EVALUATION OF THE POST HARVEST HANDLING OF MANGO FRUIT (*Mangifera indica* L.) IN THE AKWAPIM-SOUTH, DANGME-WEST, LOWER MANYA AND THE YILO KROBO DISTRICTS OF GHANA

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MASTER OF SCIENCE (POST HARVEST TECHNOLOGY)

Department of Horticulture, Faculty of Agriculture, College of Agriculture and Natural Resources

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DECLARATION

I hereby declare that this submission is my own work towards the M.Sc. and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

With love and affection, gratitude and appreciation, I dedicate this thesis to my wife, Theresa and daughter, Anastasia for their prayers and support throughout the period of the work.

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To my maker, the Most High God, I say glory and honour unto His name, for the knowledge, protection and blessings He has given me throughout my education up to this level.

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ABSTRACT

Ghana as a tropical country has a great potential for the growth and development of the mango industry. There are many problems facing the mango industry, especially, the post harvest handling of the fruits. A study was set up in the Akuapem-South , Dangme-West , Lower Manya and YiloKrobo Districts of Ghana to evaluate the postharvest handling practices of mango and how they affect the fruits and to identify the major postharvest problems handlers in the industry are facing .In this study ,information was sought from mango farmers ,fruit sellers , processors, exporters, officials from Ministry of Food and Agriculture (MOFA) and Ghana Export Promotion Export (GEPC) through questionnaires, interviews, field study , and observation .The best postharvest handling practices that could maintain and enhance the quality of the mango fruits were used as parameters .The parameters used were harvesting and maturity indices used for harvesting , sorting and grading , packaging , transportation , storage ,processing , postharvest diseases and pests , sanitation practices and technologies used to extend the shelf-life of mangoes. It was realized from the study that the handlers, especially ,the farmers had received some support and training from the Ministry of Food Agriculture and Non-Governmental Organizations but the emphasis had been on the pre-harvest handling of the crop .The fruit sellers had not received any form of training. The major problems that handlers had been encountering include inadequate and unskilled labour for harvesting , high incidence , pests and diseases , lack of cold storage facilities , mechanical injuries due to improper handling , bad road network , inappropriate transport , poor packaging , and few processing plants . These identified problems , if properly addressed as has been recommended in the study could enhance the quality and quantity of mango fruits offered for sale at the market.

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1.0 INTRODUCTION

According to the Ghana Export Promotion Council (GEPC, 2007), the potential to cultivate mango on a commercial scale was identified in the early 1990's in the country. This food security programme was supported by the United States Agency for International Development (USAID) with the dissemination of grafted varieties of mango for commercial mango farming. It was realised that the favourable natural conditions in the country offer a better opportunity for people to invest in this horticultural sector. It was expected that the country could export 6000 metric tonnes of mangoes valued at $3.3 million per year (GEPC, 2007).

Food and Agriculture Organization (FAO, 1995), estimated that global production of fruits would be 469 million and it would increase at a rate of 1.6% per year. Despite the lack of adequate infrastructure and technology, developing countries, including Ghana, will continue to be the leaders in providing fresh exotic fruits to the developed world. The production of major tropical fruits is expected to reach 82 million tonnes by 2014, an increase of 28.8 million tonnes over the 2000-2004 base period (FAO, 2010).

Mango (*Mangifera indica L.)* is the dominant tropical fruit variety produced worldwide (FAO, 2003a). Global production of mangoes is forecast to reach 30.7 million tonnes by 2010, accounting for nearly 50% of world tropical fruit production. India remains the world's largest producer and exporter of mangoes accounting for 40% of the total global output with Africa producing only 9%. Mango is grown commercially in 87 countries (FAO, 2003a).

According to the Ghana News Agency (2007), Ghana needs to develop the mango sector to capture a fair share of the international market since the agro-ecological zones of the country give an advantage of growing the crop at different times of the year.

The increasing demand for fresh horticultural produce, especially, mango and consumer demand for quality of fresh produce require that producers present horticultural produce in their best state of condition. This would help the farmer to attract good prices for their farm produce (CTA, 2009).

According to Liu (1991a), post-harvest handling of fruits has a decisive effect on the extent of the final quality, losses and the market value of horticultural crops. The quality of mango fruits on the markets in Ghana is too frequently of sub-standard quality. While it is recognized that many factors can contribute to the losses of fruit quality, the role of the post-harvest handling cannot be under-estimated. Kenya Agricultural Research Institute (1994) reported that, 40-45% of the mango fruits is lost through poor postharvest handling practices. Lizada (1993) stated that the mango trade has been limited by the highly perishable nature of the fruit and therefore ripening cannot be delayed sufficiently to allow for long-distance transport. The fruits are highly susceptible to disease, extremes of temperature and physical injury.

Post harvest handling practices play a major role in the marketing of fruits. The stakeholders in the mango industry, according to the Ministry of Food and Agriculture (MOFA, 2008) have received tremendous support from the Ghana Government Adventist Development and Relief Agency (ADRA), Agro-Chemical Companies, the Millennium

Challenge Account (MCA) etc. It is therefore important that an evaluation of the postharvest handling of fruits is undertaken to find out the status of the handling the fruits after harvesting to the time the produce reaches the final consumers.

Mango (*Mangifera indica L.*) is an important food and cash crop grown in Ghana. The commercial production of the crop varies from small-scale farms to huge commercial farms where improved cultivation practices are applied (MOFA, 1998). Mango is a tropical and sub-tropical fruit crop which belongs to the family, Anacardiaceae. According to Mukherjee (1996), mango originated from Tropical Asia mainly Sri Lanka and India. There are about a thousand varieties grown worldwide but in Ghana especially, in the study area, the commercial varieties grown include Keitt, Kent, Haden, Julie, Erwing, Palmer and Spring field (MOFA, 2008).

The mango plant is a dicotyledonous, evergreen tree which can grow to a height of about 26 metres (Purseglove,1987). It has a bushy, spherical shape. The leaves and the unripe fruits have a milky latex which could stain the fruit after harvest. The fruit is a succulent drupe with fleshy mesocarp and stony endocarp. The immature fruit is green, hard and sour while the mature fruit is yellow, orange, succulent and sweet with a very strong smell (Purseglove, 1987). Fibres are more pronounced in fruits grown with hard water and chemical fertilizers. The mango fruit matures in 100-150 days after flowering. The fruit is 60-70 percent flesh,11-18 percent skin, and14-22 percent seed, depending on cultivar , with flesh being 20 percent dry matter. Most of the mangoes produced are marketed in the fresh state for consumption as a dessert fruit.(Nakasone and Paull,1998).

The fruit is rich in dietary fibre, Vitamin C, polyphenols, carotenoids, potassium, copper and 17 amino acids at good levels. The mango peels contain pigments that may have antioxidant properties, pro-Vitamin A compound: beta carotene (CTA, 2009). It is mostly consumed raw as dessert and it is processed into juices, ice cream, fruit bars, jams, chips and jellies (CTA, 2009).The cultivation of mango provides employment to the people, generates income for the farmer and other handlers and has the potential to generate more foreign exchange for the country. (MOFA,1998).

Mango thrives well in a frost-free climate at elevations from sea level to 1200 metres in the tropics but it does best at 600 metres in climates with strongly marked seasons and dry weather for flowering and fruit setting (Purseglove, 1987). The optimum growth temperature is between 24-30C and an average rainfall of 254mm-2540mm per annum, but heavy rains cause reduction in pollination, fruit setting and fungal infections on inflorescence. The best soils for cultivation ranges from well-drained sandy-loam to loamy soils with a preferable pH of 5.5–7.5. The crop is usually propagated by seed, grafting, aerial layering and budding but grafting is the most commonly use method for commercial growing. The land used for cultivation should be prepared by deep ploughing followed by harrowing and levelling with a gentle slope for good drainage. The spacing varies from 10.5metres by 10.5metres to 15.2metres by 15.2metres depending on the variety (Morton, 1987).

The mango fruit is climacteric and highly perishable with a relatively short life span and reaches the peak of the ripening process on the third to fourth day after harvesting at

ambient temperature (Narayana *et al.*, 1996). The shelf life, however, of the fruit varies among the varieties and the storage conditions used. Herianus *et al.* (2003) stated that the ripening process after harvesting in mature green mango fruits involves a series of biochemical reactions resulting in increased respiration, ethylene production, change in the structure of the polysaccharides causing softening and degradation of chlorophyll, development pigment of carotenoids, biosynthesis change in carbohydrates or starch conversion into sugars, organic acids, phenolics and volatile compounds. These lead to the opening of fruits with soft texture to acceptable quality. The short period of storage seriously limits the long distances commercial transportation of the fruit (Gomer-Lim, 1997).

According to Carillo *et al.* (2000), the shelf life ranges from four to eight days at room storage at 13^0C. Hoa et al (2002) also stated that the fruit sensitivity to decay, low temperature and the perishable nature of the fruit due to rapid ripening and softening limit the storage, handling and transport potential. Because of the short shelf life, most mangoes which are exported to distant markets around the world are often subjected to various postharvest treatments including hot water treatment, wax-coating, cold storage, modified atmospheres, controlled atmospheres, thermal quarantine and fungicidal sprays. These are done to extend to shelf life and to prevent the spread of invasive pests and diseases that cause economic and environmental harm (Mitcham and Yahia, 2008).

In spite of these treatments, poor postharvest handling practices remain as some of the leading causes of economic losses to farmers, fruit sellers, exporters etc. and the nation as a

whole. Kader (1992) stated that post-harvest losses have been estimated in developed countries to range from 5-25% while in the developing countries it is between 20-50%.

According to the Ministry of Food and Agriculture, Ghana (2008) the areas under study have favourable climatic and suitable soils for the cultivation of mango. The farmer population has increased and large tracts of land have been put under cultivation. The potential to increase incomes and reduce poverty in the areas of study is, therefore, very high. However, the incidence of diseases and pests, low financial support to farmers, lack of infrastructure such as packinghouses and cold chain facilities militate against the mango industry. The CTA (2009) reported that recent years have seen a sharp increase in demand for mangoes in North America and the European Union more than 200% since 1985. Massive quantities of mangoes produced each year, however, are lost through high level of deterioration of the fruits. An evaluation of the postharvest handling of the fruits and an intervention are therefore required to reduce the losses to acceptable levels. There have been some studies on the production of mango in Ghana but there is little information on the specific postharvest problems stakeholders face in the study area (MOFA, 1998). The scope of this study is restricted to the postharvest handling of mangoes in the Akuapem-South, Dangme-West, Lower Manya and Yilo Krobo Districts of Ghana which have been some of the major areas of rapid mango production in the country.

The study was carried out with the support of the farmers, fruit sellers, processors, exporters, personnel from the Ministry of Food and Agriculture(MOFA) in the districts and the Ghana Export Promotion Council (GEPC). These stakeholders were required to answer

some questionnaire, interview questions, interact with researchers on key issues in the production and handling of mango fruits.

The postharvest handling practices that were used for the study are harvesting methods, sorting , grading, pre-cooling, packing and packaging, transportation, processing of fruits, postharvest diseases and pests, produce technologies to enhance shelf life and sanitation practices by farmers, fruit sellers, transporters, processors and exporters.

The objectives of the study were:

- To evaluate the postharvest handling practices of mango and how they affect the fruits.
- To identify the major postharvest problems that handlers of mango fruits are facing in the area under study.

2.0 LITERATURE REVIEW

Postharvest handling has decisive effect on the extent of post postharvest losses, the final quality and the market value of horticultural crops. Mango not only provides human beings with nutritional and healthy food, but also generates considerable income for the stakeholders in the mango industry in many countries. Mango, one of the leading horticultural crops in the tropics, typically has a high moisture content, tender texture and high perishability. If not handled properly, this high-value, nutritious product can deteriorate and rot in a matter of days or even hours. The quality of the fresh fruit has a decisive effect on its value, particularly, when consumers have high income and the market provides a wide choice of produce (Liu, 1991a).

Modern and series of sophisticated technologies have been developed and applied in postharvest handling of horticultural crops in the last few decades. Many tropical countries, including Ghana, have not been able to use the advanced technologies owing to cost and the technical know-how to manage them. While it is cultural practices, climate, plant materials and location factors which determine the quality of produce at harvest, proper postharvest handling ensures that the quantity is preserved until the produce reaches the final consumer (Olympio and Kumah, 2008).

According to Brecht *et al*.(2010) the best postharvest handling practices that ensure that quality mango fruits are delivered to consumers include harvesting methods, maturity indices of mango, sorting , grading , pre-cooling , packaging , transportation , processing and preservation , storage , postharvest diseases and disorders , postharvest pests , produce

technologies that enhance shelf life of fruits and sanitation practices would be adopted as a general discussion on the postharvest handling practices which determine the status of the mango fruits and products until they get to the consumers.

2.1 Harvesting Practices and Methods

Harvesting is the act of detaching or severing of plant produce from the parent plant or its production area or the normal growing environment. Harvesting is undertaken in horticultural crops when they attain maturity. A fruit is termed matured when it reaches a stage it is able to ripen to maximum eating quality but in which ripening has not yet commenced. Maturity may be classified as physiological in fruits and vegetables when maximum growth and maturation have occurred: and horticultural or commercial maturity when the plant or plant part possesses the pre-requisites for utilization by consumers for a particular purpose. At harvest, maturity either physiologically or commercially, the produce should not be toxic, meet the correct market size, be able to develop the right flavour and appearance and have adequate shelf-life (Olympio and Kumah, 2008).

Reid (2002), stated that fruit producers and postharvest produce technologists consider these terms; `ripe` and `mature` to have distinct meanings. The condition of fruit at the time of harvest has an important effect on consumers' level of satisfaction at consumption. While many consumers use the terms 'ripe' and mature interchangeably to describe the state of a fruit when it is ready for consumption. Reid (2002) indicated the term `mature` is best described by the Webster's Dictionary definition as: `having completed natural growth and development whiles `Ripe` means having attained a final or desired state (Reid, 2002).

It is important to know the stage of maturity for determining when to harvest fruit since fruit harvested at an immature stage will not be able achieve a level of quality acceptable to consumers.

Lakshminarayana (1980) stated that in a climacteric fruit such as mango, the fruit is not considered to be of desired eating quality at the time it initially becomes mature, but requires a ripening period of 8 – 10 days at 25C before it achieves the taste and the texture desired at the time of consumption.

According to Yahia (1999), the selection of adequate maturity indices is very important. They are important for deciding when a given commodity should be harvested to provide some marketing flexibility and to ensure attainment of acceptable eating quality to the consumer. The quality of postharvest shelf life of mango fruit is strongly dependent upon the stage it was harvested to develop the most adequate organoleptic quality and the longest postharvest life. Less mature fruit is usually more sensitive to chilling injury. Fruit harvested before it reaches full maturity may not be ripened adequately at harvest or in some cases it will never ripen. On the other hand, fruits harvested when over-ripe are very sensitive to bruising, decay and to water loss, quality deterioration and would not have a long postharvest life. In addition fruits harvested over-ripe will show defects, such as jelly seeds and jelly pulp very shortly after harvest. Jelly seed deteriorates the internal quality of the fruit (Yahia,1999).

Kader (2008) stated that because the maturity level is critical to the development of good flavour quality in the fruit when fully ripe, it is important that individuals harvesting fruits to have effective methods of determining mango maturity. The appearance of red colour on the skin (in some cultivars) is not a reliable index for maturity. Likewise, the change in skin ground colour (the greenest spot on the fruit) from dark-green to light-green or yellow is not reliable because of variations between cultivators. Differences in ground colour between immature and mature green mangoes can be subtle. A number of alternative mango maturity indices studied include the number of days after bloom, the flesh colour ,fruit shape (fullness of the 'cheeks' or 'shoulders', skin colour, soluble solids content, specific gravity, starch content, titrable acidity and total solids content (Reid, 1998).

Cultivar differences in the growing environment can affect the indices, and while there is currently no consensus on the optimal maturity index for mango, Kader (2008) observed that the flesh colour has the most consistent performance across cultivators. The author concluded that the development of a non-destructive flesh colour sensor for mango could allow improved training of harvesting crews to better recognize an external attribute such as fruit shape associated with minimum maturity levels in the orchard.

Iqbal (2010) stated that the maturity of mango fruit could be determined by putting the fruit in 2 % salt solution. Those that sink are considered mature while those that float are considered immature. The period from fruit set, external colour break, starch breakdown, sugar content, proximal shoulder development and firmness are some of the maturity indices that are used to determine the maturity of mango fruits (Kruger, 1998).

Measurements of maturity indicators provide indices which can be related to storage life, ripening attributes and marketability of fruit. The rate at which mango fruits ripen and the eating quality are affected by the fruit maturity at the time of harvest (Medlicott *et al*, 1988). Khan (1989) also reported that mangoes showed decrease in fibre, protein, acidity and ascorbic acid content and increase in total sugar and mineral content on maturity.

Depending on the type of fruit or vegetable, several devices are employed to harvest produce (FAO, 2003a). The commonly used tools for fruit and vegetable harvesting are secateurs, knives, and hand-held or pole-mounted picking shears. When fruit such as mangoes and avocados are difficult to catch, a cushioning method is placed around the tree to prevent damage to the fruit when dropping from high trees (FAO, 2003a).

Iqbal (2010) stated that harvesting of mango should be done, when possible, by hand from the ground by snapping the mangoes from the stem. Fully-mature fruit will detach easily, whereas half-mature fruits will not. Optimum harvesting involves using secateurs to cut the stem 2-3cm away from the fruit and the latex allowed to drain. Later the stem should be further trimmed with a sterilized knife. Where harvesting by hand from the ground is not possible, harvesting implements should be used. The most suitable method involves a long pole with a cutting blade and a small bag under the blade to catch the fruit. Alternatively, climbers may use cotton bags which are filled and lowered to the ground. Mangoes should never be knocked from the tree, dropped or thrown to the ground. Fruits that are injured or bruised due to impact results in decay, poor quality and attract low price (Iqbal,2010).

Yahia (1999) recommended that it is important that fruits are picked at the early hours of the morning when temperatures are not high and kept under shade. This would reduce field heat and respiration in the fruit and thus maintain it for longer periods. Cultivars with high latex content should be harvested very early in the morning to reduce latex flow. Harvest during warm hours of the day will increase fruit deterioration, increase the need for fast cooling, increase energy requirement for cooling and negatively affect worker comfort (some workers are allergic to the sap that exudes from mango). Fruits should not be picked all at the same time, especially, when harvesting is done at earlier stages of maturity. Repeated harvest of the same tree should be carried out to ensure that only mature fruit is picked each time (Yahia, 1999).

Yahia (1999) reported that latex flow causes problems including sap burn on the skin of the fruit, prevention of adequate development of colour and promotion of decay. This problem is made possible when the fruit is cut without a stem. Latex will not usually exude from a longer stem because there is no continuity between the fruit and the stem resin ducts. Cultivars differ in the flow of latex and in the extent of damage caused by latex. High nitrogen content in the fruit has been associated with more severe latex burn. Latex-burned fruit skin can be invaded with *Aspergillus spp.* especially in hot conditions (Yahia, 1999). Adequate handling operations that can reduce latex flow including picking fruit with a stem, washing of fruit, packing fruit on a table not on the ground and packing stem-up in the package. Several methods that have been tried to eliminate the latex on mango fruit include: treatment with 1% solution of calcium hydroxide ; washing fruit in 1%

solution aluminium potassium sulphate ; applying surface coating to fruit prior to eliminating the latex (Yahia,1999).

Hand harvesting is practised when fruits have light skin, easily gets damaged and are meant for fresh market. Mechanical harvesting is normally used for fruits meant for processing, have tough skin and has the ability to heal wounds quickly. Mechanical damage is caused by inappropriate methods during harvesting and this can lead to tissue-tissue wounds, abrasion, breakage and squeezing of fruits. These could increase susceptibility to decay and growth of micro-organisms (Alzamoora *et al*, 2000a). All the methods of harvesting can cause bruising and damage to cellular and tissue structure in which enzyme activity is greatly enhanced as cellular components are dislocated (Holdsworth, 1983). Quality cannot be improved after harvest, only maintained .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 in storage as that picked at proper maturity (Wilson *et al*., 1995).

2.2 Sorting and Grading of Fruits

Hyfoma (2010) defined sorting as the separation of raw materials and food slurries into categories on the basis of shape, size, weight, image and colour. The author explained sorting is carried out in horticultural produce before sending them to the market because most of the raw materials contain some components which are inedible or have variable physical characteristics. It is carried out to obtain the required uniformity for processing or for direct fresh fruit sale to the consumer.

Sorting allows the separation at first sight some of the undesirable or additional materials such as leaves and stones or inappropriate raw materials (immature, rotten produce) to ensure that only good quality is preserved or passed through for processing. Different methods of sorting are used in the horticultural industry. For size sorting, various types of screens and sieves with fixed or variable apertures can be used. According to Liu (1991b), round or nearly round fruits are often sized according to diameter using automated chain or roller sizers or hand-carried ring sizers. An inefficient sizing operation can also cause significant injuries.

Shape sorting can be accomplished normally or mechanically with, for example, a bell-or roller-sorter (Liu,1991b). Weight sorting is a very accurate method and is therefore used for more valuable foods like meat, fruits and vegetables. Image processing is used to sort foods on the basis of strength; diameter and appearance that is, surface defects and orientation on a conveyor. Colour sorting can be applied at high rates using micro-processor controlled colour sorters (Hyfoma, 2010). The author again defined grading as the assessment of a number of characteristics of a food to obtain an indication of its overall quality. Many characteristics are not examined automatically. Trained personnel carry out this activity in order to produce a uniform high quality product (Hyfoma, 2010).

Liu (1991b) stated that sophisticated marketing systems require precise grading standards for each kind of product. More primitive markets may not use written grade standards but the products are sorted and sized to some extent. Typical grading facilities in large packing

houses include dumpers and conveyors. Produce is graded by human eyes and hands while moving along conveyor belts or rollers (Lui, 1991b).

Yahia (1999) stated that mango could be categorized into different and uniform groups either on the basis of size or weight. Mango fruit can be classified manually but uniformity will be much better when sizing is done mechanically either by size or weight according to uniformity, maturity stage, colour, absence of injuries and defects, latex stain, disease and pest infection (Yahia, 1999).

Brecht *et al*. (2010) stated that fruit grading at the packinghouse is done to remove unmarketable fruits. This eliminates the waste of time, money, and energy that accompany shipping unmarketable fruits that must eventually be removed from palletized cartons and discarded. Fruits with the following defects must eventually be removed and discarded. The defects include: fruits with physical injuries such as cuts scraps, bruises, which favour the development of shriveling and decay; any evidence of decay or incipient decay; misshapen fruits flat and immature fruit which are susceptible to several physiological disorders and fruit with lenticels damage, surface scald, or collapse area, which are symptoms of hot water damage (Brecht *et al*, 2010).

Dirou (2004) stated that before grading, mango fruits are sprayed with a fungicide to control anthracnose disease as the fruit ripens. Fruits are also dipped in an approved insecticide to control fruit fly. A drying tunnel or fans can be used to dry the fruit. Brushes on the grader polish the skin and enhances the fruits bloom. Fruits are usually graded into 3

quality grades: 1st grade, 2nd grade and 3rd grade and processing fruits depend on the type and size of the blemish (Dirou, s2004).

2.3 .0. Packaging of Mango Fruits

According to Appiah and Kumah (2009), packaging is the art, science and technology of enclosing or protecting products for distribution, storage, sale and use. It is thus the act of making product handy by putting them in containers to enhance mobility but exclude contaminates such as pathogens, dirt and undesirable reactions with the environment in order to improve their shelf-life and make them presentable to the consumer. The authors further explained that the package is the physical entity that contains the product; packing as the act of enclosing a single item or multiple items in a package or a container and the pack as the unit of containment or package with the produce in it (Appiah and Kumah, 2009).

The Baron's Marketing Dictionary (2000) defined the package as the container or wrapper for a consumer product that serves a number of purposes including protection, description of the contents, theft deterrence and product promotion. Innovative packaging may actually add value to the product if it meets a consumer needs such as portion control, recyclability, tamper-proofing, child-proofing, easy–open, easy- store, easy- carry and non-breakability. Packaging must be small enough to accommodate available space and large enough to deter theft. It must also contain an adequate amount of product to keep the unit price competitive. It should also be designed to highlight product benefits (Appiah and Kumah, 2009).

Boyette (1995) stated that packaging fresh fruits and vegetables is one of the more important steps in the long and complicated journey from grower to consumer. Much work is required before the produce reaches the consumer. The author further stated that more than 1500 different types of packaging are used for produce in the United States alone and continues to increase as the industry introduces new packaging materials and concepts. The researcher also stated that a significant percentage of produce buyer or consumer complaints may be traced to container failure because of poor design or inappropriate selection and use. Boyette (1995) outlined as the major functions of packaging as containment, protection and identification . According to Liu (1991b) fancy containers such as fibre board or wooden or plastic crates are often used for high value products but the `ideal` is yet not found.

Khan (1989) stated that the choice of suitable packaging and packing methods must take into account the type of produce to be transported and the type of damage likely to occur. Rough handling causes bruises, cuts and abrasions that break the natural protective covering of the skin. Such injuries not only spoil the appearance of the produce but also hasten ripening and deterioration (Khan, 1989).

2.3.1. Packaging Materials

According to Wills *et al.*(1998) modern packages can be classified as flexible sacks, wooden crates , plastic crates , fibreboard or cardboard boxes.

Boyette (1995) stated other materials that could also be used for packaging. These include wood pallets, pallet bins, wire-bound crates and wooden baskets and hampers. Pallets

literally form the base on which most fresh produce is delivered to the consumer. Standard size pallets make efficient use of truck and van space and can accommodate heavier loads and more stress than higher single-use pallets. Ship sheet, an alternative to the pallet, is considerably less expensive to buy, store and maintain (Boyette,1995).

Wooden wire-board crates are used extensively for snap beans, sweet corn and several other commodities that require hydro cooling (Boyette, 1995). Wire-board crates are sturdy, rigid and have very high stacking strength that is essentially unaffected by water. Although few are re-used, wire-board crates may be dissembled after use. Wooden baskets and harpers, wire-reinforced wood veneer baskets and harpers of different sizes were used for a variety of crops from strawberries to sweet potatoes. They are durable and may be nested for efficient transport when empty (Boyette, 1995).

2.3.2 Packaging Methods and Techniques

Most horticultural crops are packed and packaged in packing houses. These packing houses serve as collection centres for fruits and vegetables prior distribution and marketing. These houses can be simple packing sheds with limited equipment and material operations or a large complex that is well equipped and facilities for specialized operations. The types of operations carried out vary with different commodities and market requirements. Produce that are for export or supermarkets are often subjected to elaborate operations compared to local markets (FAO, 2003b).

According to FAO (2003b) the purpose of food packaging is to maintain quality and to increase the shelf life of products by reducing mechanical damage and retarding microbial spoilage. Liu and Ma (1983) stated that the choice of suitable packaging and packing methods must be taken into account the type of produce to be transported and type of damage likely to occur. Three principles should be generally observed when packaging perishable products: individual specimen should not be moved against each other or the walls of the package, the package should be full but not overflowing and it should not be tightly packed (Lui and Ma, 1983). In addition the package must retain it strength throughout the marketing chain. The most suitable package for a given type for a produce will depend on such factors as distance to be travelled, nature of the market, method of handling and transport, environment availability and cost of packaging materials and the need of refrigeration. (Wills *et al.*, 1981).

Yahia (1999) reported that mango packaging commonly used in the world one usually one piece cartons and fruits are usually packed in a single layer. Packing on the ground is not comfortable for workers neither are it appropriate for the fruit. It should be done on tables that can offer comfort for packers and thus increase packing efficiency and decrease fruit deterioration and loses. Some packers use papers as liners in the package but should be substituted with other types for clean paper (Yahia, 1999) .

Mango fruit is usually packed by count, depending on the size of the fruit in Egypt. Commonly packed sizes are 6,8,10,12,14,16 and 18 fruits. Packaged with 8,9,10,12 fruits

are the most common in demand in Europe. In Germany, the most popular fruit size is 300-500g, while it is 225-500g in the rest of Europe (Yahia, 1999).

FAO (2003a) stated that vacuum packaging of fresh commodities improves eliminating (at least one) the air in the package using suction on machine. This method reduces the level of both oxygen and nitrogen in the package, prolonging the shelf life of fruits for extended periods. The removal of air retards the developments of enzymatic reactions and bacterial spoilage. Modified atmosphere packaging (MAP) is created by passively using proper permeable packaging materials or by actively gas mixture, together with permeable packaging materials. The purpose of this procedure is to create an optimal gas balance inside the package, where respiration activity of the product is as low as possible. On the other hand the oxygen concentration is not detrimental to the product (FAO., 2000a). In general, the objective is to have a gas composition of 2-5% CO2, 2-5% O2 and the rest nitrogen. One limitation in design of controlled atmosphere packaging is in finding good permeable material that will match the respiration rate of the produce. High oxygen Modified Atmosphere Packaging treatment has been found to be particularly effective at inhibiting enzymatic browning, preventing anaerobic fermentation reactions and inhibiting aerobic and anaerobic bacterial growth. The modified atmospheres that best maintain the quality and storage life of minimally processed foods have been found to have an oxygen range of 2 to 8 percent and carbon dioxide concentration of 5 to 15 percent. (Cantwell, 2001).

2.3.3. Packaging of Mango Fruits

Yahia (1999) stated that the types of packages commonly used for mango in the world are bamboo and other types of wooden baskets; wooden crates which are used in Mexico, Malaysia, Thailand, Singapore and the Philippines; rigid plastic containers, corrugated cartons and package liners. Yahia (1999) again reported that most packages that are used for mango recently in Egypt are made of corrugated cartons. The packages used are general purpose packages that are used for several fruits and vegetables. The re-use of packages is common; they are not specific and usually characterized by weak stalk force due to multiple uses and can be a major source of decay infection. Packages used are big and heavy with a capacity of 10kg or more Yahia (1999).

Yahia (1999) stated that big packages result in significant fruit injury because of weight compression of upper fruits. The packages are difficult to handle by workers and so are subject to mishandling and dropping, resulting in significant fruit losses. The author further stated that fruits packed are not uniform and therefore get bruised at the time of packing and had serious latex-staining problem. Bruising and other defects are extremely high especially when the fruits are exposed to extreme climatic conditions and not refrigerated.

Anwar *et al.* (2008) reported that most mangoes in Pakistan, packed in wooden crates which apart from causing physical injuries; and bruises during transmit; are being restricted in international markets on account of quarantine concerns and special disinfestations treatments necessary for international trade.

Brecht *et al* .(2010) stated that packaging for mangoes primarily serves to protect the fruit from injuries caused by cuts, compression, vibration and impacts. Packaging can also facilitate or interfere with good temperature management. Packaging also helps to identify and advertise the product and the company selling the mangoes. The authors further stated mangoes should be handled in single-layer cartons with or without lids and with base dimensions that result in 100% coverage of the surface area of standard pallets used. Mango cartons shipped for distance by truck can be single-walled whiles those shipped over lager distance require double-wall construction. Ventilation holes should be properly located and oriented to allow air flow during cooling, shipping and storage without compromising strength. (Brecht *et al*., 2010)

Medina and Garcia (2009) stated that mangoes are also packaged in full-telescopic two-piece fibre board carton or one-piece waxed self-locking cartons may be used. Central dividers and shredded paper may be used to assist the carton strength and product protection. When staples are used for carton construction care should be taken to ensure complete staple closure to avoid fruit damage. Wooden boxes are also commonly used in India for packaging mango fruits. Under dynamic transport conditions, nails come out due to vibration and puncture the fruits which result in bruising decay and low prices of fruits. Too much ventilation affects the quality of fruits due to shrinkage, loss in weight, colour etc (Medina and Garcia, 2006).

Dirou (2004) stated that mangoes are pattern- packed in trays using plastic inserts with moulded crops. Packs should be firmed to avoid fruit movement during transport. Fruits

should be packed in such a way that the coloured cheek would show. Fruit stitches are used to indicate variety, brand name and price look up number. Anwar *et al.,* (2008) stated that more than 90 percent of fruits are packed in wooden crates but this practice is eliminated at the export markets.

2.4. Transport and Transportation of Fruits

According to the FAO (1989) transportation is a big and often the most important factor in the marketing of fresh produce. Ideally, transport would take produce from the grower directly to the consumer (FAO,1989). In more complex marketing systems, such as those serving towns, cities, or distant countries, the cost of transport contributes significantly to the price paid by the consumer and sometimes exceeds the value of the raw product.

The FAO (2003b) stated that transportation is a serious problem faced by fruit growers in developing countries where vehicles used in transporting bulk raw fruits to markets are not equipped with good refrigeration systems. Raw foods that are exposed to high temperature during transportation soften in tissue and bruise easily, causing rapid microbial deterioration.

Kader (2005) stated that 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 for local and export to other countries and the majority of producers have small holdings and cannot afford to own their own vehicles. In a few cases, marketing organizations and co-operatives have been able to

acquire transport vehicles, but they cannot do much about poor road conditions (Kader, 2005).

According to Liu (1991b), inland transportation of horticultural crops is usually by rail or by trucks. Overseas transportation is by sea or by air. A limited amount of high-valued produce is sometimes transported overland by air. The basic requirements or conditions during transportation are similar to those needed for storage, including proper control of temperature, humidity and adequate ventilation. In addition, the produce should be immobilized by proper packaging and standing, to avoid excessive movement or vibration. Vibration and impact during transportation may cause severe bruising or other types of mechanical injury (Lui1991b).

The FAO (1989) further stated that losses that are directly attributed to transport conditions can be high. To reduce the losses, the produce should be properly packaged and properly loaded on a suitable vehicle. The damage and loss incurred during non-refrigerated transport are caused primarily by mechanical damage through careless handling of packed produce during and unloading, shaking of the vehicle on bad roads, fast driving and poor condition of vehicles, and packages stacked too high (FAO, 1989).

The FAO (1989) stated that another cause of damage and loss is overheating. This can occur not only from external sources but also from heat generated by the produce within the package itself. Overheating promotes natural breakdown and decay; and increases the rate of water loss from produce. The causes of overheating include the use of closed

vehicles without ventilation; the lack of ventilation of the packages themselves and the exposure of the packages to the sun while awaiting transport or while trucks are queuing to unload at their destination.

Liu (1991b), again stated that Controlled Atmosphere containers are not used much for transporting fruits and vegetables. Only a small number of Controlled Atmosphere containers are used for long distance shipping, whether by sea, rail or truck. Shipping by refrigerated trucks is not only convenient but also effective in preserving the quality of product. Another possibility is insulated or properly ventilated trailer trucks. Pre-cooled products can be transported by well-insulated non-refrigerated trucks for up to several hours without any significant rise in product temperature. There are considerable cost savings without any sacrifice of quality if trucks are only insulated, rather than refrigerated for short-distance shipping. If the product is not pre-cooled or if the shipping distance is long, a ventilated truck is a better choice than an insulated truck without ventilation and without refrigeration. Ventilation alone does not usually provide a uniform cool temperature, but it may help dissipate excessive field heat and respiration heat and thus avoid high temperature injury (Lui, 1991b).

The FAO (1989) stated that the use of Controlled Atmosphere (C.A) in refrigerated marine containers continues to benefit from technological and scientific development. Controlled Atmosphere transport is used to continue cold chain for commodities such as apples and peas that have been stored in C.A immediately after harvest. C.A transport of banana permits their harvest at a more advanced stage of maturity. In the case of avocados, C.A

transport facilities use of lower shipping temperature (5^{o}c) if shipped in air. C.A in combination with precision temperature management allows insect control without the use of chemicals in commodities for markets that have restrictions against pests endemic to exporting countries for markets with a preference for organic produce (FAO, 1989).

2.4.1. Transport of Mango Fruits

Mitcham and Yahia (2009) stated that the means by which mangoes are transported are through the air, water, rail and road (use of aircraft, ship, truck and railways).

The truck has been adopted as the most convenient mode of transport for mango in India. This is due to its easy approach from the orchards to the markets. However, those trucks were not found suitable for transporting this live material as they exert a lot of pressure on the fruits and do not work well with the temperature control devices. Reefer containers (refrigerated vans) may be found useful for long distance transport and export purpose as they would help in reducing the postharvest losses (Mitcham and Yahia, 2003).

Brecht *et al*., (2010) recommended that mangoes should always be shipped as unitized pallets of single-layer cartons. Attention should be given to ensuring that cartons are stacked squarely on pallets so that their weight is evenly distributed on the carton corners. Attention must also be paid to vent alignment either vertically or horizontally so that air can flow properly through the load. Wraps, interior sheets or anything else that may block carton vent and interfere with airflow should not be used. Mangoes should be loaded into reefer trailers so as to remove heat from all sources by the refrigeration systems and the

load must also be protected as much as possible from physical damage (Brecht *et al.*, 2010).

Yahia (1999) reported that all mango transport to the local markets in Egypt is done in non-refrigerated trucks and cars. Temperature during the mango production season are high and thus non-refrigerated transport increases the deterioration of quality and causes major losses of fruit, especially when it is done inadequate. Yahia (1999) further stated that the use of non-refrigerated transport to local markets may be feasible if the distance is short and the weather is not very warm. In warm weather transport should be done at night when the temperature is much lower. Non-refrigerated cars and trucks should be covered adequately to protect fruit from wind and high temperature. Refrigerated land containers should be checked and adjusted before loading to ensure that conditions and functioning are proper. Fruit should be loaded after cooling and containers should be pre-cooled before loading. Transport containers should be clean and fruit should be stacked correctly to permit circulation of cold air and to prevent warming-up of the fruit.

Yahia (1999) again reported that Modified Atmosphere and Controlled Atmosphere are used for transporting significant quantity of mango. The author further stated that they should be used as a complimentary treatment to an adequate handling system. Controlled Atmosphere maintains a constant temperature, oxygen and carbon dioxide concentration and a low ethylene concentration. Mango is fairly resistant to anaerobic conditions and therefore it can tolerate relatively extreme gas concentrations. To control insects, Yahia (1999) stated that atmospheres with very low levels of oxygen and/or very high levels of

carbon dioxide, especially at high temperatures are being developed as quarantine system for mango.

2.5. Storage of Horticultural Crops

The FAO (1989) stated that horticultural crops are stored to meet a regular continuous demand and provide a degree of price stabilization. It also meets the demands of populations of developed countries and of the richer inhabitants of developing countries. It provides an all-year round availability of various local and exotic fruits and vegetables. Storage of produce under the appropriate conditions extends the shelf life and usable period of the produce. Storage takes off excess produce from the market that would otherwise cause glut and thus reduce the market value of the product resulting in the loss of income to the farmer. Storage is needed to extend the marketing period of the produce (FAO, 1989).

According to Liu (1991c) various storage methods have been used on a commercial scale. Air-cooled common storage houses are often used or underground or cave storage using natural cold air. In many developing countries, where seasonally produced plant foods are held back from sale and released gradually, storage in a controlled environment is not possible because of the cost and the lack of infrastructural development and of maintenance and managerial skills. However, there are still many people who for their own consumption, preserve and store fresh produced by traditional methods (FAO, 1989).

Most perishable fresh produce cannot be stored without refrigeration, but the possibilities for extending the storage life of even most durable fresh produce under ambient conditions are limited. Storage at low temperatures has been an effective means of extending the shelf-life of fresh fruits and vegetables. (FAO, 1989).

Karen and Flores (1991) stated that cold storage slows down produce respiration and breakdown by enzymes, slows water loss and wilting, slows or stops growth of decay-producing microorganisms, slows down the production of ethylene (the natural ripening agent) and "buys time" for proper marketing. The objective of optimum storage conditions is to limit the production, storage and absorption of heat of produce (Karen and Flores, 1991).

According to the FAO (1989) the factors that affect the storage life of all types of fresh produce are temperature, water loss, mechanical damage , and decay in storage. Many researchers including Derbyshire and Shipway (1978); Hall (1979); Hardenburg (1978) and Harvey (1978) stated that most decay-producing organisms grow slowly at low temperatures. Therefore, temperature control is probably more critical for vegetables than other types of crops in reducing the development of storage pathogens. Low temperatures delay the development of postharvest diseases by inhibiting host ripening, by prolonging disease resistance associated with immaturity, and by inhibiting the pathogen with temperatures unfavorable to its development (Rippon, 1980). According to Hardenburg *et al.* (1986), temperature remains the single most important factor in maintaining quality after harvest. Temperature management is the most critical factor in the management of

ripening in mature-green mangoes. Paull and Chen (2004) indicated that holding the fruit in the temperature range 20^{o}c to 23^{o}c provides the best appearance, palatability and decay control when ripening mangoes. Kader and Mitcham (2008) indicated that holding the fruit between 15.5^{o}c to 18^{o}c during ripening provides the most attractive skin colour.

2.5.1 Storage Structures

The FAO (1989) stated that the storage structures that are used for crops include ventilated stores which are widely used to store horticultural products which have good keeping quality even without a precise low temperature. However, its use is generally limited to cool seasons in temperate and sub-tropical regions or high altitude where there are low ambient temperatures at night. The underground or cave storage often provides better temperature control than above ground air-cooled storage for major crops like apples, pears and citrus fruits (Liu, 1991).

The other storage structures as stated by the FAO(1989) are Clamps and refrigerated storage. According to Liu (1991c) refrigerated storage is a well-established technology widely used for storing horticultural crops all over the world Its application is limited by cost and benefit considerations.

Hardenburg *et al*., (1986), stated that temperature is the simple most important factor in maintaining quality after harvest. According to Hardenburg (1978) refrigerated storage retards the following elements of deterioration in perishable crops through ageing due to ripening, softening and textural and colour; undesirable metabolic changes and respiratory

heat production; moisture loss and the wilting that results; spoilage due to invasion by bacteria, fungi, and yeasts undesirable growth such as sprouting of potato.

Wills *et al*. (1998) stated that another important function of refrigeration is to control the crops respiration rate. Respiration generates heat as sugars, fats, proteins in the cells of the crops are oxidized. The loss of these stored food reserves through respiration means decrease food value loss of flavour, loss of salable weight and more rapid deterioration. The respiration rate of a product strongly determines its transit and postharvest life. The higher the storage temperature, the higher the respiration rate will be, hence, faster deterioration rate (Wilson *et al.,* 1998).

On-farm cooling facilities are a valuable asset for any produce operation. A grower who can cool and store produce has greater market flexibility because the need to market immediately after harvest is eliminated. The challenge for small producers is the set-up cost (Bachman and Earles, 2000). The amount of heat in produce is governed by the temperature around it. The temperature difference between newly-harvested produce and its optimum storage temperature is an indicator of field heat. Rapidly lowering the temperature of harvested produce to near storage temperature is known as pre-cooling or the removal of field heat (Gast and Flores, 1991).

The field heat (heat the product holds from the sun and ambient temperature) of a freshly harvested crop is usually high and should be removed as quickly as possible before shipping, processing or storage. Rapid pre-cooling to the product's lowest safe temperature

is most critical for crops with inherently high respiration rates. These include snap beans, cut flowers, green onions, broccoli, mushroom, sweet corn etc. (Wilson *et al*., 1995). Pre-cooling slows ageing and ripening, retards the growth of decay organisms and reduces water loss due to reduced vapour pressure (Hardenburg , 1978).

Prompt cooling helps maintain the produce at a reasonable temperature during shipment (Hall,1979). The more quickly field heat is removed from the crop, the longer it can be maintained in good marketable condition. In a tropical environment, a delay of two hours between harvesting and cooling can reduce shelf life by a whole day (Hall, 1979).

According to Gast and Flores (1991), the most common pre-cooling methods growers use in the United States are room cooling, forced air cooling, hydro cooling, top/liquid/package icing, vacuum cooling, and evaporative cooling. Many fruits and vegetables store best at temperatures slightly above freezing point (0^{o}c); others are sensitive to chilling and suffer physiological disorders if not stored at moderate temperatures (Hall, 1979).

Many tropical fruits like banana and mangoes will be damaged if stored below 7.5^{o}c (Morris 1982). Chilling injury is a major problem in postharvest handling of susceptible plant materials because it precludes the storage of many commodities at low temperatures. The problem of chilling injury is best resolved by avoiding exposure to harmful temperatures. Treatments that have shown promise include conditioning with cool temperatures before chilling, intermittent warming , hypobaric conditioning increased

atmospheric carbon dioxide during chilling and pre-treatments with calcium or ethylene (Morris, 1982).

Liu (1991c), stated that practical experience seem to show that modified atmosphere is usually less reliable and effective in terms of extending storage and preserving quality. Despite advances in the knowledge and application of controlled atmospheres, temperature regulation is still the most effective means of maintaining quality after harvest. It is by far the simplest and most direct way of retarding respiration, ripening and ageing process (Hall, 1979).

2.5.3 Storage of Mango Fruits

Storage of mangoes fruits is essential for extending the consummation period of fruits, regulating their supply to the market and also for transportation to long distances (Lui, 1991c). The mature green fruits can be kept at room temperature for about 4-10 days depending on the variety. Shelf life of fruits could be extended by pre-cooling chemical treatment , low temperature etc .The fruit could be stored for 3-4 weeks in good condition at low temperature. The problem of chilling injury can be overcome by keeping the fruit in 0.5% ventilated polythene bags (Lui, 1991c).

Mango fruits picked at the optimum stage, harvested and handled adequately and maintained at the optimum temperature and relative humidity can be stored for up to 4-6 weeks depending on the cultivar (Lui, 1991c). Low temperature is needed to reduce

metabolic activity, delay ripening and senescence, water loss, disease and insects activity and thus maintain postharvest life and quality (Liu, 1991c).

Mango, like almost all tropical fruits, is very sensitive to low temperature (Morton, 1987; Lui, 1991c). Chilling injury in mango is manifested initially as a brown discolouration on the skin, often accompanied by pitting. Chilling injury can also cause uneven ripening, poor colour and flavour and fruit becomes prone to decay. Generally, storage below 10°C causes chilling injury in all cultivars of mango, although the time for a visible symptom to appear is cultivar- dependent. Ripe fruits can tolerate lower temperatures than the less mature fruits (Lui, 1991c). The best control of chilling injury is to avoid exposure to temperatures lower than the optimum. Other measures include maintenance in modified/ controlled atmosphere and conditioning at higher temperature (35-38°C) for few hours before storage at low temperature (Liu, 1991c).

Morton (1987) stated that any temperature below 13°C is damaging to `Kent` variety of mango. In Florida this is regarded as the optimum for 2-3weeks. The best ripening temperatures therefore are 21.11°C-23.89°C. The author reported that in Australia mature-green Kensington Pride variety of mangoes have been dipped in a 4% solution of calcium chloride under reduced ethylene-free atmosphere, ripening was retarded in a week, that is, the treated fruit ripened in 20-22 days whereas the control ripened in 12-14 days (Morton, 1987).

Nakasone and Paull (1998), stated that controlled atmosphere have been tested on mangoes and indicated some possibilities: storage in atmosphere of 5% oxygen and 5% carbon dioxide is possible for 20 days, while off flavours and skin decolouration occur at 1% oxygen or high carbon dioxide (15%). Cultivator differences in response have been reported and the extension in shelf life may not be commercially viable. Modified atmosphere storage using plastic bags or wraps and waxing shows some decay in ripening off-flavours have been reported with some wraps and waxes that delayed ripening (Nakasone and Paull, 1998).

According to Brecht *et al*., (2010), temporarily holding mangoes in 10°C-14°C in storage rooms prior to loading onto marine containers or truck trailers is an important post-harvest good temperature management practice. Refrigeration capacity in mango storage rooms should be sufficient to maintain uniform product temperature (within 1°C) throughout the load. This requires both sufficient cooling capacity and adequate air circulation. Paull and Chen (2004) indicated that the storage life of mangoes can be extended by holding the fruit in an environment with 3-5% oxygen and 5-10% carbon dioxide at 7-9°C temperature and 90% relative humidity atmosphere.

Kader (2008) noted that holding mangoes in atmosphere below 2% oxygen or above 8% carbon dioxide may result in skin discolouration, greenish flesh colour and off-flavour development.

Wilson *et al.,* (1995) reported that when different commodities are stored or transported together, it is important to combine only those products that are compatible with respect to

their requirements for temperature, relative humidity, and atmospheres (oxygen and carbon dioxide).

2.5.5 Cold Chain Management

The FAO (2003b) stated that, in practice, cold chain management means often temperature maintaining at each step within the production, storage and transportation chain on inner- and inter-operation levels. It also means management of produce temperature from harvesting through to customer to maintain the quality of the product. Harvey (1978) explained cold chain management to mean the facility for maintaining proper temperature during different segments of marketing. The principal aims of cold chain management are optimization of product quality and product safety and minimization of wastage (FAO, 2003b).

In technologically advanced countries, the cold chain is well-developed but in less-developed countries few of the links in the cold chain exist and it is lack of refrigeration that is largely responsible for the enormous postharvest losses that these countries incur (Liu, 1991c). The maintenance of the cold chain is the best way to minimize all forms of deterioration after harvesting. The forms of deterioration include: weight loss resulting from wilting and limpness; softening ; unwanted ripening; bruising; colour changes; texture degradation and development of rots and moulds (Maalekuu, 2008).

Mangoes are not commonly stored for a prolonged period. The cold storage room must be maintained at the importing end and before arrangement for marketing are finalized. It is

important that the cold chain should not be interrupted. There should be fast pre-cooling, prompt placing in the cold room or cold transport container and no exposure to high temperature (Yahia, 1999).

2.6.0 Postharvest Diseases, Disorders and Pests

Mango suffers from several diseases at all stages of its life. All parts of the plant including the flower and the fruit are attacked by a number of pathogens including fungi, bacteria and algae. They cause several kinds of rot, die back, scab, necrosis, blotch, spots, mildews etc. (Morton, 1987).

Due to the acidity of raw fruits, the primary spoilage organisms are fungi, moulds and yeasts (Alzamoora *et al*., 2000b). The existence of pathogenic bacteria in fresh fruit and vegetable products has been reported by Alzamoora *et al*., (2000b) which include *Listeria monocytogenes*, and *Escherichia Coli* 0157:117 *(E. coli*). These bacteria are found in both fresh and minimally processed fruit and vegetable products.

According to Brecht *et al.*, (2010), mangoes are susceptible to many physical, physiological and pathological defects, some of the defects are of pre-harvest origin. These include anthracnose, insect damage, jelly seed, scab, scars, sunburn, misshapen and lenticels damage (Brecht *et al.*, 2010). Mangoes exhibiting these defects are usually eliminated at the packinghouse, but anthracnose symptoms do not appear until the mangoes ripen, resulting in significant losses at destination markets and consumer homes.

Brecht *et al*. (2010) identified some of the defects caused by harvesting and postharvest handling as bruising, heat and chilling injury, internal flesh discolouration, sap burn, shrivelling, uneven ripening, sunken shoulder areas and decay. Yahia (1999) also confirmed that decay is usually one of the most important causes of postharvest losses in mango. There are three primary fungal diseases affecting mango fruit, namely, alternaria rot, anthracnose and stem-end rot (Brecht *et al*., 2010).

2.6.1 Postharvest diseases of mango

Mango fruit is infected by several diseases of which the most important one is the anthracnose. It is considered the serious disease in most mango-growing regions of the world, especially, those with high rainfall and humidity (Brecht *et al*., 2010).. The disease is caused by the fungus *Collectotrichum gloeosporioides.* The infection can be on the fruit, leaves and young branches. The symptoms include small dark spots that enlarge to irregular, dark brown to black areas as the fruit ripens. The infections occur during flowering and fruit set and its severity increases with high humidity and rainfall. In addition to attack through the wounds, the organism can penetrate the fruit through the cuticle and natural openings of the fruit surface. The fungus often remains dormant on green fruits and develops as the fruit ripens and loses its natural resistance during handling and shipping. Postharvest fungicide treatments and postharvest heat treatments control and reduce incidence and severity of anthracnose (Brecht *et al*., 2010; Iqbal, 2010; Yahia, 1999). Spoilage from anthracnose has been reduced by immersion for 15min in water at 51.67^{o}C or for 5 min at 55.56^{o}C. Dipping in 500ppm maleic hydrazide for one minute, storing at 32^{o}C also retards decay but not loss of moisture (Morton, 1987).

The decay can be minimized by practising good sanitation in the field and throughout the entire harvest and post-harvest chain. It could also be reduced by rapid cooling, controlled or modified atmosphere, store and transport mangoes at the harvest safe temperature (12^{o}C) and relative humidity (85% RH) (Brecht *et al*., 2010).

The stem-end rot is a fungal disease caused by several fungi spp. which include the organism *Diplodi natalensis*. The disease usually starts at the stem end of the fruit but the fungus can attack any part of the fruit especially that which becomes injured during harvesting or handling. Infection can be reduce byleaving a stem of about 1-2cm on the fruit. Hot water treatment for about 7 minutes is effective for the treatment of the disease (Yahia, 1999).

Disorders associated with Mango Fruits

The defects that have been identified by Brecht *et al*., (2010) include: flesh breakdown, jelly seed, soft nose and stem-end cavity; and sap burn which is a brown to black discolouration of mango skin which results from latex exudate from the cut stem at harvest; mechanical damage which includes surface abrasions, cuts, skin breaks and cracks, compression, bruising and vibration. Mechanical damage increases mango susceptibility to water loss (shrivelling) and infection by decay-causing fungi. The authors further stated that, careful handling during harvesting, transport to the packinghouse, packinghouse operations, transportation to destination markets, wholesale and retail markets is the main strategy for reducing the incidence and severity of mechanical damage. Chilling injury is another disorder that affects mango. The injury symptoms include

lenticels spot (red or brown lenticel discolouration), uneven ripening, poor colour and flavor, surface pitting, grayish scald- like skin discolouration, increased susceptibility to decay, and in severe cases, flesh browning. The severity depends on the cultivar maturity and ripeness stage (riper mangoes are less susceptible). Exposure of mature-green mangoes to temperatures below 12^{o}C and exposure of partially ripe mangoes to temperatures below 10^{o}C can result in chilling injury. Avoiding exposure of mangoes to chilling temperatures throughout their postharvest life is the main strategy for reducing incidence and severity of chilling injury.

Brecht *et al*., (2010) again stated that heat injury results from exceeding the time and/or temperature combinations recommended for decay and/ or insect control, but most commonly occurs when immature mangoes are treated. Symptoms include lenticel spot, skin scald, shoulder collapse, blotchy colouration, uneven ripening and void spaces in the flesh due to tissue death. Heat injuries can be reduced by effective monitoring and management of heat treatment and prompt cooling after heat treatment. Mangoes should be protected from water loss by maintaining 90-95% relative humidity and/or using plastic film liners or bags (Brecht *et al*., 2010).

According to USAID/TIPCEE (2007), other serious diseases that infect the fruits of mango are bacterial black spot (*Xanthomonas campestris)* and powdery mildew *(Oidium mangiferae).* The bacterial black spot is a fungal disease which infects the leaves, stem and fruits of the crop. The symptoms are that the fruit lesions start as water-soaked spots which then become raised, black and crack open to exude gum. The gum is full of bacteria and

one finds a tear-stained pattern where the gum has washed down the fruit and started a number of new lesions. Control is by regular inspection, pruning and destruction of affected branches. Recommended fungicides could also be used (USAID/TIPCEE, 2007).

The powdery mildew is one of the most serious diseases of mango (Morton, 1987). The fungus affects the flowers and causes young fruits to dehydrate to fall and 20% of the crop is lost. It causes skin cracking and corky tissue especially on fruits around pea size. The disease is air-borne. Control is by regular spraying of the recommended fungicide and the removal of excess branches to improve aeration and prevent formation of micro-climates (Morton, 1987).

2.6.3 Postharvest Pests of Mango

Several insects which attack the fruit of mango include mango weevils, mango seed borer and several fruit flies. The Mediterranean fruit fly (*Ceratitis capitata*), established in ninety-five countries, is considered the most destructive among the many fruit flies in existence. Many importing countries of mango require quarantine systems for this insect (Yahia, 1999). Measures to control this pest include pre-harvest and postharvest programmes. The pre-harvest programmes include cultural practices traps, chemical treatments and the use of sterilized insects (pheromones). Crop and field sanitation should be practised by collecting and destroying fallen and damaged fallen fruits. Mature green fruits should be harvested early since they are not susceptible to their attack (USAID/TIPCEE, 2007).

The postharvest treatments include the use of chemicals, low temperatures, high temperatures and the possible use of controlled atmospheres and irradiation (Yahia, 1999). Morton (1987) stated that all mangoes for interstate shipment and for export must be fumigated or immersed in hot water at 46.11^{o}C for 65 minutes.

According to Morton (1987), eleven species of scale insects have been recorded on the fruits in South Africa. The mango stone (seed) weevils have been identified in India, South Africa and Hawaii and many parts in the tropics as major pests of mango. They are undetectable until the larvae turned their way out. It has a grayish-brown colour with high brown markings on the back. The weevil hides and blends with the bark of mango trees. It appears dead when touched or disturbed. It makes small and dark marks on the skin of green immature fruits and unsightly holes on mature and ripening fruits. Control is by frequent inspection of immature fruits, strict orchard sanitation by collecting and destroying fallen fruits and applies a full orchard cover spray with a recommended insecticide after first egg laying sites have been identified (USAID/TIPCEE, 2007).

2.7.0 Processing and Preservation of Mango

According to the FAO (2002), food processing is the set of methods and techniques used to transform raw ingredients into food or to transform food into other forms for consumption by humans or animals either in home or by food processing industry to make it attractive, marketable and often extend shelf life of the products. Food preservation, on the other hand, is the process of treating and handling food to stop or greatly slow down spoilage (loss of quantity, edibility or nutritive value) caused or accelerated by micro- organisms.

Preservation usually involves preventing the growth of bacteria, fungi and other micro-organisms as well as retarding the oxidation of fats which cause rancidity, inhibit natural ageing and discolouration (FAO, 2002).

Taylor *et al*., (2009) defined food preservation specifically as processing techniques that are used to keep food from spoiling. Spoilage is any change that makes food unfit for consumption and includes chemical and physical changes such as bruising and browning, infestations by insects or other pests or growth of micro-organisms such as bacteria, yeast and mould. Modern food processing also improves the quality of lives of allergists, diabetics who cannot consume certain types of materials; and can also add extra nutrients such as vitamins (Appiah and Kumah, 2009).

Food processing, however, through heating destroys vital nutrients such as Vitamin C in canned fruits. Preservatives that are created or added during processing to extend the shelf-life of products such as nitrites and sulphites may cause adverse health effects. Processed food ingredients which are often produced in large quantities and distributed widely often have failures and have serious consequences for many final products (Appiah and Kumah, 2009).

According to the FAO (2002), the methods of food preservation include the use of heat treatments, freezing and refrigeration, canning and bottling curing and smoking ,use of chemicals ,pulse electric field processing, vacuum packing and high pressure preservation.

Nakasone and Paull (1998) stated that considerable amount of mango fruits are processed into products such as juice ,jams ,marmalades ,pulp ,canned slices throughout the world. Yahia (1999) stated that the popular processed mango in Egypt is in the form of juice .The excellent internal quality (flavor, flesh colour) makes it an excellent material for the different processing derivatives.

Morton (1987) stated that mango fruits can be eaten in a fresh-cut form. Mango may be cut in half to the stone, the two halves twisted in opposite direction free the stone which is then removed and the halves served for eating as desert or appetizers. In Mexico, the fruit is peeled and the flesh sliced as dessert in fruit salad. The ripe flesh may be spiced and preserved in jars. Ripe mangoes may be frozen whole or peeled, sliced and packed in sugar and quick-frozen in moisture-proof containers. The sliced flesh of ripe mangoes, bathed in sweetened or unsweetened lime juice to prevent discoloration, can be quick-frozen as can-sweetened ripe or green mango puree (Morton, 1987).

2.8.0 Post Harvest Mango Fruit Treatments

Much research work has been conducted on the development of techniques and technologies to facilitate the extension of storage life of mangoes. Ben-Yehoshua (2005) noted that ripening and senescence rate in many climacteric fruits like mangoes can be affected by the control of the availability of oxygen and carbon dioxide to the fruit during respiration and that these two compounds can have a significant inhibitory effect on ability of ethylene to initiate ripening.

Based on studies with Florida mangoes ,Yahia (2006) stated that the optimal range of oxygen (3-5%) and carbon dioxide (5-10%) are required in modified or controlled atmospheres (Yahia, 2006).

Modified atmosphere packaging with or without ethylene absorbers can delay ripening and can reduce water loss of mature green mangoes (Yahia, 2006). Paull and Chen (2004) indicated that the storage life of mangoes can be extended by holding the fruit in an environment with 3-5% oxygen and 5-10% of carbon dioxide at 7ºC to 9ºC and 9% relative humidity atmosphere. Yahia (2006) , however, stated that exposure of mature green mango fruits to oxygen levels of below 2% and or carbon dioxide levels 10 % for longer than a few days induced skin discolouration, grayish or pale colour, uneven ripening and off colour development due to fermentative metabolism.

A number of studies have been conducted demonstrating that edible coatings can be used as less costly modified atmosphere package to provide some control of ripening and extending the storage life mango fruits. Baldwin (2005) noted that edible coatings can provide a suitable atmosphere for each fruit that has low oxygen and high carbon dioxide levels to reduce ripening rates in many climacteric fruits as long as coating has been designed not to create an environment that causes anaerobic respiration.

According to Brecht *et al*., (2010) waxing mango fruit by using carnauba or beeswax improves appearance increasing the natural fruit gloss and reduces water loss which causes mango to appear dull. Waxes must be applied according to label. Examples of coatings

that could be used include protein, shellac and cellulose, aloe-vera gel ,and starch. Morton(1987) also stated that coating mango with paraffin wax or fungicidal wax and storing at 20-30C delays ripening for 2 weeks and prevents shriveling but interferes with full development of colour.

The use of the compound 1-Methylcyclopropene (1-MCP), an odourless gas, has a physical similarity to ethylene allowing it to bind to the ethylene receptors in fruits thus inhibiting the normal action of ethylene and prolonging the storage life of fruit. Sozzi and Beaudry (2007) noted that the majority of current usage for 1-MCP is a supplement to proper postharvest temperature management or controlled atmosphere storage. Several studies have shown that the number of days required to ripen mangoes can be delayed by up to several days through the use of 1-MCP.

However, Lalel *et al., (*2003) observed that 1-MCP treatment of "Kensington pride" mangoes suppressed the development of aromatic volatiles during ripening. A number of studies have been conducted investigating a calcium chloride ($CaCl_2$) treatment for extending storage life of mangoes. In the studies of "Julie" mangoes (Mootoo, 1991) stated that treatments of 4% calcium chloride on mango fruits extended the shelf life of the fruit by 5 days. In Australia, mature green "Kensington pride" mangoes was dipped in a 4% solution of calcium chloride under reduced pressure (250 mm Hg) and then stored in containers at 25^{o}C in ethylene-free atmosphere. Ripening was retarded by a week, that is, the treated fruit ripened in 20 to 22 days whereas the controls ripened in 12 to 14 days.

Eating quality was equal except that the calcium treated fruits were found slightly higher in ascorbic acid (Morton, 1987).

Morton (1987) stated that gamma irradiation (30 krad) causes ripening delay of 7 days in mangoes stored at room temperature. The irradiated fruits ripen normally and show no adverse effects on quality. Most insects are sterilized when subjected to irradiation doses ranging between 50 to 750 Gy. The actual dosage required varies in accordance with the species and its stage of development. An irradiation dose of 250 Gy has been approved for certain fresh commodities such as mangoes, papayas, and lychees by the U.S quarantine authorities in the light of its efficacy in preventing adult emergency of tropical fruit flies (Kader, 2008).

According to Mitcham and Yahia (2009) hot water immersion of mango fruits is an efficient treatment used to disinfect mango fruits of fruit flies.Hot water treatment had been used by growers as quarantine treatments for *Tephritidae* fruit flies in mango and papaya fruits. Large commercial hot water treatment immersion at a temperature of 46.1^{o}C to 46.5^{o}C from 65 to 110 minutes depending on fruit weight and variety has been very effective (Mitcham and Yahia, 2009).

Hydro-cooling of fruit is done immediately after the hot water treatment. If 10 minutes is added to the heat treatment time the fruit may be hydro-cooled after a waiting period of at least 30 minutes at ambient temperature. The post-hot water treatment hydro-cooling process is done to improve the overall quality of mango fruit on the market (Mitcham and

Yahia, 2009). Despite the advantages of hot water treatment of mango fruit, many people in the mango industry in the U.S attribute the substandard quality of mango on the market to hot water protocol (Mitcham and Yahia, 2009).

The possible alternatives to hot water treatment as stated by Mitcham and Yahia (2009) are Vapour Heat and Forced-Hot Air treatments and microwave or radio frequency treatment. Vapour Heat Treatment (VHT) is a high humidity air treatment which is used to control Mexican fruit flies and papayas in Hawaii for shipment to the United States markets (Mitcham and Yahia, 2009).

Many horticultural crops are quite sensitive ethylene damage .Ethylene, a natural hormone produced by fruits as they ripen, promotes additional ripening of produce exposed to it. As fruits ripen, they become more susceptible to diseases (Bachmann and Earles, 2000). Many horticultural produce are quite sensitive to ethylene damage.. According to Reid (1995), ethylene results in acceleration of deterioration and reduced post harvest life. Also, ethylene accelerates chlorophyll degradation, causing yellowing of green tissue, thus reducing the quality of leafy, floral and immature fruits and vegetables and foliage ornamentals. Ethylene induces softening of fruits and several physiological disorders. It increases decay development and inhibits the formation of antifungal compounds in host tissue (Reid, 1995).

Kader (1986) stated that ethylene avoidance and/or scrubbing techniques are used to reduce ethylene damage. Potassium permanganate, an effective oxidation of ethylene is

commercially used as an ethylene scrubber whiles 1-MCP is also used as an ethylene action inhibitor. Ethylene levels in ripening rooms can be minimized by venting ripening rooms to the outside on completion of exposure to ethylene and the use of battery-powered forklifts instead of engine-driven units in ripening areas. The mango fruit is very susceptible to diseases and can be contaminated by bacteria, viruses and human pathogens which normally begin with field operations. In view of this Brecht et al (2010) stated among others, that, the general sanitation practices should start from the packing house. The authors advised that workers should be provided with adequate sanitation equipment and adopt strict sanitation practices like the use of gloves, soap, clean towels, etc. in the packinghouse.

Brecht *et al*., (2010) also stated that pests, rodents, birds and insects in storage and enclosed work areas should be eliminated. All water that is used in package houses should be clean and potable. Sanitizers should be used to prevent the spread of decayed or human pathogens such as *Salmonella entericia*, E. coli 0157:H7 etc. Properly sanitizing water (especially reticulated water) used in damp tanks, hydro coolers and for other purposes in the packaging house is important for delivering sound produce to the consumer Brecht *et al*., (2010).

Boyette (1995) stated that used forms of chlorine like sodium hypochlorite ,calcium hypochlorite and chlorine gas could be used to control a wide range pathogens. Bachmann and Earles (2000) stated that ozonation is a technology that can be used to sanitize produce. Boyette (1995) again stated that hydrogen peroxide can also be used as an

effective disinfectant for inhibiting the development of postharvest decay caused by a number of fungi.

3.0 METHODOLOGY

A structured survey method was used for the study. The detailed design for the study outlined the target population, the sample size, and sampling procedure, methods of data collection instruments, field study ,data processing and analysis ,discussion, conclusion and recommendations.

3.1 Target Population

The target population that was used for the study was four hundred respondents which is made up of mango farmers, fruit sellers, fruit processors (individuals and companies) exporters, Non-Governmental Organisations (NGO's), personnel from the Ministry of Food and Agriculture (MOFA) District Offices at Nsawam, Dodowa, Somanya and Odumase, all found in the study area and personnel from the Ghana Export Promotion Council (GEPC) in Accra.

3.2. Sample Size and Sampling Procedure

The study sought and selected a sample size of one hundred respondents. The stratified random sampling method was used for the study. This sampling method was used because the target population was found in certain strata, that is, the farmers, fruit sellers, exporters etc were located at different places. There was also the need to represent all the groups in the target population in the sample. The sample size was disproportionate to the units of the target population. Unequal number of males and females, farmers, fruit sellers, exporters and personnel from MOFA and GEPC were selected. The simple random

sampling method was then used to select respondents from each group. In all, seventy farmers were selected from the three districts.

Thirty farmers randomly selected from the Yilo Krobo district; thirty from Lower Manya district; and ten from the Dangme West district .In all, twenty fruit sellers were randomly selected from the three districts: ten fruit sellers from Yilo Krobo; five from Lower Manya; and five from Dangme West district. One exporter each was chosen from the three districts. Three processors were randomly chosen: two from Yilo Krobo and one from Akwapim South districts. Farmers were not chosen from Akwapim-South since mango production has not been successful this area (MOFA, 2008).

One person each was chosen from Ministry of Food and Agriculture District Offices at Odumase, Somanya and Dodowa. One person answered the questionnaire from Ghana Export Promotion Council.

3.3. Data Collection Methods (instruments)

The instruments that were used to gather data for the study were questionnaire, interviews and through observation and discussions.

3.3.1 Questionnaire

The questionnaire, that was used to solicit information for the study was given to the mango farmers, fruit processors, exporters and personnel from MOFA and GEPC. Written questions were given out through the questionnaire for the information required. This was

done to offer greater assurance of anonymity, less opportunity for bias and errors, objective views on the issues and a wider coverage of issues (Sarantakos, 1998).

3.3.1.1 Structure of the Questionnaire

The questionnaire constructed had three main parts: the introduction , personal characteristics of respondents and the main body.

3.3.1.2 Content of the Questionnaire

Different types of questionnaire were given to each identifiable group. There were, however, some similarities in the question to each group to answer.

3.3.1.2.1 Farmers' Questionnaire

The introduction gave reasons for the study and Section B of the questionnaire asked respondents about their background characteristics which included the sex, educational background, background in agriculture and the work experience as a mango farmer. Most of the questions were the select-type of objective which provided alternative answers for the respondents to choose from. Few of the questions were the supply- type of questions where respondents were asked to provide their own answers. There were a total of forty-four questions.

3.3.1.2.2 Processors' Questionnaire

The processor's questionnaire had three main sections: the introduction, respondents background characteristics and postharvest handling practices undertaken by the

processors. The questions were based on the location of the processing plant and factory, estimated losses during processing, sources of supply of fruits, sorting and grading, availability of storage facilities, sources of finance, transportation of fruits to factory, marketing of processed products, problems encountered during processing, preferable varieties for processing and reasons and suggestions as to how losses could be reduced during the postharvest period. The total number of questions was twenty-three.

3.3.1.2.3 Exporters' Questionnaire

The exporters' questionnaire also had three sections: the introduction, respondents background and postharvest handling activities by exporters. The questions were basically of the supply- type of objective questions where the respondents were asked to provide their own answers to the questions. Twenty questions were asked for responses.

3.3.1.2.4 Questionnaire for Personnel from Ghana Export Promotion Council (GEPC)

This questionnaire also had three sections, namely, the introduction, respondents background and postharvest handling questions. Again , the respondents were asked to supply their own answers to the questions asked. In all there were fifteen questions.

3.3.1.2.5 Questionnaire for Personnel from the Ministry of Food and Agriculture (MOFA)

The questions had three sections – introduction, respondents' background and post-harvest handling practices. The questionnaire asked respondents to provide answers to the average number of mango farmers in their areas of operation, location of the mango farms,

programmes put in place to reduce postharvest losses, support services to mango farmers, causes of postharvest losses and the interventions put in place to improve postharvest handling in their areas of operation. Eighteen questions were asked.

3.3.2. Interview with Fruit Sellers

A structured interview guide was used for the exercise. The reason for using this tool was that many of the respondents were illiterates and therefore needed some assistance from the interviewer to answer the questions . The structured interview determined the operation of this research instrument and allowed no freedom to make adjustments to any of the elements such as the content, wording and order of the questions. It also offered the respondents the same style, appearance, prompts etc.

The interview guide had three main sections: the introduction, background characteristics of respondents and questions based on postharvest handling of fruits for sale. Twenty-six questions were asked for responses.

3.3.3 Field Study, Observation and Discussions held with Stakeholders

The researcher visited four mango farms, Offices of Ministry of Food and Agriculture and Ghana Export and Promotion Council, stalls of fruits sellers and Factories of fruit processors. During the visits to the farms, the researcher observed the equipment and facilities used, harvesting methods, packaging equipment, method of controlling weeds, diseases, and pests and noted them. The various means by which the fruits are moved from the farms to the markets was also observed and noted . The interaction also centred on storage facilities, export of fruits and other pre-harvest practices.

The visit to the fruits stalls by the roadside also took cognisance of types of sheds and structures under which the fruits are displayed and sold, packaging equipment, means of carting fruits from the farms. Photographs were also taken of the post-harvest equipment and facilities that were in use at the time. The fruits sellers were also asked to mention some of the problems they face in the handling of the fruits and recommend how those problems could be solved or improved.

There were also some interaction with fruits processors about the efficiency of the equipment that they use, products made from the fruits, transportation etc. There was some interactions with officials from the Ministry of food and Agriculture and Ghana Exports Promoting Council.

The researcher also had interaction with the Farmers Association in the area of the study. They gave reasons for the formation of the Association, Year of formation, support from N.G.O's and Government Agencies, problems and their future plans.

3.3 .4. Data Analysis and Presentation

The raw data collected from the field was examined through sorting , editing and coding and eliminated the errors and omissions. The cleaned data was then analyzed using the Statistical Package for Social Sciences (S.P.S.S) and presented as tables , graphs and charts to frequenciesand the percentages. The qualitative aspects were discussed and summarized in the form of texts ,quotes and extracts.

4.0 RESULTS

The analysed data from the questionnaire, interviews, field study and observations have been presented in Figures 4.1 to 4.9, Tables 4.1 to 4.7 and further explained in sentences.

Background Information of Respondents

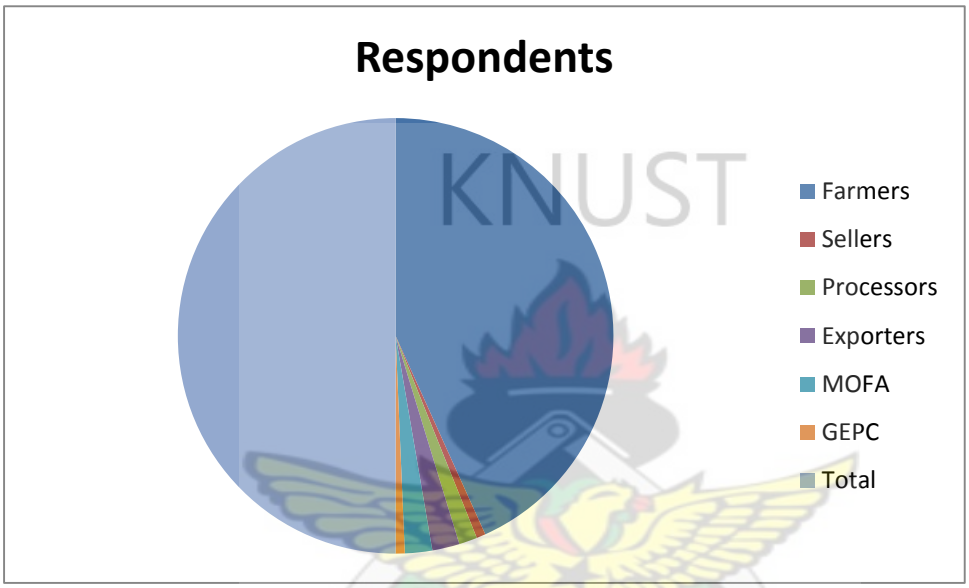

Figure 4.1: Respondents of the study

Figure 4.1 shows the category and number of respondents of the study. Seventy of the respondents are farmers. Twenty of the respondents were sellers. There were three processors. Three of the respondents were exporters of mango. One respondent each from the Ministry of Food and Agriculture (MOFA) and the Ghana Export Promotion Council.

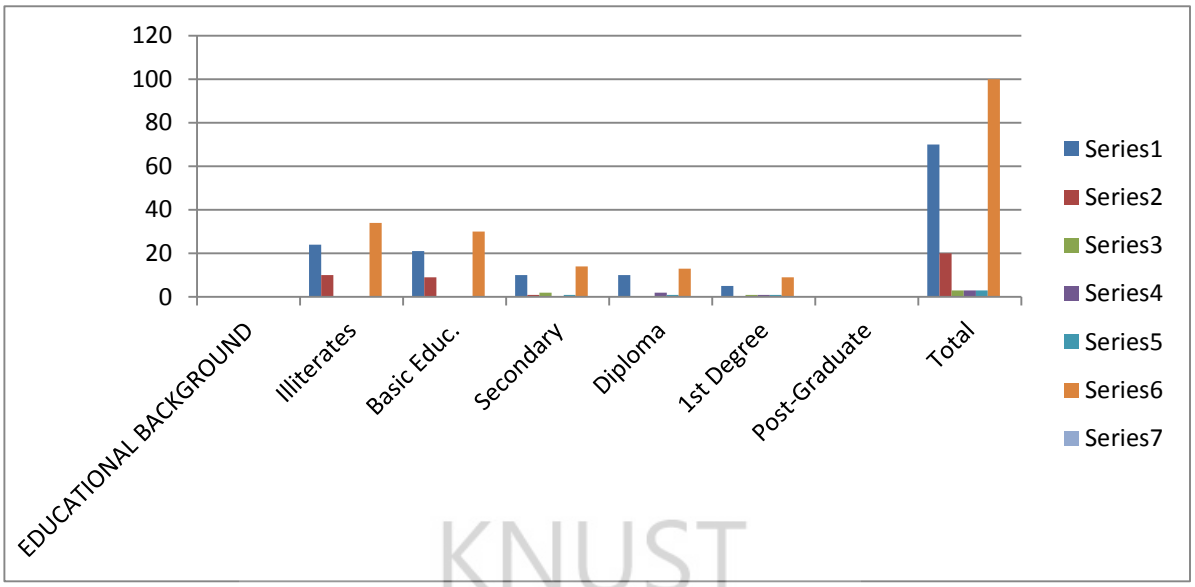

Figure 4.2 Educational Background of Respondents

The educational background of all the respondents has been represented on Figure 4.2 . It can be realized from the Figure that majority of the farmers and sellers were illiterates or have basic education. However, the processing and exporting of the fruits were dominated by respondents with Diploma or First Degree holders.

Table 4.1: Varieties of mango fruits handled by respondents

Variety	**Frequency**	**Percent (%)**
Keitt	43	**44.79**
Kent	30	**31.25**
Haden	18	**18.75**
Erwing	4	4.17
Palmer	1	1.04
Total	**96**	**100%**

The varieties of mangoes that were used by the respondents were Keitt, Kent ,Haden ,Erwing and Palmer. 44.79% of the respondents indicated that Keitt is the variety they use most. Kent followed with 31.25% and Haden 18.75%. Erwing and Palmer are represented by 4.17% and 1.04%, respectively.

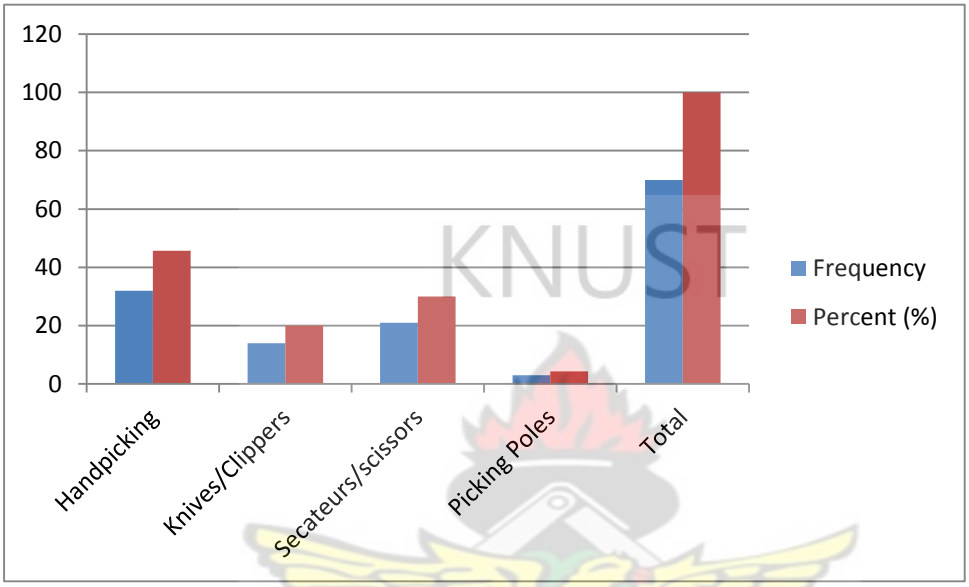

Figure 4.3 Devices used for harvesting mango fruits in the selected districts

Majority of the handlers (32 people) representing 45.70% of the respondents harvested the fruits by handpicking, 20.00% harvested by knives and clippers; 30.00% by using secateurs and 4.30% used picking poles.

Maturity indices used by farmers for harvesting mango fruits

The maturity indices farmers used to harvest fruits as indicated on Figure 4.4 shows that 35 farmers representing 50.0% used the nature of shoulders/cheeks, 17.14%,2.86% and 30% used the number of days after bloom and the colour of the fruit respectively to determine the maturity of the fruit.

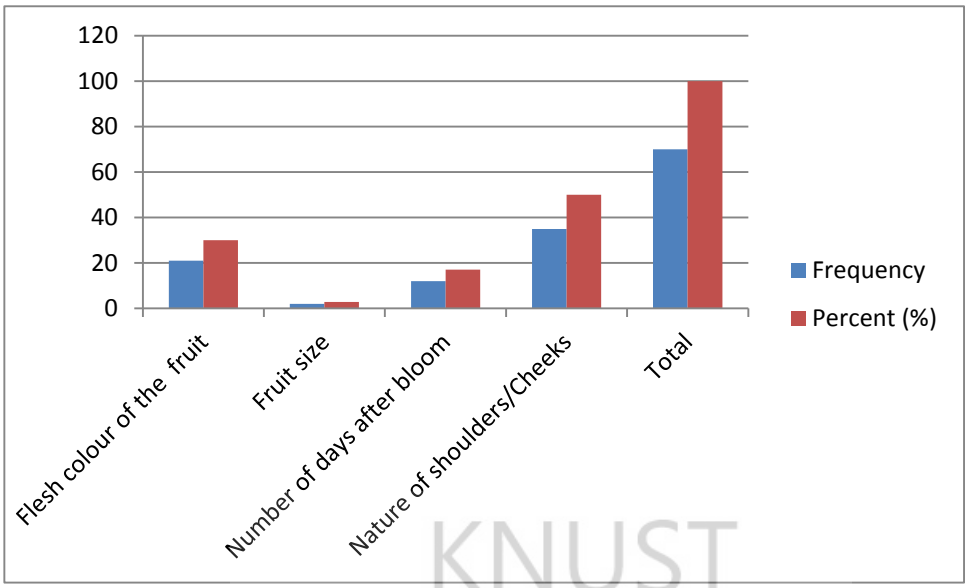

Figure 4.4 Maturity indices used by farmers for harvesting mango fruits

Table 4.2 indicates the criteria handlers used to sort out fruits. 51.04% of the respondents stated that they used the presence of the injuries on the fruit to remove the bad ones, while 21.88% used misshapen fruits and the remaining 27.08% used decay and rots to remove the bad fruits.

Table 4.2 Criteria used for sorting mango fruits

Criteria	Frequency	Percent (%)
Physical Injuries	49	51.04
Misshapen Fruits	21	21.88
Decay/Rots	26	27.08
Total	**96**	**100**

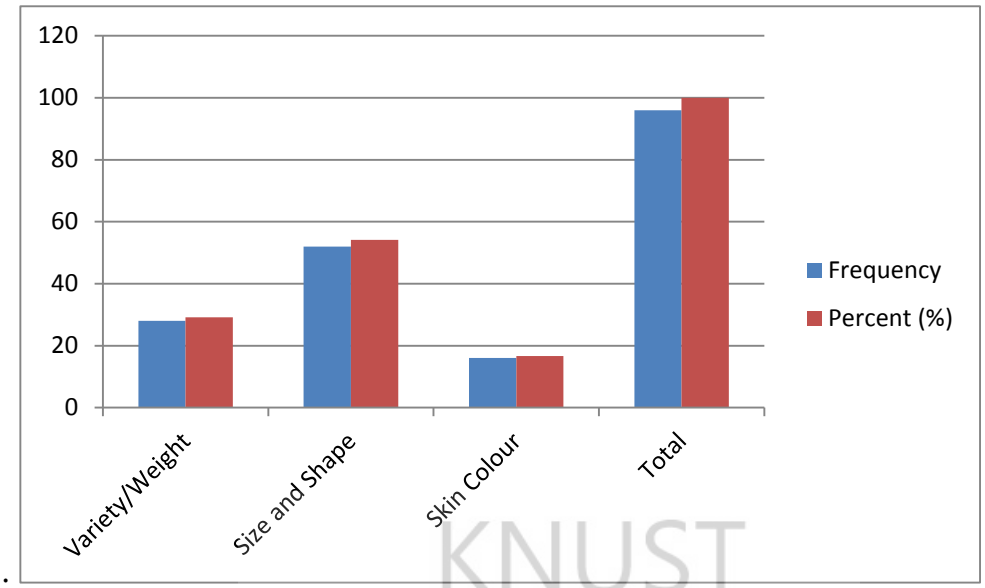

Figure 4.5 Criteria used by respondents for grading mango fruits

The respondents of the study in Figure 4.5 used weight or variety , size and shape, skin colour of the fruits for grading of the fruits. The majority of the respondents (54.14%) used size and shape , 29.17% used variety/weight and 16.66% used skin colour of the fruits.

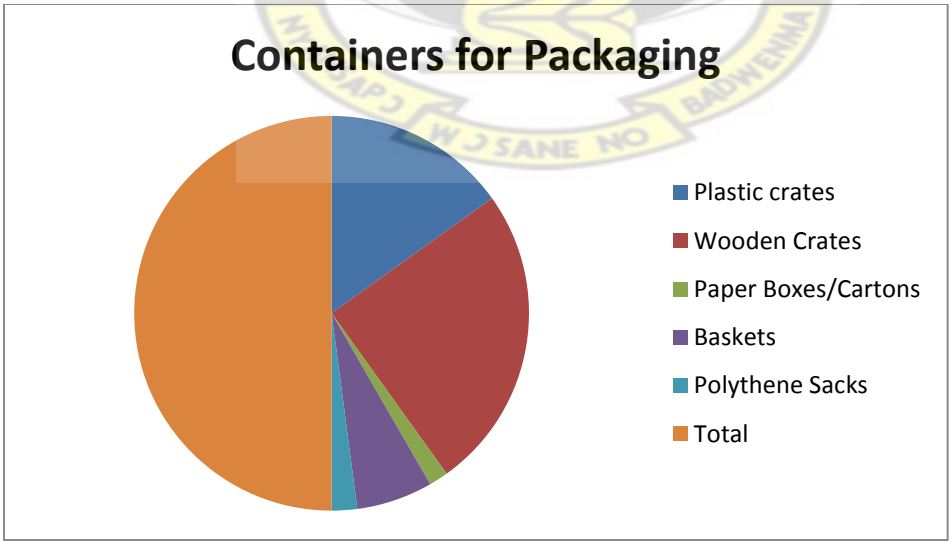

Figure 4.6 Containers used for packaging of the Mango Fruits

Figure 4.6 represents the containers respondents used for packaging mango fruits. Most of the respondents used plastic and wooden crates representing 30.21% and 50.00% respectively, While 3.13% used paper boxes/cartons, while 12.50% and 4.16% used baskets and polythene sacks respectively to package the mango fruits .

Table 4.3 Type of transport used to convey the mango fruits

Type of Transport	Frequency	Percent (%)
Trucks	**66**	68.74
Open Vans (pick-ups)	14	14.57
Tractor	**8**	8.32
Mini-buses	5	5.21
Taxis	3	3.16
Refrigerated Trucks	**0**	0.00
Total	**96**	**100**

From Table 4.3, more than sixty eight percent (68.74%) of the respondents used trucks to convey the fruits, 14.57%, 8.32%, 5.21% and 3.16% respectively used open vans (pick-ups), tractor, mini-buses, 3.16% and taxis to convey fruits. None of them used refrigerated trucks.

Figure 4.7 represents the nature of the roads used by the respondents. 66.67%, 21.18% , 4.17% and 1.04 respectively stated that the roads are in poor condition, fair condition, good condition or very good condition.

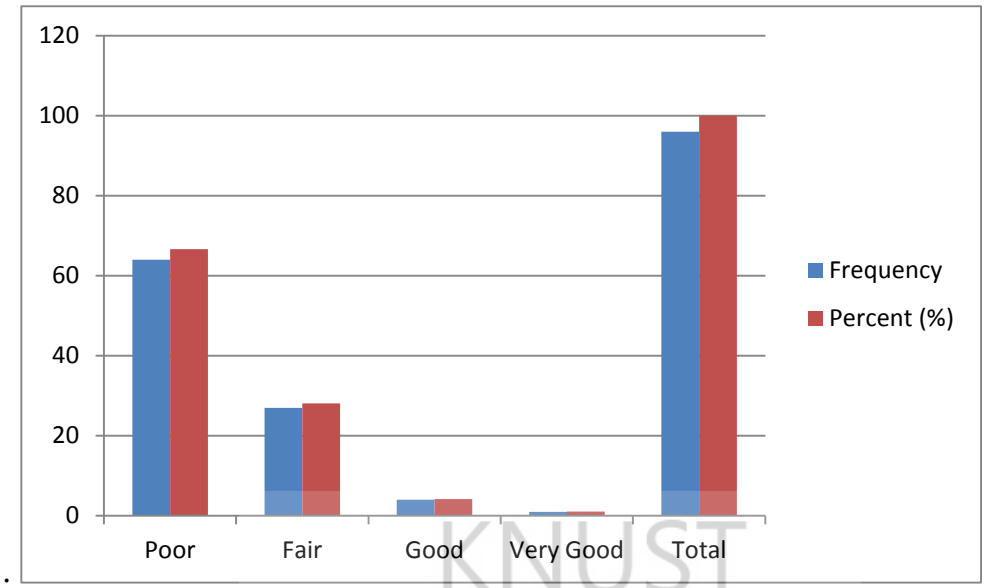

Figure 4.7 Nature of roads used by Mango handlers

Table 4.4 Storage facility used by mango sellers

Facility	Frequency	Percent (%)
Farm Sheds	**68**	70.83
Open Air Sheds	27	28.13
Cold Storage (Refrigeration)	**01**	1.04
Total	**96**	**100**

Table 4.4 shows the storage facilities used by the respondents to store the fruits. Only one respondent representing 1.04% had access to cold storage facility. With the other handlers, 70.83% used farm sheds and 28.13% used open-air sheds to keep the fruits for some time.

Table 4.5 Problems of transportation faced by stakeholders in the mango industry

Problem	Frequency	Percent(%)
Overloading	25	26.04
Physical Injuries	28	29.17
Poor Road Network	10	10.41
Delays	33	34.38
Total	96	100

The problems respondents face when transporting mango fruits have been shown on Table 4.5. 26.04% of the stakeholders responded that they had problems with overloading of the vehicles, 29.17% indicated that the fruits got physical injuries while 10.41% stated that the poor road network affected the quality at which the fruits during transportation. 34.38% of the respondents stated that unreliable transport caused delays in conveying the produce.

Table 4.6 Availability of processing plant

Responses	Frequency	Percent (%)
Not Available	94	94.00
Few Available	6	6.00
Available	0	0.00
Total	**100**	**100**

Table 4.6 represents the availability of processing plant in the area of study. It was realized that the processing plants are not available in the study area as indicated by the high percentage (94%) of the respondents.

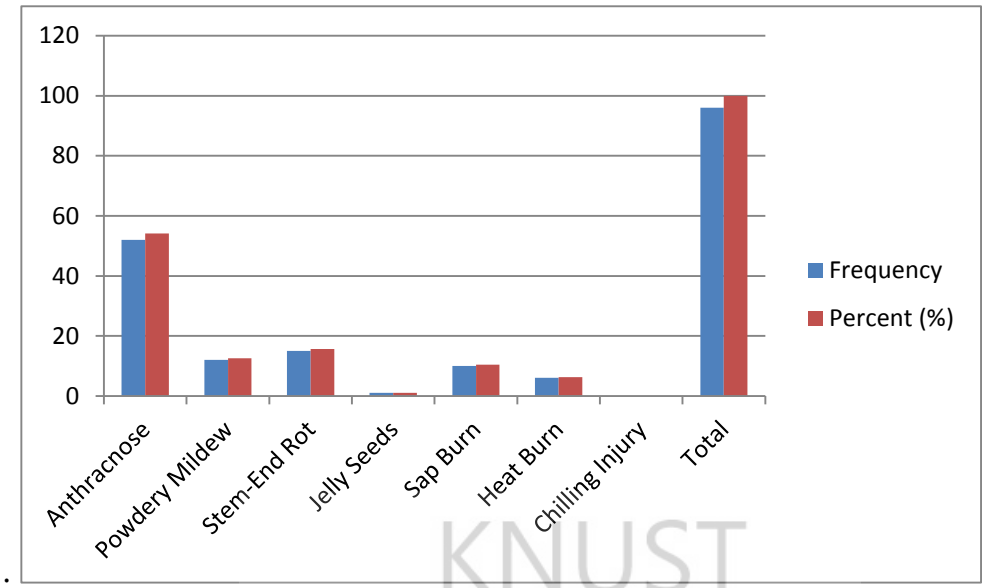

Figure 4.8 Postharvest Diseases and Disorders of Mango

The Figure 4.8 below represents the postharvest diseases and disorders that affected mango fruits. Majority of the respondents representing 54.17% stated that anthracnose is most prevalent postharvest disease that affect ripe mango, 12.50% stated powdery mildew, 15.62% stated stem-end rot. One of the respondents indicated that jelly seeds are encountered while 10.42% stated sap burn and 6.25% stated heat burn. None of the respondents stated chilling injury as a disorder .

Table 4.7 Postharvest pests of mango

Pests	Frequency	Percent (%)
Mealy bugs	16	6.25
Stone Weevils	**40**	**41.67**
Fruit Flies	**48**	**50.00**
Mango Thrips	2	2.08
Total	96	100

Table 4.8 indicates postharvest pests of mango. 6.25% which represents 6 respondents stated that they encounter mealy bugs. Stone weevils and fruit flies had 40 and 48 respondents out of the total of 96 respondents. Only 2 respondents who represent 2.08% of the respondents stated that mango thrips were the pests they encounter.

Table 4.8 Post harvest treatments of mango fruits

Treatment	Frequency	Percent (%)
Wax Coating	0	0.00
Hot Water Treatment	**0**	0.00
Edible Coating	1	1.04
Chemical Treatment	0	0.00
No Treatment	**95**	**98.96**
Total	**96**	**100**

Table 4.8 represents postharvest treatments respondents give to mango fruits . 98.96% of the respondents stated that they did not treat the mango fruits after harvest. Only one respondent stated that edible coating was applied to the fruits.

5.0 DISCUSSION

5.1 Harvesting of Fruits

From the study, it was realized that majority of the farmers harvested snapping from the stem by hand .Other respondents use secateurs and knives . Other respondents use secateurs and knives. This is confirmed by the FAO (2003a) which stated that the commonly used tools for harvesting fruits are secateurs, knives and pole-mounted picking shears. Iqbal (2010) stated that harvesting of mango should be done, when possible, by hand from the ground by snapping the mangoes from the stem. Optimum harvesting involves using secateurs and cutting the stem 2-3cm away from the fruit and the latex allowed to drain away (Iqbal, 2010). When hand harvesting is not possible, a long pole with a cutting blade and a small bag under the blade to catch the fruit is used. Mangoes should never be knocked from the tree, dropped or thrown to the ground since they would be bruised. The impact would result in decay, poor quality and attract low price in the market (Iqbal, 2010).

The study also indicated that most farmers picked the fruits at the early hours of the morning. Earlier workers such as Yahia (1999) had recommended that fruits should be picked at the early hours of the morning when temperatures are not high and kept under shade. This would reduce field heat and respiration in the fruits and thus maintain it for longer periods.

It was realized from the study that the maturity indices used by the farmers are the number of days after bloom, fruit shape and size. These indices are being used by the farmers because they seem easy to use and at the same time, most reliable. The farmers who use

the fruit flesh colour have been trained by MOFA officials and some non- governmental organizations. This is supported by Kader (2008) who stated that the maturity level of fruit is critical to the development of good flavour quality in the fruit. It is important that individuals have adequate knowledge about the indices used to harvest fruits in order to harvest fruits at the right time which ultimately affect the storage life of fruits. Harvesting fruits with an appropriate devices like knives and secateurs control latex flow which causes sap burn on the skin of the fruit .This assertion is supported by Yahia (1999).The farmers who used the flesh colour as a harvest index is consistent with Kader (2008) who stated that the flesh colour is the most consistent criteria used across all cultivars though the practice is destructive.

5.2 Sorting and Grading of Mango Fruits

The study revealed that most of the farmers sorted the mangoes by removing fruits that had physical injuries such as cuts and bruises, evidence of decay and misshapen fruits , probably because they were easy to use. Grading of the fruits was done by variety, uniform size and shape and skin colour by farmers and fruit sellers. The exporters and some farmers use weight and size of the fruits. These practices are in agreement with Yahia (1999) who stated that mango could be categorized into different and uniform groups either on the basis of size or weight.

It was, however, realized that no chemical was applied at the grading point to control anthracnose and fruit fly. The practice is not consistent with Dirou (2004) who stated that before grading, mango fruits are sprayed with a fungicide to control the anthracnose

disease and an insecticide to control fruit fly as the fruit ripens. Fruits are not usually graded into quality grades as 1st grade, 2nd grade and 3rd grade as stated by Dirou (2004). Fruits were graded by size and shape ,variety and weight and skin colour by most farmers and could be the most preferable by consumers.

5.3 Packing and Packaging of Mango Fruits

The packaging materials and containers that were identified in the study were baskets, wooden and plastic creates, paper boxes (cartons) and polythene sacks. Fruits that were meant for the local markets were put in large cane baskets, those for distant markets were put in wooden and plastic crates and those for export were put in paper boxes (cartons) the use of wooden crates and baskets. This is supported by Yahia (1999) who stated that the type of packages commonly used for mango are paper boxes or cartons which are used in Mexico, Malaysia, Thailand, Singapore and the Philippines and accepted internationally. The re-use of packages is common. Packages used are big and heavy and result in significant fruit injury because of weight compression of upper fruits. Anwar *et al*. (2008) also reported that most mangoes packed in wooden crates which apart from causing physical injuries and bruises during transit are being restricted in international markets on account of quarantine concerns and special disinfestations treatments necessary for international trade. Exporters in the study pack mangoes in one piece paper boxes in a single layer. This practice is also reported by Yahia (1999) that mangoes packaging commonly used in the world is usually one piece cartons.

Vacuum and Modified Atmosphere Packaging which maintain the quality and storage life of fruits as reported by Cantwell (2001) are not used by exporters and other handlers. This might be due to lack of knowledge about these technologies and facilities. Ventilation holes, however made on paper boxes by the exporters allows air flow during cooling, shipping and storage without compromising strength as reported by (Brecht *et al.*,2010)

5.4 Transport and Transportation of Fruits

Ideally, transport would take fresh produce from the grower directly to the consumer. The cost of transport contributes significantly to the price paid by the consumer and sometimes exceeds the value of the raw produce (FAO, 1989). A careful analysis of the data presented revealed that the final quality of mango to the consumer is affected by the type of transport used to convey the produce. The handlers mostly use trucks which are not equipped with good refrigeration systems. The fresh fruits are therefore exposed to high temperature during transport of fruits which could soften the tissue of the fruits and bruise easily causing rapid microbial deterioration (Yahia,1999). The results also agree with the FAO (2003b) that stated that transportation is a serious problem faced by fruit growers in developing countries where vehicles are used to transport bulk raw fruits to markets. Kader (2005) also reported the effect of bad roads on the transportation of the mango fruits. The author stated that in most developing countries, roads are not adequate for proper transport of horticultural crops. The mechanical injuries caused to fruits due to bad roads as stated by the handlers in this study agrees with Liu(1991b) who reported that vibration and impact caused by bad roads during transportation may cause bruises and other types of mechanical injuries. But the respondents in the study used the trucks and tractors because

they coped with the bad roads , and were more affordable. Refrigerated trucks and vans were found expensive and unavailable for farmers to use.

Mitcham and Yahia (2009) also stated that the trucking has been adopted as the most convenient mode of transport. However, trucks were not found suitable for transporting fruits as they exert a lot of pressure on the them and not combine well with temperature control devices. Yahia (1999) suggested that non-refrigerated cards and trucks should be covered adequately to protect fruits from wind and high temperature. In warm weather, transport should be done at night when the temperature is much lower. Malik and Mashar (2007) reported that maximum fruit loss of mango occurs at the stage of harvest and transportation from orchard to the wholesaler.

5.5 Storage of Mango Fruits

Storage of produce under the appropriate conditions extend the shelf life and the usable period of the produce. Data collected from the respondents indicate that they did not have access to cold storage facilities. The farmers, fruit sellers and exporters rely on natural cold air. They usually spread fruits under shade trees and airy places. These practices are supported by Liu (1991c) who reported that in developing countries the common storage facilities are air-cooled common storage houses which rely on natural cold air. Storage in a cold controlled environment is not possible because of the cost and the lack of infrastructural development and of maintenance and managerial skills (FAO, 1989).The farmers might have stored the fruits, possibly, awaiting transportation and sale to consumers.

However, one large-scale processor of mangoes stated that the enterprise had access to adequate cold storage facilities. Most perishable fresh produce, like mango, cannot be stored without refrigeration, but the possibilities for extending the storage life of even most durable fresh produce under ambient conditions are limited. Karen and Flores (1991) stated that cold storage slows down produce respiration and breakdown by enzymes, slows water loss and wilting, slows down the production of ethylene (the natural ripening agent) and "buy time" for proper marketing. It is therefore important that this technology is adopted by those engaged in the mango business.

5.6. Processing of Mango Fruits

The study revealed that only about 20% of farmers were interested in going into the processing of mango fruits. The reason might be due to the high capital investment involved. Farmers have indicated that they are not able to access credit from the financial institutions. (MOFA, 2008).

According to Nakasone and Paull (1998), most of the mangoes are marketed in the fresh state for consumption as a dessert fruit. A small amount is processed into various products such as mango juices, jams and caned slices. This condition is also prevailing in the study area.

Morton (1987) stated that mango fruits can be eaten in a fresh-cut form. Mango may be cut in half to the stone, the two-halves twisted in opposite direction, freeing the stone which is then removed and the halves served as dessert in fruit salad in Mexico. Among the

limitations to shelf-life of fresh-cut product are microbial spoilage, dessication, discolouration or browning, bleaching, textural changes and development of off-flavour or off-odour. Processors in the study area may not be aware of this technology and therefore, are not using it.

5.7 Postharvest Diseases and Disorders

Mango is a tropical fruit crop which is infected by many diseases and disorders because of the perishable nature. The common disease identified at all levels of handling by the respondents was the anthracnose. The incidence of this disease in the study area is supported by Nakasone and Paull (1998) who stated that this disease is perhaps the most important disease in all mango–growing areas. The symptoms include small dark spots that enlarge to irregular, dark brown to black areas as the fruit ripens. Brecht *et al.,* (2010) reported that that the fungus often remains dormant on green fruits and develops as the fruit ripens and loses its natural resistance during handling and shipping. Powdering mildew and stem-end rot also infect mango fruits. According to Yahia (1999) stem-end rot is a fungus that can attack any part of the fruit especially the part that becomes injured during harvesting and handling. This is in agreement with some of the respondents, especially, the fruit sellers who encounter this disease at the ripening stage of the fruit. Hot water treatment for about seven minutes is effective for the treatment of the disease (Mitcham and Yahia, 2009).

The disorders that affect the fruits as indicated by the respondents are sap-burn, heat damage and jelly seed. Brecht *et al.,* (2010) reported that sap-burn is a brown to black

discolouration of mango skin which results from latex exudates from the cut stem at harvest. The latex released immediately upon harvesting causes injury over a period of an hour. Harvesting mangoes in the morning helps to minimize sap injury. Heat injury results from exceeding the time and/ or temperature combinations recommended for decay or insect control but most commonly occurs when immature fruits are treated. Symptoms include lenticel spot, skin scald, uneven ripening and void spaces in flesh due to tissue death. Heat injuries can be reduced by prompt cooling after heat treatment. Jelly seed is a disorder which was identified by fruit processors when the fruits were cut. The jelly seed is a physiological disorder caused by disintegration of the flesh around the seed into a jelly-like mass (Brecht *et al.*, 2010) . The authors further stated that these disorders could be reduced by increasing fruit calcium content via proper pre-harvest calcium applications. Yahia (1999) agreed to the prevalence of these defects in the fruit.

5.8 Postharvest Pests of Mango

The respondents stated that the common fruit pests include fruit flies, stone weevils and mealybugs. Yahia (1999) reported that the fruit flies are established in ninety-five countries and it is considered as a very destructive insect pest of mango. USAID\ TIPCEE (2007) also stated that several fruit flies render fruits useless for human consumption. The adult female punctures the outer wall of the mature fruits and deposits the eggs inside the mesocarp of the fruit. After hatching the larva feeds on the pulp of the fruit which appears normal from the outside but drops down finally. Crop and field sanitation should be practiced by collecting ad destroying fallen and damaged fallen fruits. Mature green fruits should be harvested early since they are susceptible to pests attack. The mango stone

weevils were identified when the fruits were cut. They are undetectable until the larvae turned their way out. The weevil hides and blends with the bark of mango trees. It appears dead when touched or disturbed. Control is by strict farm sanitation by collecting and destroying fallen fruits and spraying recommended insecticide. These measures have been suggested by Morton (1987) and USAID/ TIPCEE (2007) who recommended that the pests should be controlled by using these methods.

5.9 Technological Treatments given to enhance Shelf Life of Mango Fruits

Through the questionnaire to the farmers, processors, exporters and the interview questions to the fruit sellers, only one of the respondents stated that they were using edible coating to enhance the shelf-life of mango. The edible coatings on the mango fruit could enhance its gloss and shelf-life (Baldwin, 2005).

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

The postharvest handling practices that were used as parameters for the study were harvesting methods and maturity indices for harvesting mango fruits, sorting and grading, pre-cooling, packing and packaging, transport and transportation, processing and preservation, storage, control of postharvest diseases and pests, technologies used to enhance the shelf-life of fruits and sanitation practices.

It was found out that harvesting fruits with the appropriate methods, maturity indices and tools could reduce mechanical injuries, diseases and pests infestations. The use of proper sorting and grading methods at the farm level reduce the level of pathogens that may attack the fruits and injuries suffered by mangoes at the sales point. The use of appropriate packaging materials and packing methods protect the mango fruits from mechanical damage and poor environmental conditions such as overheating and microbial spoilage. It was found out that most handlers of the mango fruits used trucks without refrigeration. This exposed the fresh fruits to high temperatures which led to softening. This caused the fruits to bruise easily leading to rapid deterioration of the fruits. The poor road network of the study area also had negative effects on the fruits. The unavailability of cold storage facilities in the study area also negatively affected the proper handling of the fruits. The few processing plants in the area led to the high losses of the fruits which could not be sold immediately after harvest. It was also observed that the high incidence of postharvest diseases such as anthracnose and stem- end rot caused significant losses of the fruits. Pests such as fruit flies and mango stone weevils also caused a reduction in the quality of the

mango fruits offered for sale at the market. Apart from cleaning and washing fruits with water no other treatments like wax-coating, fungicide application and heat treatments were undertaken to control diseases and pests. Most handlers continued to using old crates and boxes to package the fruits and these could be sources of infection for the fruits. Finally, it was discovered that the farmers, exporters, processors had been receiving training and education through the technical personnel from the Ministry of Food and agriculture and Non-Governmental Organizations but the emphasis had been more on the pre-harvest handling of the crop. Fruit sellers who happen to have longer periods of handling had never received any form of training.

6.2 Conclusion

The postharvest handling practices that could enhance the quality of mango and increase its shelf-life include harvesting methods and maturity indices, sorting and grading, pre-cooling, packing and packaging, transport and transportation, processing and preservation, cold storage facilities, control of postharvest diseases disorders and pests, the use of acceptable produce technologies and proper sanitation practices. The effective use of the appropriate postharvest practices would enable the handlers offer consumers the best quality produce, increase the shelf-life of fruits, reduce the perennial losses and increase the income of the handlers.

6.3 Recommendations

In view of the afore-mentioned problems identified during the study, the following recommendations are suggested for implementation and adoption:-

- There is the need for continuous education and training for all the stakeholders in the mango business – farmers, fruit sellers, fruit processors and exporters.
- Adequate storage facilities should be put in place in the major areas of production to store the produce. These include pre-cooling and cooling facilities, cold transport containers that are essential for export.
- Adequate financial assistance should be given to, especially, the growers and others, to venture into the processing of the fruits to help stabilize prices and to remove excess produce from the markets.
- Producers should be given the necessary help and education to meet export criteria.
- There should be a mass diseases and pests control programme to control especially the fruit flies and stone weevils which cause massive loss of fruits every growing season.
- The transportation system in the growing communities should be improved to reduce losses. Transport of mango fruits should be done, preferably, in refrigerated vehicles.

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APPENDICES

APPENDIX I

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

INSTITUTE OF DISTANCE LEARNING

DEPARTMENT OF HORTICULTURE

QUESTIONNAIRE FOR MANGO FARMERS

INTRODUCTION

This is a study being undertaken by an M.Sc. Post Harvest Technology Student of the Institute of Distance Learning, Kwame Nkrumah University of Science and Technology on the Evaluation of the Post Harvest Handling of Mango Fruits (Mangifera indica L.) in Ghana. The purpose of the study is to evaluate the post harvest handling of mango fruits in the Akwapim-South, Dangme-West, Lower-Manya and Yilo Krobo Districts of Ghana. The questionnaire is basically for academic proposes only and respondents are assured of privacy and confidentiality. Thank you. Contact Line 0208846378.

Please tick (√) the appropriate box and fill in the blank space where appropriate.

SECTION A: BACKGROUND CHARACTERISTICS OF RESPONDENTS

1. Sex (a) Male [ ] (b) Female [ ]
2. Educational Background

   (a) Basic Education[ ] (b) Secondary Education[ ] (c) Diploma[ ]

   (d) First Degree[ ] (e) Post-graduate[ ] (f) Others (specify)……

3. Background Education in Agriculture

(a) Nil [ ] (b) Basic [ ] (c) Secondary [ ] (c) Diploma[ ]

(e) First Degree [ ] (f) Post-graduate [ ]

SECTION B: LAND ACQUISITION AND PREPARATION

4. Which of the following factors did you consider as the most important factor for selecting the site for your farm?

(A) Fertility of the soil (b) Nearness to residence (c) Accessibility

(d) Price of the land (e) Availability of water (f) Good road network

(g) Availability of labour

(h) Land close to other mango farms. Rank them 1, 2, 3, 4, 5, …….in order of preference

5. What is the average size of your farm?

(a) 1-10 acres (b) 11-20 acres (c) 21-50 acres

(d) 51-100 acres (e) above 100 acres

6. What method do you use to prepare your land?

(a) slash and burn (b) ploughing and harrowing

(c) use of agro-chemicals to spray (d) bullock ploughing

SECTION C: SELECTION OF VARIETIES FOR CULTIVATION

7. What variety/varieties have you planted on your farm?

   (a) Keitt (b) Kent (c) Haden (d) Palmer (e) Erwing

8. What reason(s) did you consider for your choice?

   (a) Fast growth rate (b) Bigger fruit size

   (c) Longer shelf-life (d) well-patronised by consumers

   (e) Resist handling pressure (f) Resistant to diseases and pests

   (g) Meet export standards (h) Higher yield per tree

SECTION D: CULTURAL PRACTICES ON MANGO FARM

9. What method(s) do you often use to control weeds on your farm?

   (a) use of Agro-chemicals (b) Growing of cover crops

   (c) use of slashers (d) weeding by human labour (e) intercropping

10. What common pests do you encounter on your farm?

    (a) mealybugs (b) scale insects (c) fruit flies

    (d) mango stove weevils (e) mango thrips

11. Which of (No.10) causes the greatest damage?

    ……

12. What method do you use to control the pests?

    (a) use of chemicals (b) cultural methods – pruning and scouting

    (c) biological methods (d) physical methods – steam of water, handpicking etc.

13. What common diseases are found on your mango farm?

    (a) anthracnose (b) bacterial spot (c) powdery mildew (d) stem-end Rot

    Which of them causes the greatest harm?

    …….

14. Which of these methods do you use to control the diseases?

    (a) cultural methods – pruning, burning of diseased plants etc.

    (b) Chemical methods – fungicides, nematicides etc.

15. What are the sources of infections?

    (a) Local mangoes

    (b) The weather – rainfall and winds

    (c) Related crops – oranges, pawpaw etc.

    (d) transport, harvest and packaging materials

SECTION E: MEMBERSHIP IN MANGO FARMERS ASSOCIATION

16. Are you a member of the Mango Farmers Association?

    (a) Yes (b) No. If yes, how many members are in the association? …

17. What facility/support does the Association provide you?

    (a) soft loans (b) farm implements (c) fertilizers, chemicals etc.

    (d) Education and Training

18. What type of support does your Association receive from the Ministry of Food and Agriculture and other N.G.S.s?

    (a) Education and Training (b) Provision of farm inputs

(c) Relay of information (d) Facilitation of loans from banks

(e) Any other …….

19. Mention any N.G.O. that gives assistance to your Association

(a) …… (b) ……..

SECTION F: HARVESTING OF MANGOES

20. Have you had any form of training in harvesting mangoes?

(a) Yes (b) No

21. What measures do you put in place before harvesting?

(a)…….

(b)……

(c) ……..……

22. Which of the following maturity indices do you use for harvesting mango?

(a) Flesh colour of the fruit

(b) Fruit size and shape

(c) Number of days after bloom

(d) Nature of shoulders/cheeks of fruits

23. What method do you use to harvest mangoes?

(a) Handpicking (b) use of knives/chippers

(c) shaking (d)use of secateurs/scissors

(e) use of picking poles (f) any other method …….

24. At what period of the day do you harvest the fruits?

(a) early mornings (b) late mornings (c) afternoons (d) evenings

25. How many times do you harvest fruits in a season?

(a) once (b) twice (c) three times (d) when necessary

SECTION G: HANDLING OF HARVESTED FRUITS

26. Which of the following problems do you encounter during harvesting of mango fruits?

(a) inadequate labour (b) delay caused by buyers

(c) no proper place to keep fruits

(d) mechanical injuries to fruits

27. What criteria do you use to sort fruits?

(a) physical injuries (b) misshapen fruits (c) decay and rots

28. Do you have packing houses where harvested fruits are kept?

(a) Yes

(b) No. If no, where do you keep them? (a) under trees (b) farm sheds

(c) open-air sheds (d) refrigerated (cold) rooms

29. What containers do you use for packaging mango fruits?

(a) Paper cartons (b) Baskets (c) Plastic crates

(d) Wooden crates (e) Polythene sacks

30. How are the produce transported from the farm to the point of sale?

(a) use of refrigerated vans/trucks (b) use of cargo trucks

(c) open buses (pick-ups (d) taxis (e) use of tractor

31. State some of the problems you encounter during transportation.

i……..

ii……..

iii……..

32. How would you classify the nature of the roads from your farm?

(a) poor (b) fairly good (c) good (d) very good

33. What do you do with excess produce?

(a) for processing (b) sell cheaply

(c) dried for future use (d) discard them

34. Are there enough processing factories in your area to process fruits?

(a) None (b) Yes (c) Few

35. Do you export some of the harvested fruits?

(a) Yes (b) No

36. At what stage of handling do you encounter the highest losses of fruits?

(a) during harvesting (b) packaging (c) transportation

(d) storage (e) processing

37. State some ways by which post-harvest losses could be reduced in the mango business.

i……..

ii……..

iii……..

38. How are the fruits marketed?

(a) direct sales to consumers (b) through market women

(c) to processors (d) to sold exporters

39. Which of the following disorders do you encounter after harvest?

(a) sap burn (b) heat damage (c) jelly seeds (d) sun burn.

40. What type of treatment do you give to fruits after harvesting?

i……..

ii……..

iii……..

41. What criteria do you use to grade fruits after harvesting?

(a) variety and weight (b) size and shape (c) skin colour of fruit

42. Which postharvest disease do you encounter?

(a) anthracnose (b) stem-end rot (c) powdery mildew (d) black spot

43. Which postharvest pests do you encounter?

(a) fruit flies (b) mango stone weevil (c) mealybugs (d) mango thrips

44. Are you aware of any technology that is used to control postharvest pests and diseases?

(a) Yes (b) No. If yes, mention some of them

…….

APPENDIX II

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

INSTITUTE OF DISTANCE LEARNING

DEPARTMENT OF HORTICULTURE

INTERVIEW GUIDE FOR FRUIT SELLERS

INTRODUCTION

This is a study being undertaken by an M.Sc. Post Harvest Technology Student of the Institute of Distance Learning, Kwame Nkrumah University of Science and Technology on the Evaluation of the Post Harvest Handling of Mango Fruits (Mangitera in dica L.) in Ghana. The propose of the study is to evaluate the post harvest handling of mango fruits in the Akwapim-South, Dangme-West, Lower Manya and Yilo Krobo Districts of Ghana. The questionnaire is basically for academic proposes only and respondents are assured of privacy and confidentiality. Thank you. Contact Line 0208846378.

Please tick (√) the appropriate box and fill in the blank space where appropriate.

SECTION A: BACKGROUND CHARACTERISTICS OF RESPONDENTS

1. Sex (a) Male [ ] (b) Female [ ]
2. Educational Background

   (a) Basic Education[ ] (b) Secondary Education[ ] (c) Diploma[ ]

   (d) First Degree[ ] (e) Post-graduate[ ] (f) Others (specify)……
3. Background Education in Agriculture

   (a) Nil [ ] (b) Basic [ ] (c) Secondary [ ] (c) Diploma[ ]

   (e) First Degree [ ] (f) Post-graduate [ ]

4. Where do you sell the mango fruits?

   (a) By the roadside (b) In the open market (c) In refrigerated shops

SECTION B:

5. Who are the main suppliers of the fruits?

   (a) Commercial farmers (b) Small-scale farmers (c) Middlemen/Traders

6. In what containers do you use to transport the fruits?

   (a) Baskets (b) Wooden crates (c) Plastic crates (d) Paper cartons

   (e) Polythene sacks

7. What diseases attack fruits during sales?

   (a) anthracnose (b) black spot (c) powdery mildew (d) stem-end rot

8. Which of the following criteria do you use to sort out the fruits?

   (a) Physical injuries (b) Misshapen fruits (c) Softened and Rotten fruits

9. What criteria do you use to grade the fruits?

   (a) variety (b) uniform size and shape (c) skin colour of fruits

10. What type of transport do you use to cart the fruits?

    (a) Cargo truck (b) Open vans (pick-ups) (c) Tractor

    (d) Taxis (e) Refrigerated vans/trucks

11. Where do you store fruits during sales?

    (a) Farm sheds (b) Open-air sheds (c) Packinghouse /Refrigerated houses

12. How do you classify the road network of the area you buy fruits from?

    (a) Poor (b) Fairly good (c) Good (d) Very good

13. State some of the problems you encounter in handling fruits?

    i……..

    ii……..

    iii……..

14. What is the commonest variety of mango you handle in selling mango fruits?

    (a) Keitt (b) Kent (c) Haden (d) Erwing (e) Palmer

15. What is the reason for selling the variety in Q14?

    (a) Attractive colour and shape (b) Sweet taste (c) Big size (d) Long shelf life

16. Do you give any form of treatment to the fruits you handle?

    (a) Yes (b) No. If yes, state some of the treatments you give

    i…… ii…… iii……

17. Are there enough processing plants in the area you sell the fruits?

    (a) None (b) Yes (c) Few

18. What pests have you identified in handling fruits?

    (a) Fruit flies (b) Mealybugs (c) Stone weevils (d) Mango Thrips

19. What postharvest diseases have you seen on mango fruits?

    (a) Black spot (b) Anthracnose (c) Powdery mildew (d)stem-end rot

20. What type of treatments do you give fruits that are attacked by the diseases and pests?

    (a) sorted and discarded (b) applying chemicals

    (c) No action (d) put into refrigeration

21. How many years have you been in mango trade?

(a) 1-5 years (b) 6-10 years (c) 11-20 years (d) above 20 years

22. Do you belong to any Mango Sellers Association?

(a) Yes (b) No. If yes, how many are you? ……

23. Have you received any form of training in handling mango fruits by the Ministry of Agriculture or by an N.G.O?

(a) Yes (b) No. If yes, how many times? ……

24. At what stage of handling do you encounter the heaviest losses?

(a) Transportation (b) Storage (c) Sorting and grading

25. What are the probable causes of the losses?

(a) Mechanical injuries (b) Overheating (c) Overloading of fruits

(d) Wrong packing of fruits (e) Long delays in sales/low patronage

APPENDIX III

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOTY

INSTITUTE OF DISTANCE LEARNING

DEPARTMENT OF HORTICULTURE

QUESTIONNAIRE FOR FRUIT PROCESSORS

INTRODUCTION

This is a study being undertaken by an M.Sc Post harvest Technology student of the Institute of Distance Learning, Kwame Nkrumah University of Science and Technology on the Evaluation of the Post Harvest handling of Mango Fruits (*Mangifera indica*) in Ghana. The purpose of the study is to evaluate the post harvest handling of Mango Fruits in the Akwapim-South, Dangme-West, Lower- Manya and Yilo Krobo Districts of Ghana. This questionnaire is basically for academic purposes only and respondents are assured of privacy and confidentiality.

Thank you. Contact line 0208846378

Please tick ( ) the appropriate box and fill in the blank spaces where appropriate

SECTION A

Background characteristics of respondents

(1).Sex Male [ ] Female [ ]

(2) Educational Background

i Basic education [ ] ii. Secondary education [ ] iii. Diploma [ ]

iv. First Degree [ ] v. Second Degree [ ] vi. Other (specify) .....

(3) Do you have background education in Agriculture? i. Yes ii. No

If Yes, What level? i. Basic ii. Secondary iii. Diploma iv. Degree

SECTION B

(1)Where is/are your processing plant/factories located?

(a) Near the farms (b) In the urban centre (c) In an industrial area

(2) Which of the following factor(s) determined the location of the factory?

(a) Ready market for the product (b) Easy to transport product

(c) Availability of labour (d) Availability of utilities like water, electricity etc.

(e) Availability of raw materials (f) Localisation of other processing factories

(3) Is your processing factory located close to the source of raw material?

(a) Yes (b) No.

If No, which of the following problem(s) do you encounter in transporting product?

(a) High transport cost (b) difficulty in getting suitable mean of transport

(c) Poor road network leading to high losses(d) Produce exposed to long periods of heat

.(4) Which of the following constitute the estimated value of losses?

(a) 1 – 10% (b) 11 – 20% (c) 21 – 30% (d) 31 – 40% (e) 41 – 50% (f) above 50% .

(5) What is the main source of the mango fruits for processing?

(a) Major farmers (b) Small-scale farmers (c) Middlemen/market women

(d) Roadside sellers (e) Personal farm

(6) Do you get ready market for the processed product? (a) Yes (b) No

If No, state some of the causes of the low patronage.

a. …… b..... c. .....

(7) Do you have enough storage facilities for the raw materials and processed product?

(a) Yes (b) No If Yes, mention some of the storage facilities.

(i) ..... (ii) …… (iii) .....

(8) Can you mention some of the constraints you face in processing mango fruits?

(a) ..... (b) ..... (c) .....

(9) Do you receive any financial support from any institutions? (a) Yes (b) No

If Yes, which of the following bodies support you?

(a) Banks (b) NGO's (c) Government Agencies (d) Credit Unions

(10) How long does it take you to move the produce from the farm to the factory?

(a) 1 – 2 days (b) 3 – 7 days (c) more than 7 days (d) one month or more

(11) If fruits are not transported immediately to the factory how do you keep them?

(a) Under shade (b) Refrigerated (c) Kept in pack houses

(d) left in the open (e) Any other, ...

(12) How are the processed fruits marketed? (a) Direct sales to consumers

(b) Through market women (c) To wholesalers (d) Sold to exporters

(e) Export them myself

(13) Can you mention some other problems you encounter with the processing of the fruits?

(i) .....

(ii) .....

(iii) .....

(14) What do you do with excess produce? (a) For processing (b) Sell cheaply

(c) Store for sometime (d) Dried for future use (e) discard them

(15) Are there other processing plants to process excess fruits?

(a) Yes (b) No (c) Few

(16) Are the facilities/resources – financial support, equipment, sales/marketing enough to encourage you to process more of the fruits? (a) Yes (b) No

(17) At what stage of handling do you encounter the highest losses of the fruits?

(a) packing and packaging (b) Loading (c) During transportation

(d) Off-loading (e) During processing

(18) Can you give reasons for the high losses?

(i) .....

(ii) .....

(iii) .....

(19) Suggest some ways by which losses in mango fruits could be reduced in your area of operation.

(a) .....

(b) .....

(c) .....

APPENDIX IV

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOTY

INSTITUTE OF DISTANCE LEARNING

DEPARTMENT OF HORTICULTURE

QUESTIONNAIRE FOR PERSONNEL FROM THE MINISTRY OF AGRICULTURE/ N.G.O.

INTRODUCTION

This is a study being undertaken by an M.Sc Post Harvest Technology student of the Institute of Distance Learning, Kwame Nkrumah University of Science and Technology on the Evaluation of the Post Harvest Handling of Mango Fruits (*Mangifera indica*) in Ghana. The purpose of the study is to evaluate the post harvest handling of Mango Fruits in the Akwapim-South, Dangme-West,Lower- Manya and Yilo Krobo Districts of Ghana. This questionnaire is basically for academic purposes only and respondents are assured of privacy and confidentiality.

Thank you. Contact line 0208846378

Please tick ( ) the appropriate box and fill in the blank spaces where appropriate

SECTION A

Background characteristics of respondents

1. Sex Male [ ] Female [ ]

2. Educational background

i .Basic education [ ] ii. Secondary education [ ] iii. Diploma [ ]

iv. First Degree [ ] v. Second Degree [ ] vi. Other (specify) .....

3. Do you have background education in Agriculture? i. Yes ii. No

If Yes, What level? .....

SECTION B

Please provide answers to the following questions .

4. How many mango farmers do you work with/identified in your area of operation?

.....

5. How many of them can you classify as large-scale farmers and small-scale farmers?

(i) Large-scale .....(ii) Small-scale ……

6. Where are the farms located ? ……

7. Are they easily accessible? …….. .....

8. What kind of support does your outfit give to the farmers?

(a) .....

(b) .....

(c) .....

9. What programmes have you put in place for the farmers to reduce post-harvest losses(a)

.....

(b) .....

(c) .....

10. What is the average post-harvest losses of mango fruit in your area of operation?

. .....

11. What problems have you identified as the causes of the post-harvest losses in mango?

(i) .....

(ii) .....

(iii) .....

12. Do you have any policy information on mango production in your area? If Yes, state it.....

13. What would you recommend to be put in place to improve the marketing and handling of mangoes after harvest?

(i) .....

(ii) .....

(iii) .....

14. Are there some farmers who are interested in processing and export of mango fruits?(a) Yes (b) No

If Yes, can you estimate the percentage of farmers who are engaged in those activities?

.....

15. Can you mention some specific post harvest handling activities that your outfit is helping the farmers to undertake in order to reduce post harvest losses?

(i). .....

(ii).. .....

(iii) …….. ..

APPENDIX V

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOTY

INSTITUTE OF DISTANCE LEARNING

DEPARTMENT OF HORTICULTURE

QUESTIONNAIRE FOR MANGO EXPORTERS

INTRODUCTION

This is a study being undertaken by an M.Sc Post Harvest Technology student of the Institute of Distance Learning, Kwame Nkrumah University of Science and Technology on the Evaluation of the Post Harvest Handling of Mango Fruits (*Mangifera indica*) in Ghana. The purpose of the study is to evaluate the post-harvest handling of Mango Fruits in the Akwapim-South, Dangme-West,Lower- Manya and Yilo Krobo Districts of Ghana. This questionnaire is basically for academic purposes only. Respondents are assured of privacy and confidentiality.

Thank you. Contact line 0208846378

Please tick ( ) the appropriate box and fill in the blank spaces where appropriate

SECTION A

Background characteristics of respondents

1. Sex Male [ ] Female [ ]

2. Educational qualification

i Basic education [ ] ii. Secondary education [ ] iii. Diploma [ ]

iv. First Degree [ ] v. Second Degree [ ] vi. Other (specify) .....

3. Do you have background education in Agriculture? i. Yes ii. No

If Yes, What level? i. Basic [ ] ii. Secondary [ ] iii. Diploma [ ]

iv. Degree [ ]

SECTION B

1. How many years have you been in the export of mangoes ? …….
2. Have you had any training in the handling and export of mangoes? (a) Yes (b) No

   If yes, how many times have you had the training? .....
3. Which organizations or institutions organize the training?.....
4. What are the main sources of supply of the mango fruits for the export? ……

   i. ..... ii.....

   iii……..
5. What varieties do you normally export? ……..
6. Can you give reasons for the varieties chosen in Q. 4?

i. .....

ii. .....

iii. .....

7. Do you have any method of grading of the fruits that are exported? (a) Yes (b) No

If yes, state them…….....

8. What containers do you use to package the fruits?.....

10. Are they able to give you the maximum satisfaction by protecting the fruits from damage (a) Yes (b) No

11. What means of transport do you use to move the fruits from the farm to the point of export? .....

12. What is the nature of the roads of the mango producing area? .....

13. Do you encounter any form of damage during transportation? (a) Yes (b) No

If yes, state the type of damage caused to the fruits ….....

15. Do you give any form of treatment(s) to the fruits before the export of the mango fruits? (a) Yes (b) No . If yes, state the kind of treatment given ….....

....

16. Do you have access to any storage facility like a pack house? (a) Yes (b) No

If no, where do you keep the food from spoilage? .....

17. What do you do with mango fruits that may have blemishes on them? .....

....

18. How long does it take you to move the produce from the farm to the point of export?.....

19. Are you given any support by the Ministry of Agric., Ghana Export Promotion council or any NGO? (a) Yes (b) No If yes, state the type of support you receive.

(i) .....

(ii) .....

20. What is the average tonnage of mango do you export every year? .....

21. State the problems you encounter in the handling of the mango fruits in the export trade? i.....

ii.....

22. Can you state specifically the methods you have adopted to improve the post-harvest handling of the mango fruits?

i. .....

ii. .....

APPENDIX VI

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOTY

INSTITUTE OF DISTANCE LEARNING

DEPARTMENT OF HORTICULTURE

QUESTIONNAIRE FOR PERSONNEL FROM THE MINISTRY OF AGRICULTURE/ N.G.O.

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Please tick ( ) the appropriate box and fill in the blank spaces where appropriate

SECTION A

Background characteristics of respondents

1. Sex Male [ ] Female [ ]

2. Educational background.

i Basic education [ ] ii. Secondary education [ ] iii. Diploma [ ]

iv. First Degree [ ] v. Second Degree [ ]vi. Other (specify) .....

3. Do you have background education in Agriculture? i. Yes ii. No

If Yes, What level? i. Basic [ ] ii. Secondary [ ] iii. Diploma [ ] iv. Degree [ ]

SECTION B

1. What are the major areas of cultivation of mango in Ghana ?

.....

2. What is the annual tonnage of mangoes exported for the past five years?

I . 2006 .....

ii. 2007.....

iii. 2008.....

iv . 2009.....

v. 2010 ……..

3. Has there been an increase in the volume of mangoes exported for the past five years?

(a) Yes (b) No, If yes, what factors have promoted the increase in the export?

i.....

ii.....

(b) If no, what are the causes of the decrease in the export of the mango fruits?

i.....

ii.....

4. Does your outfit encourage the farmers/exporters to export a specific variety of mango?

   (a) Yes (b) No If yes, name the varieties.

   i.....ii.....

   iii.....

5. What reason(s) would you give for the export of a particular variety?

   i.....ii.....

   iii.....

6. Does your outfit give technical and financial support to mango farmers/exporters?

   (a) Yes (b) No If yes, specify the type of support

   i.....ii.....

   iii.....

7. What post-harvest problems have you identified with the export of mango fruits?

   i.....ii.....

   iii.....

8. How is your outfit helping to solve the problems? i…….

   ii.....

   iii…….

9. Does your outfit have some specific standards farmers/exporters must adhere to?

   (a) Yes (b) No If yes, state some of them

   i.....ii.....

   iii.....

10. What post-harvest support does your outfit give to exporters in terms of handling to improve and maintain the quality of mango fruits exported?

    i.....ii.....

    iii.....

11. Do you collaborate with other bodies/NGO's to assist farmers/exporters to improve and maintain the quality and quantity of the mango fruits exported?

    (a) Yes (b) No If yes, state some the ways by which the exporters are supported.

    i.....ii.....

    iii.....

12. Can you briefly give any other relevant information concerning the post-harvest handling of mango/fruits in Ghana?

    i.....ii.....

    iii.....