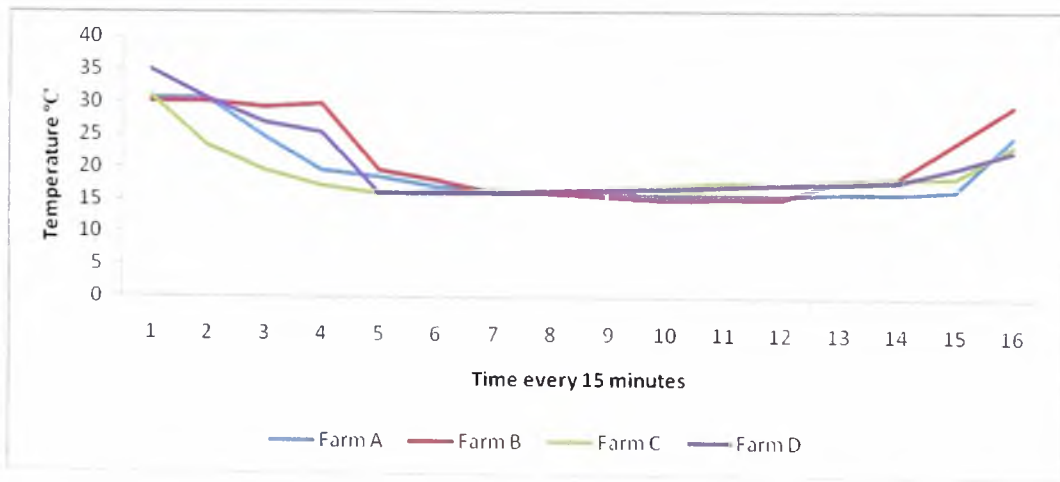
Average fruit temperatures in each of the holding rooms visited are presented in Table 8. It was observed that, fruit temperature in the cooling chamber ranged from 10 to 11°C.

**Table 8: Fruit temperature at the Pack house**

Average Temperatures				
Farms	A	B	C	D
	11.20	11.00	10.90	11.10

#### 4.4.3 Measurement of Temperature during Transportation

The duration of transporting fruits from all the four farms was about 3 to 4 hours from the point of exit. The logger was taken out of the van at the point of exit and the results were presented in the form of graphs and tables.



**Figure 8: A graph of Temperature Measurement during Transportation**

From the results, it was observed that, fruit temperature at the beginning of each journey was on the high considering the temperature recorded at the holding chamber. Temperatures however stabilized after an hour of transportation after an equilibrium temperature has been reached between the product temperature and the van temperature. However, getting to the end of the journey a rise in temperature was observed.

**Table 9: Average Temperature Recorded during Transport**

Average Temperatures				
Farms	A	B	C	D
	19.38	21.24	18.98	20.49

#### 4.4.4 Total Soluble Solids of fruit from different farms

From Table 10, it was observed that the average % Brix from each of the farm was between 12-14. It is however worth noting the reading for farm B which was the highest.

**Table 10: Brix Measurement**

BRIX°				
Farms	A	B	C	D
	13.20	14.50	12.90	12.10

#### 4.4.5 Average pH of water from different farms

Table 11 shows the various pH readings from the four (4) farms visited. The average pH for the water used for washing ranged from 8.2 to 8.6. Farm B however had the highest pH reading.

**Table 11: pH Measurement**

Average pH				
Farms	A	B	C	D
	8.54	8.67	8.25	8.62

#### 4.4.6 Chlorine water Measurement

Table 12 shows the averages of chlorine water readings from all the farms visited. All but Farm D had their readings below 3. Farm D had a reading of exactly 3.

**Table 12: Chlorine Test Result**

Average Chlorine Reading				
Farms	A	B	C	D
	2.80	2.50	2.90	3.00

## CHAPTER FIVE

### 5 Discussions

#### 5.1 Status of fruit growers

According to the SPEG and the VEPEAG, there are lots of opportunities in the horticultural sector in the country especially the export sector. From the results gathered however, it was observed that even some of the producers in good standing with their respective associations were going out of business. According to (GEPC, 2007), Ghana's horticultural sector has seen great improvements with increase foreign exchange. Though this statement is true it is also worth mentioning that the pineapple sector which is one of the most vibrant sectors of Ghana's horticulture has suffered a lot of setbacks as a result of the transition from smooth cayenne to MD2. According to (MoFA, 2007) the MD2 variety is much preferred by importers from Europe. It however requires a very high capital investment. The cold chain is of paramount importance to the variety and there are very strict regulations from buyers outside the country regarding its handling. The inability of producers to meet these requirements has led to the folding up of business. Pineapple farms currently out of production attributed their inability to produce to the high level of capital investment requirement needed to sustain the business. The inability of these farms to afford the installation of cold chain facilities was one of the paramount reasons for the collapse of their business. This supports what was observed by OECD, (2008), that the sector suffers from public underinvestment.

Jaeger (2008) reported that the number of pineapple exporters has dropped dramatically and most of the big players in the sector both on the export and import sector are inactive.

#### 5.2 Awareness of Cold Chain Management

On the awareness of cold chain practice in the country, the sector recorded a 100% awareness of the practice. The pineapple sector was predominantly aware of the practice and was at the time of the research involved in the practice. According to the USAID report (2007), through Sea

Pineapple Exporter of Ghana (SPEG's) efforts, Ghana's exporters have privilege to a lot of information and opportunities which explains the major awareness and knowledge of the sector in terms of cold chain practice and management.

### **5.3 Cold Chain Practice**

There has been a great improvement in the horticultural sector over the last few years. About 9% of farms had a complete cold system with a well shaded pack house to good cooling and holding chambers. These farms have customers all over the EU and export large quantities of fruits every week. The 38.6% of farms not practicing the system had knowledge of the practice but did not have the facilities. They were characterized by the small quantities of produce export and most of the time serves as out grower farms to the bigger farms. It was encouraging however to find about 52.3% of the farms in partial practice. Partial practice of the cold chain involved the availability of a good pack house, a cooling chamber which also serves as a holding room and a transportation system which is most of the time hired from transport agencies. Those farms that were in the practice did so effectively to meet all regulations set by overseeing bodies.

An earlier investigation estimated that 10% of perishable food losses resulted from insufficient temperature control and physical damage, and the same investigation also indicated that up to 16% of food was wasted for reasons of cold chain breakage during distribution (Bin and Labuza, 1992). The availability of chain cold facilities and their effective use in the country have led to an improvement in the quality of produce exported hence the increase in the demand for Ghanaian fruits on the world market.

### **5.4 SWOT Analysis**

The SWOT analysis showed great strengths in the sector and confirms the PFID (2007), report on the state of the horticultural industry in Ghana. It stated the tremendous support of the sector

by the government, private and international bodies. A transformation of the sectors strengths into opportunities will boost its growth and development.

According to an appraisal report by the African Development Fund (2005), there has been a tremendous increase in the demand for tropical fruits in the world and Ghana over the past ten (10) years has tapped into the opportunity which should therefore encourage stakeholders in the sector to invest more into and improve upon their activities.

Weaknesses observed in the sector included lower quantities of export, lack of information and management capacity among other. According to USAID, (2007), the introduction of the MD2 to replace the smooth cayenne led to the collapse of most farms. Other major players in the sector became inactive as a result. This perhaps might have caused the current weakness observed in this study.

Threats in the sector were mainly as results of competition from other exporting countries. This is supported by the report of AHORD, (2005) which stated that Costa Rican farmers have dramatically improved their efficiency while little improvement has been made in Ghanaian production yields per hectare over the last 40 years. Consequently, on average, the yield (production level) of pineapples per hectare in the Ghanaian sector is a long way below that of Costa Rica and the Ivory Coast.

## **5.5 Best Practices in the chain**

### **5.5.1 Farming systems under practice**

All of the systems were observed on the field confirming their findings. Majority of producers however were medium scale export farms producing different varieties of produce for the different markets available to them. All the farms practicing the specialized plantation system had state of the art facilities to sustain the practice. They had customers ready to buy their produce and had certification for all the quality standards relevant in the sector. The farms practicing specialized plantation without growers were also compliant with most of the best

practices in the sector. They ensured that their out growers complied with the standards of their buyers and in some cases performed certain agricultural practices like fertilization and spraying for them. The small scale exporters were mostly found in the vegetable sector exporting to small scale buyers in Europe and Asia. These farming systems conform to the classification of the horticultural sector by PFID and USAID, (2007)

### **5.5.2 Harvesting and Field Operations**

According to SAADI (2003), horticultural produce are best harvested in the early hours of the morning and the late hours of the evening. On the field however harvesting took place throughout the day. The reason given was the strict schedules the producers had to meet in terms of export. Harvested fruits were also most of the time left at the mercy of the sun while they await transportation to the pack house. This practice also did not conform to the regulations as stated in the production manual certified by GLOBAL GAP and SAADI (2005), which recommended that fruits should be shaded at every opportunity. Field operations observed during the research did not meet the standard requirements.

### **5.5.3 Washing and Cleaning**

According to APEDA and USDA, (2007) cleaning and washing of fruits is done at the pack house facility through automated washing system fitted with overhead sprayers and smooth rotating brushes to clean and wash the fruits. Although not all the farms visited had automated system, cleaning was done effectively to meet standard requirements. The pH of the water was kept constant checking periodically to meet the standard requirements. Chlorine content of the water was also measured every hour to check the concentration. In the case where there were no automated machines, workers manually brush off dirt on fruits with care and selected only the best for packaging. Fungicidal treatments of the fruits were also done effectively. Though cleaning and washing of fruits did not meet the standard stipulated by APEDA and USDA they met all of GLOBAL GAP requirements.

#### **5.5.4 Grading and Selection**

Grading and selection was done effectively and efficiently by trained professionals according to “Post Harvest Manual for Fruits” published by APEDA though it was observed in some cases that graders did not have the standard uniform for the process. To achieve the best results all farms visited had available weighing scales for graders to facilitate better grading of fruits.

#### **5.5.5 Packing and Packaging**

According to the FAO, (2007), all export farms should have a well shaded pack house with places of convenience for the staff. Fair Trade also states that fairly good facilities should be available in the pack house. They should include benches for workers, padded grading tables, lights for working at night, fans, etc. All the farms visited were in compliance with all the regulations and practiced it to their maximum capabilities. Best practice was the hall mark in this area of the production.

#### **5.5.6 Cooling and Holding**

According to SAADI (2005), a standard pack house must have a cooling chamber and a holding room. The cooling chambers for removing field heat from the product immediately after harvest and the holding room to store the produce while they await transport to the point of exit. Some farms visited (2) had both facilities installed and running effectively while the other two had one. In the case of farms which had both facilities, proper monitoring was done to ensure that fruits temperatures were in conformance to GLOBAL GAP regulations. The farms operating the single facility found it difficult keeping fruit temperatures within the stipulated limits. And they sometime suffered chilling injury.

### **5.5.7 Transportation**

According to GDV (2010), the best way to transport horticultural produce is by a temperature controlled transport system. Maintenance of transport temperature is however of paramount interest. All farms visited used refrigerated tracks for the transportation of fruits. The tracks were either hired or owned by the farm. The farms however did not pre cool the tracks before loading which was not in conformance to the regulations of the GDV (2010). Temperature monitoring tools like the data loggers were also absent in all the farms and therefore farmers are unable to know whether their produce met the requirements of the buyer. This perhaps explains the report by the VEPEAG (2005) that most Ghanaian produce are rejected upon arrival at the destination or are valued less than should be.

## **5.6 Temperature and other quality parameters**

### **5.6.1 On farm Temperature**

Average temperature from all the farms ranged between 35°C and 40°C. These temperatures according to literature are on the higher side. The higher temperature could be attributed to the time of harvesting. SAADI 2005, stated that the optimum temperature, fruits should be harvested in the early hours of the morning and late in the evening. In the case of all the farms visited fruits were harvested throughout the day and left in the sun while they await transportation. Produce harvested during the recommended time often have their temperatures between 25°C to 30°C which is far below those recorded (35°C and 40°C). Farms visited however attributed their inability to perform appreciably to the stringent schedules they have to follow to meet their buyer's demands.

### **5.6.2 Temperature in the holding room**

According to the Pack House Guideline Manual standardize for use by pineapple producers by GLOBAL GAP, chilling room temperatures should be set at 8°C. Individual fruits which were

randomly selected and their temperatures measured had on average temperatures ranging from 10°C to 11°C. This was just within the FAO's quality control chart on temperatures for pineapples (10°C to 12°C). It is however very important to state that those farms with the highest temperatures between 11.10°C to 11.20°C were the ones with the cold room acting as the holding room. Power was turned off in such cases when the temperature is so low to prevent chilling injury and was effective and efficient in reducing and maintaining the temperature of the fruits.

### **5.6.3 Measurement of Transport Temperature,**

One key feature of transportation of fruits according to SAADI, (2005) is transport temperature monitoring. This is often done through the use of data loggers. On all the farms visited however temperature monitoring was absent. Farms did not know the quality in terms of temperature at which their fruits get to their buyers. This might perhaps be the cause of the high volumes of rejected Ghanaian fruit from the EU as by VEPEAG, (2007). The temperature recording was initially very high, in fact, higher than that from the holding room. This was due to the inability of farms to pre cool their trucks before loading as stated by APEDA, (2008). Farms claimed they most of the time needed to meet deadlines hence their inability to fulfill that requirements.

### **5.6.4 Total Soluble Solids of fruits from different farms**

A major quality parameter in horticultural is the text for Brix. Brix on the field was measured before and after harvest. Brix measurement for export fruit was based on transportation. Fruits for transport by ships have a Brix range from 12 to 15. Temperature above this level may be transported by air. On the field, the averages ranged from 12 to 13. Careful monitoring was done to make sure fruits do not exceed the recommended levels. Fruits found to be above the limit were sold to the local market or in extreme situations disposed of. All farms made sure the best practice in this area was followed effectively.

### **5.6.5 Average pH of water from different farms**

The source of water determines its pH. Farms visited obtained their water from pipe, rivers and bore holes. The recommended pH for washing pineapple fruits ranges from 8.2 to 8.9. According to FAO, (2000) guidelines for fruits preparation, pH above 7.5 is good enough for washing. It was therefore encouraging to find all farms using water with pH within the recommended range and efforts being made to maintain it. Periodic checks were carried out every hour by the quality assurance managers of all the farms to comply with this procedure.

### **5.6.5 The Chlorine Test**

According to FAO (2000), concentrations of active chlorine in the range of 0.2 to 5 ppm are able to kill most bacteria and fungi present in water. However, in commercial operations higher concentrations are used (100-200 ppm) for washing and hydro cooling. Average readings taken on the field ranged from 2.8 to 3.0 indicating best practice in the sector in conformity with the regulations in the sector. Anytime the concentration dropped below the standard, more chlorine was added to maintain quality.

## CHAPTER SIX

### 6.0 Conclusions and Recommendations

The study showed that pineapple producers successfully exported fresh produce from Ghana by sea and air and all these facilities were found to meet international standards. Growers are aware of maturity indices and use them to determine when to harvest, e.g., pineapples are tested for °Brix using a refractometer before ethephon is applied to develop color for harvest. Other quality parameter measurements were done with the aid of simple but effective technologies on the farms. Sorting and packing were done under shade in all the farms visited and some growers have fairly good facilities in the pack house, including benches for workers, padded grading tables, lights for working at night, fans, etc.

The handling facility for fresh produce was mostly adequate and grading and sorting of fruit was not automated. Workers manually brushed ants off pineapples, weighed fruits, sorted by color and rejected substandard fruit. Cold chain monitors were however absent throughout the chain.

In general, growers are aware of GLOBAL GAP, HACCP and many other sophisticated systems and strive to abide by these regulations. Medium and large-scale farmers have an understanding of the acceptable regulations and international standards used in the global markets (such as GLOBAL GAP), and are taking steps to comply and become certified. Quality is however not consistent but within acceptable levels of variability, in terms of size, color, brix level, ripeness, among others. Main factors causing inconsistency are the lack of an appropriate and integrated cold chain for fresh produce, poor handling of products, and low quality packaging. There is however a general lack of appreciation for the importance of adequate cooling in the supply chain especially in the vegetable sector.

Medium and large-scale producers have, in general, an integrated system for managing their operations and inland transportation activities. All the farms visited had their own pack

house, and adequate vehicles to support harvesting and transportation. Some farmers even own modern fleets of vehicles, including cooled trucks with air suspension. Regarding cold chain temperature monitoring and management, it became evident that though local growers have taken steps to acquire either complete or partial cold chain systems, little has been done to improve the management and monitoring of produce temperature especially that of produce in transit from the farm to the port.

## 6.1 Recommendations

From the results of this study the following recommendations can be made to improve the fruits and vegetable industry in Ghana.

- Farmers should harvest fruits early in the day and transport them from the field to the pack house within 30 minutes of harvest.
- Fruits are to be shaded at every opportunity. Use a shaded truck during transportation to the air terminal or harbour. If possible use a damp covering material to cause some evaporative cooling.
- A shade and rain shelter should be constructed in the unloading area outside the air terminal so that produce can be unloaded and palletized while protected from the sun and rain. This is a relatively simple and inexpensive means of improving quality.
- Growers should be encouraged to cool produce before loading onto the plane, even if produce can only be cooled to 10 to 20°C.
- Growers should be encouraged to establish some form of cold storage at the farm even by simply installing an air conditioner in the packing shed where fruit is sorted and held until transported. Ideally, growers should have a long term plan to either cool on the farm or transport in refrigerated trucks, or at least to air condition fruit and transport fruits in cool trucks.
- Encourage training of people involved in fresh-cut industry - information on relevant short courses for fresh-cut commodities. HACCP training is provided in this report. Local training on sanitation etc is important.
- Include a measurement of titratable acidity in quality evaluation especially when considering processing of other cultivars, since those with a higher acidity will probably have a longer shelf life.
- Refrigerated sea containers should be used in the supply chain whenever feasible. They should be loaded at the packing house and kept cold throughout, until they reach the ultimate consignee. Besides minimizing loading time and offering the ability to minimize trip time, this is the best way to preserve the quality of the fruit. Improvements should be made to the public infrastructure: better roads, refrigerated terminals, and investment incentives.

- When temperature abuse during transit is a concern, temperature abuse indicators on packages should be considered which relatively inexpensively record temperatures if they rise above a certain critical point. Temperature tracking devices should be used when there is a question about the location of breaks in the cold chain.
- Reduce number of main players in the industry, by encouraging medium and large-scale growers to work closely with out-growers, as the best approach to increase production volumes. This tactic will also help optimize the use of the extant integrated inland logistic systems (owned by large farmers), improve quality (out-growers focusing only on production and receiving technical assistance), increase flexibility (to face changes in market demand), reduce risks (splitting risks with out-growers), and the need for capitalization.

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## Appendices

### Appendix 1 Map of Ghana



### Appendix 2: Map Depicting Major Horticultural Production Regions

#### Project Area



**Appendix 3: Transport**



**Appendix 4: Processing**



**Appendix 5: Washing**



**Appendix 6: Waxing**



**Appendix 7: Packaging**



**Appendix 9: Grading**



**Appendix 10: Labeling**



**Appendix 11: Palletizing**



**Appendix 12: Holding Room**



**Appendix 13: Cooling Chamber**



**Appendix 14: Cooling Chamber**



**Appendix 15: pH Meter**



**Appendix 15: Thermometer**



**Appendix 16: Chlorine Test Kit**



**Appendix 18: Hand Refractometer**



**Appendix 19: Palletization**



**Appendix 20: Harvested Fruits Procedure**

**Appendix 21: Tracking**



## Appendix 22: Questionnaire/Discussion Guide

### Discursion Guide

#### Cold Chain Management in Ghana

#### The Fruit and Vegetable Sectors

##### Background/Production

1. Name of farm:  
.....
2. Location: .....  
.....
3. What type of crop produced? ....
4. For which market is the commodity produced .....  
.....
5. What is the average area planted?  
.....
6. Do any farming practices have an effect on produce quality (planting density, planting pattern, irrigation, weed control, fertilization practices, field sanitation)? .....
7. What are the grower's sources of labor? .....
8. Are there any insects, fungi, bacteria, weeds or other pests that affect the quality of produce?  
.....
9. What kinds of physical or chemical pre harvest treatments might affect postharvest quality (such as use of pesticides, pruning practices, thinning)?  
.....

##### Post Harvest

10. When is produce harvested? .....
11. How is produce harvested? .....

12. By whom? .....
13. At what time of day? .....
14. Why?  
.....
15. What sort of tools and containers are used? .....
16. How do harvesters determine the proper maturity for harvest? .....
17. How is produce sorted? .....
18. By whom? .....
19. Does value (price) change as quality/size grades change? .....
20. Do local, regional or national standards (voluntary or mandatory) exist for inspection?  
.....
21. What happens to culled produce? .....
22. What kinds of postharvest treatments are used? (Describe)  
.....
23. How is produced packed for transport and storage?  
.....
24. What kinds of packages are used? .....
25. Are packages reused or recycled? .....
26. Do you know about cold chain? .....
27. How did you hear of it? .....
28. How long have you known about it .....
29. Is the practice of cold chain relevant to your production .....
30. When and how is produce cooled?.....
31. To what temperature are produce cooled? .....

32. Using which method(s)? .....
33. How do current practices compare to recommendations for the commodity?  
.....
34. Where and for how long is produce stored?  
.....
35. In what type of storage facility are the produce kept?  
.....
36. How do these compare to recommendations for optimum storage life?  
.....
37. How and for what distance is produce transported?  
.....
38. In what type of vehicle is the produce transported?  
.....
39. How many times is produce transported .....
40. How is produce loaded and unloaded? .....
41. What are the conditions of the roads?  
.....
42. Are there any delays during handling? .....
43. Who is responsible for delays and who suffers the consequences?.....
44. Do you produce the commodity for export? .....
45. What are the specific requirements for export? .....

