KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

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ASSESSMENT OF POSTHARVEST HANDLING OF CARROTS (*Daucus carota* L.)

A CASE STUDY IN THE ASANTE MAMPONG MUNICIPALITY

BY

ELVIS ASAMOAH

DECEMBER, 2012

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE

(M.Sc. POSTHARVEST TECHNOLOGY) DEGREE

BY

ELVIS ASAMOAH

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DECLARATION

I, hereby declare, that this work submitted to the school of Research and Graduate Studies, KNUST, Kumasi, with the exception of references of other researchers which have been duly acknowledged, is the result of my own research and that this thesis has never been presented anywhere for a degree.

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ABSTRACT

A study was carried out to assess the postharvest handling practices carried out on carrot roots in the Asante Mampong Municipality of the Ashanti Region of Ghana. A structured questionnaire was used during the survey to collect data on handling practices. Both quantitative and qualitative losses were determined. The study was carried out from November 2011 to April 2012. Fifty each of Producers, Traders (retailers and wholesalers) and Consumers were sampled for the study. Handling practices such as pre-cooling, packaging, transportation and quantitative loss assessment were carried out on producer's farm. Traders were also assessed on processing and quantity lost. Consumers on the other hand were assessed on methods of storing carrots and shelf life. Ninety-six percent of producers did not pre-cool their produce after harvest. For transportation, 54% of producers used KIA trucks with open buckets to transport their produce to the main market centre in Asante Mampong, while 25% used urvan buses and 18% used taxis. 92% of producers sorted and graded their produce to traders. Quantitative loss of carrots at the farm gate was 4.29±1.48%. Processing of carrots by traders was either by washing and scrapping or washing only. In all, 84% washed carrots using metal sponge, 14% used brush to scrape whiles 2% wash with bare hands. Quantitative loss of carrots at the market was 6.49±3.93%. The most preferred storage method for carrots by consumers was refrigeration. 92% stored carrots in refrigerators with 8% storing in cupboards under ambient temperature. The treatments were randomly replicated three times with 30 roots in each replication. Quality parameters such as Weight loss (g), Decay/rot (%), Appearance/Shrinkage (%), Moisture content (%), Dry matter (%), Firmness (N), and Total Soluble Salts (^{0}Brix), were studied over the period of storage. Analysis of variance showed significant differences ($P \leq 0.05$) in Weight loss which ranged between (14.13g and 26.17g), Firmness (6.97 N and 7.37 N), and Decay/rot (3.33% and 56.67%). The results of Appearance/Shrinkage (%), Moisture content (%), Dry matter (%), Total Soluble Salts (TSS) ^{0}Brix, however did not show any significant difference ($p \geq 0.05$). The raw carrot roots were found to have a longer storage life (5 days) than the washed (4 days) and the scrapped (3 days) under ambient conditions. Baby carrots not meant for immediate consumption should therefore be stored raw if storage is under ambient conditions.

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CHAPTER ONE

1.0 INTRODUCTION

Carrots (*Daucus carota* L.) are one of the most preferred vegetables, due to their versatility in culinary uses and its enriched healthy composition, such as phytonutrients, dietary fibre and minerals. It is consumed fresh or cooked, either alone or with other vegetables, in the preparation of soups, stews, curies and pies. Fresh grated roots are used in salads and tender roots are pickled (Sharma *et al.,* 2006). Its use increases resistance against the blood and eye diseases (Hassan *et al.*, 2005). However, carrots are seasonal in nature and highly susceptible to moisture losses, leading to rigidity and fresh appeal degradation. Under ideal conditions of 0^0C and 98-100% relative humidity, fresh carrots (*Daucus carota* L.) can be stored for up to 4-5 months (Hardenburg *et al*., 1986). However, during storage, carrot quality may decline as a result of excessive decay, loss of flavour and texture, and development of bitterness. Greve *et al*. (1994) stated that tissues firmness is lost rapidly in the first few minutes, when carrots are processed at high temperature (±90^0C), and then more slowly over the duration of the process period. Phenolic compounds are commodity found in vegetables. The presence of phenolic compounds in carrots contributes to their sensory qualities like colour (Zhang *et al.,* 2005), bitterness (Kreutzmann *et al*., 2008) or aroma (Naczk and Shahidi, 2003). Therefore, the response of phenolic compounds could be used as a good indicator to evaluate the vegetables quality during processing and storage. Major phenols in carrots include Chlorogenic, Caffeic, and P-hydroxybenzoic acids along with numerous cinnamic acid derivatives. Postharvest decays of fruits and vegetables account for significant levels of postharvest losses. It is estimated that about 20–25% of the harvested fruits and vegetables are decayed by pathogens during postharvest handling even in developed countries (El-Ghaouth *et al.,* 2004; Droby, 2006; Zhu, 2006; Singh and Sharma, 2007). In developing countries, postharvest losses are often more severe due to inadequate storage and transportation facilities.

Most farmers aim at increasing yield but may not pay sufficient attention to the quality of the produce, leading to low market value. Poor handling contributes to postharvest losses through the use of certain common practices or failure in using certain practices known to reduce losses and helping maintain produce quality and safety. Most of these improper practices and conditions cannot be labeled technical problems as they cannot be solved by initiating new research or simply by extending well-proven technical information (Kitinoja and Kashmire, 2002). Often postharvest losses take time to develop and the specific cause of quality problems may not be fully understood by produce handlers along the chain (Kader, 2002). A variety of methods of postharvest loss assessment can be used to pinpoint the sources of problems and to identify potential constraints to changing handling practices. Most involve direct observation of handling practices and the interviewing of key individuals regarding their standard practices (Kader, 2002). Any method used for loss assessment must attempt to understand losses within the context of the whole system of production, handling and marketing of the commodity in question since what are considered losses vary by culture and economic situation. During harvest, sources of contamination include workers, tools, bins and crates, and transport vehicles. Processing, transportation, distribution, retail display or preparation also contributes to the contamination problem (Gorny, 2006). Handling in retail outlets could also introduce pathogenic microorganisms to the surface of the fresh produce, as well as non-hygienic storage and handling in the consumer's kitchen. (Beuchat, 1996; Monaghan, 2006)

Most freshly harvested fruits and vegetables are cleaned, washed or disinfected by the grower, packer or processor to remove soil, plant debris, pesticide residue and microorganisms from the commodity surface. The removal is accomplished by dry or wet brushes, rinsing or immersion in tap water, hot water or solutions containing one of a number of cleaning or sanitizing agents, using equipment designed for the commodity (Fallik, 2004; Sapers, 2006). The consumption of fresh-cut carrots has steadily increased in popularity in the last few years, particularly baby carrots which is one of the most popular products. Baby carrots, which are prepared by peeling the outer layer of the carrot roots, are susceptible to a variety of physiological changes that reduce their quality. (Li & Barth, 1998). It is well known that the quality of minimally processed products can be maintained by cold storage and Controlled Storage as a way to minimised the wound –induced reactions.

In the last few years, carrot growers have been brushing carrots to remove the peel epidermis before storage in order to improve the product's appeal; this practice enhances the appearance but may lead to some post-harvest diseases, increases tissue susceptibility to chemical and physical damage (Eshel *et al.*, 2009). Post-harvest moisture loss causes carrots to become shrivelled (Hurschka, 1977), lose their bright orange appearance, and become susceptible to post-harvest decay (Van den Berg and Lentz, 1966), 1973).

Fresh fruits and vegetables are perceived by consumers to be healthy and nutritious food, because of the plethora of scientifically substantiated and documented health benefits derived from consuming fresh fruits and vegetables (Huxley *et al*., 2004).

An understanding of physical and physiological characteristics that influence moisture loss during short term storage can contribute to the development of ways to enhance shelf life of carrots. Ethylene production, respiratory activity, enzymatic and non-enzymatic browning and nutrient release from cells are stimulated by plant injuries. These lead to lowered quality and shorter shelf life compared to that expected from the whole intact product (Wiley, 1994.). The appearance of a fresh-cut fruit or vegetable is the attribute most immediately obvious to the consumer, and strongly affects the decision to buy. Many unrelated factors influence appearance, from wound related effects to drying to microbial colonization. These factors have different causes, and different effects, but all result in an unattractive product. The carrot industry contributes substantially to nutrition and livelihood in the Asante Mampong Municipality and many people are involved in its trade. Retailers in Ghana have adopted various techniques in improving the appeal of their carrots. Though farmers and traders claim there is a considerable loss in quantity produced and transported, unfortunately, the effect of the various handling practices on postharvest quality and loss has not been sufficiently reported.

The objectives of the research were therefore to;

1. Identify postharvest handling practices carried out on carrots in the Asante- Mampong Municipality.
2. Determine postharvest losses of carrots in the Asante Mampong municipality
3. Assess the effect of common pretreatments in Ghana on the quality and storage life of carrots.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 ORIGIN AND DISTRIBUTION OF CARROT

The modern cultivar carrot has been derived from wild carrot (*Daucus carota* L.) found in Europe, Asia and Africa (George, 1989). The subspecies sativas has been cultivated from the early times in the Mediterranean region and it's now widely distributed in many tropical areas. It has been reported that carrots with purple roots were domesticated in Afghanistan and spread to the Eastern Mediterranean area under Arab influence in the 10^{th} to 12^{th} centuries and to Western Europe in the 14^{th} and 15^{th} centuries. At the beginning of the 17^{th} centuries, in the Netherlands, repeated selections resulted in carrots with fleshy orange roots, and this carrot provided the basis for modern cultivars of sativus species. The crop was introduced by Europeans around 1930 into Ghana (Sinnadurai, 1992).

2.2 BOTANY OF CARROT

Carrot is a dicotyledonous herbaceous crop grown for the enlarged tap root. The wild form is an annual but the cultivated crop which is believed to be have derived from the wild type is biennial. The main or the tap root becomes thickened and swollen, and varies in shape and size. The size of the carrot can vary from 2cm to 6cm in diameter and from 6cm to 9cm in length. The cross section of the root reveals two distinct zones, the outer zone where sugar and carotene are mainly stored, and some white woody inner central core which tastes less palatable. The leaves are alternate 2-3 pinnate, segmented divided with normally long petiole and often forms stealth at the base. The inflorescence is compound umbel 3-7 in diameter, and is borne on a much branded stalk.

The flowers which are normally white or pink are small with 5 sepals and petals with hairy ovary. Carrot's flowers are protandrous and are therefore cross pollinated; however, the possibility of self-pollination always remains because of its extended flowering period (George, 1989). The fruit is oblong to ovoid in shape 3-4mm long and ridges with hooked spines. The stem is solid and condensed at the proximal part of the root (Tindall, 1983).

2.3 NUTRITIONAL AND HEALTH BENEFITS OF CARROTS

The world over, healthy eating strategy has forced the general public to eat more fresh fruits and vegetables. Among these, carrots are being increasingly consumed (MAFF, 1997), mainly due to their pleasant flavor and perceived health benefits related to vitamins, minerals, and fibre that they contain; B-carotene, a dimer of vitamin A, is abundant in carrots. Carrots are good source of vitamin A because although they do not possess the actual compound (retinol) their carotene content (also known as provitamin A) is converted by the body into vitamin A (Arthey, 1975). It also contains appreciable quantities of thiamine, riboflavin (Thompson & Kelly, 1957).

The roots are used as vegetables and for preparing soups, stew curriers and other dishes; the grated root is used in salads, the tender roots are prickled. The roots and the tops can be fed to livestock. The seeds contain an essential oil which is used for flavoring and in perfumery (Purseglove, 1986). Several health benefits are associated with carrots, such as strengthening the immune system, regulating metabolism, maintaining a healthy skin and vision, and reducing the risk of high blood pressure, stroke, heart disease, and some types of cancer.

2.4 POSTHARVEST DEVELOPMENT OF CARROT

The life of fruit and vegetables can be divided into three major physiological stages following germination: growth, maturation and senescence (Wills *et al.,* 1998). Maturation usually starts before growth ceases and includes different activities, depending on the product. Senescence is defined as the period when catabolic (degradative) biochemical processes overcome anabolic processes, leading to ageing and death of tissues. After harvest, senescence gradually impairs the quality of the products and finally makes them unusable. Postharvest life functions cannot be stopped, but they can be slowed down by controlling the storage environment. Biological processes affecting the quality of vegetables during storage are respiration, ethylene production, compositional changes, growth and development, transpiration, physiological breakdown, physical damage and pathological breakdown (Kader, 1992). The relative importance of each factor varies largely from one species to another.

2.5 FACTORS CAUSING STORAGE LOSS OF CARROTS

Carrot has good physiological storability. Provided that carrots are not infected by microbes causing storage diseases, they can be stored for 6–8 months without loss of quality under optimal storage conditions (temperature 0°C and relative humidity c. 98%) (Balvoll, 1985).

Carrot has low metabolic activity at low temperatures, as shown by the low respiration rate (Stoll and Weichmann, 1987). A low storage temperature also prevents the onset of new growth. However, carrot is sensitive to wilting if not protected from water loss. In commercial refrigerated stores, storage diseases, mainly caused by pathogenic fungi, pose the greatest risk.

Ethylene in the air may impair the sensory quality by inducing the synthesis of phenolic compounds, which give rise to a bitter taste (Sarkar and Phan 1979, Lafuente *et al.*1989, 1996).

2.5.1 Transpiration

Transpiration is the mass transfer of water vapour from the surface of the plant organ to the surrounding air. The driving force is the gradient of water vapour pressure between the tissue and the surrounding air, which is affected by the relative humidity and temperature of the air and the product (Ben-Yehoshua, 1987). The rate of water loss of carrot is affected by the surface area of the root, the water vapour pressure deficit and air velocity (Apeland and Baugerød, 1971). The significance of the surface area is seen in the fact that large carrots lose less weight than small carrots and cylindrical carrots less than cone-shaped ones. Root tips, where the ratio of surface area to weight is high, are the most susceptible to water loss (Apeland and Baugerød, 1971).

Water loss due to transpiration results in shriveling, loss of bright colour and increased risk of post-harvest decay (van den Berg and Lentz, 1973, Goodliffe and Heale, 1977, Den Outer 1990). An 8% weight loss is reported to make carrots unsalable (Robinson *et al.,* 1975). Van den Berg and Lentz (1973) showed that the optimum relative humidity during storage is 98% to 100%,a level that efficiently reduced postharvest decay and moisture loss compared with storage at 90% to 95% RH. During storage, thin walled cells, such as those in phellogen and oil ducts, die and form a fatty layer of dead crushed cells, which accounts for the loss of bright colour (Den Outer, 1990).

A new periderm is formed below to prevent further desiccation, but the process is slow at low temperatures and cannot prevent water loss. Shibairo *et al*., (1997) observed some cultivar differences in moisture loss characteristics during short-term storage but they were mainly associated with the specific surface area of the root. Differences between Cultivars were pronounced when carrots were harvested at a mature stage compared with those harvested early. Pre-harvest water stress increased postharvest weight loss and shortened the shelf-life of carrots (Shibairo *et al.,* 1998a), which led the authors to recommend that carrots should not be harvested under water stress. They suggest that pre-harvest water stress lowers the integrity of the membranes in the root, which enhances moisture loss during storage. Increased potassium (K) application reduced the postharvest moisture loss by increasing root weight and maintaining tissue integrity, but the K fertilization is likely to be of benefit only in soils with a very low K content (Shibairo *et al.,* 1998b).

2.5.2 Respiration

Storage compounds accumulating in the storage organ during growth and maturation are consumed in the course of metabolic activities during storage. Respiration includes the oxidative breakdown of sugars, starch and organic acids into carbon dioxide and water, with the concurrent production of energy, heat and intermediary compounds to be used in biochemical reactions (Wills *et al.,* 1998). At low temperatures, the respiration rate is low, and it comprises only a minor part of weight loss compared with transpiration (Apeland and Baugerød, 1971).

Apeland and Hoftun, (1974) found that respiration first decreased after harvest and later increased with time in store, more at 2 and 5°C than at 0°C. Transfer to 5°C from a lower temperature initially increased the respiration rate above that at constant 5°C but the rate soon declined. The respiration intensity of carrots decreases when they are harvested after a longer growing time (Fritz and Weichmann, 1979, Mempel and Geyer, 1999). According to Fritz and Weichmann, (1979), in late maturing cultivars respiration increased again in the final two harvests in October. The differences between harvest dates persisted after storage but were smaller. Mempel and Geyer, (1999) reported that the increase in respiration soon after harvest was larger in younger than in older carrots. Mechanical loads increase the respiration rate, which may impair the quality of carrots (Mempel and Geyer, 1999). Repeated drops from a lower height resulted in a larger increase in respiration than did fewer drops from a greater height. Respiration intensity also increased with each step of packing. Lowering the oxygen concentration or increasing the carbon dioxide concentration in storage air reduces the respiration rate of carrot (Apeland and Hoftun, 1971, Robinson *et al.*, 1975), but the gas composition is critical.

2.6 SHELF LIFE OF CARROTS

Shelf life is that length of time fruits and vegetables are given before they are considered unsuitable for sale or consumption. It is also defined as the stage when a food maintains the expected quality desired by the consumer (Derry *et al.*, 2009). Foods outside of the shelf life will experience a loss in the desired qualities and an increased chance of microbial (bacteria/fungi) action. Qualities affected when the food has exceeded its shelf life are: loss of flavor, color (browning is common), mass, change in smell and texture.

Shelf life is assessed by regular visual and sensory evaluation of the vegetable (Derry *et al*., 2009). The main problems that limit the shelf life of baby carrots to 4 or 5 days are: high respiration rate (RR), development of off-flavours, acidification, loss of firmness, discoloration and microbial spoilage (Barry-Ryan & O'Beirne, 2000; Barry-Ryan, Pacussi, & O'Beirne, 2000).

2.7 POSTHARVEST QUALITY

In recent years, consumption of vegetables has been increasing, especially as a result of changes in the consumer life style. This is particularly the case with ready-to-eat or minimally processed fruit and vegetables (Ragaert *et al.,* 2004).

Mechanical damage may cause alterations in the levels of antioxidants (Tomas-Barberan *et al*., 1997). Fresh-cut products are wounded tissues, and consequently they deteriorate more rapidly and their physiology differs from that of intact fruit and vegetables. Many of the postharvest treatments and storage conditions applied to fresh-cuts are designed to ameliorate the initial effects of wounding and wounding-induced responses. For both fruit and vegetables, wounding and mechanical injury result in increased rates of respiration and production of ethylene, with effects being observed very rapidly, often within minutes to a few hours (Rosen and Kader, 1989). As a result of physiological and microbial deterioration occurring during storage and marketing of fresh produce, and especially fresh-cut produce, there is an urgent need to develop effective, non-damaging treatments for maintaining the quality (appearance, flavour, texture, nutritional value) and food safety of fresh harvested produce (How, 1990).

2.8 PRODUCTION PRACTICES

Production practices have tremendous effect on the quality of fruits and vegetables at harvest and on post-harvest quality and shelf life. In addition environmental factors such as soil type, temperature, frost and rainy weather at harvest can have an adverse effect on storage life and quality. For instance, carrots grown on muck soils do not hold up as well in storage as carrots on lighter, upland soils (Herner, 1989).

Environmental conditions and cultural practices during production have tremendous effects on produce quality, safety, and shelf life. Produce stressed by too much or too little water (by irrigation or rainfall), high rates of nitrogen fertilization, or mechanical injury (scrapes, bruises, abrasions) are susceptible to postharvest diseases. Brassicas are prone to bacterial soft rot if nitrogen is applied as foliar feed, thus nitrogen should be applied to the soil. Nitrogen above the optimal level did not result in reduced shelf life, while spraying nutrient solution appeared to be beneficial as it retarded yellowing. Potassium sulfate application also enhanced chlorophyll content and extended shelf life. Stress during growth has different effects on produce quality and shelf life. Sustained and intermittent water stress had mostly negative effects for vegetables (Jiang and Pearce, 2005).

2.9 HARVESTING

The method of harvest can determine the extent of variability in maturity and physical injuries, and consequently influence nutritional composition of fruits and vegetables. Mechanical injuries such as bruising, surface abrasions, and cuts can result in accelerated loss of vitamin C.

The incidence and severity of such injuries are influenced by the method of harvest and handling operations. Proper management to minimize physical damage to the commodity is a must whether harvesting is done by hand or by machine (Ezell *et. al*., 1947). Fresh fruits and vegetables as living tissues are subject to continual changes after harvest. Such changes cannot be stopped but can be controlled within certain limits by using various postharvest procedures (Kader and Morris, 1978). Quality cannot be improved after harvest, only maintained; therefore, it is important to harvest at the proper maturity stage and at peak quality. Immature or over mature produce may not last as long in storage as that picked at proper maturity. Carrots can be harvested when the roots are between 0.8-1.9cm in diameter (depending on the variety) about 12 weeks after sowing.

2.9.1 Time of Harvesting

The time of the day when harvesting is done also affects produce quality and shelf life. In general, harvesting during the coolest time of the day (e.g. early morning) is desirable; the produce is not be exposed to the heat of the sun and the work efficiency of the harvesters is higher. If harvesting during the hotter part of the day cannot be avoided, the produce should be kept shaded in the field to minimize product heat, weight loss, and wilting.

Research showed that harvest time of day could affect quality. Vegetables harvested at these times maintained highest water potential, resulting in a slower rate of wilting than those with lower water potential (Jiang and Pearce, 2005). However, harvesting later in the day has an added advantage because sugar levels were found to be higher as a result of photosynthesis during the day (O'Hare *et al*., 2001).

2.9.2 Harvesting Method

Harvesting is done manually; hence the harvesters have a major influence on produce quality They should be made aware of the importance of good sanitation practices, proper maturity selection, and careful handling to avoid mechanical injuries. Carrots are harvested by holding the top and pulling by hand from the soil.

2.10 FIELD HANDLING

Postharvest fruits and vegetables are usually exposed to varying surrounding temperatures during handling, transportation, storage and marketing. During marketing, the surrounding temperature is usually higher than during shipping or storage (Cameron *et al*., 1993). Results from (Nunes *et al*., 2001) indicated that, even for short periods of time, fluctuating and/or high temperatures during handling might result in rejection of the whole load. Given such facts, it is obvious that something needs to be done in order to improve the conditions endured by horticultural products during postharvest handling in order to reduce losses and provide consumers with products of the best possible quality and safety. The harvested produce is usually placed in collection containers, which may be plastic crates or bamboo baskets with cotton or paper cushioning or padding (Chen, 2007). Throwing harvested produce into the collection container or vehicle should be avoided to prevent physical injuries. Handling aids such as boxes, farm trailer, or a simple conveyer can be used. Exposure of harvested produce to the heat of the sun is detrimental except in a few cases. Leafy vegetables left in the sun after harvest may reach temperatures as high as 50^{o}C (Kanlayanarat, 2007). High product temperature accelerates quality deterioration due to increased water loss and respiration. If packed and transported without cooling, wilting and other deteriorative processes rapidly set in (Jiang and Pearce, 2005).

2.11 SORTING AND GRADING

Systematic sorting or grading coupled with appropriate packaging and storage, will extend shelf life, maintain wholesomeness, freshness, and quality, and substantially reduce losses and marketing costs. Sorting is done to separate poor produce from good produce, and further classify the good produce based on other quality parameters, such as size (Bautista and Acedo, 1987).

2.12 TEMPERATURE MANAGEMENT

Temperature management is the most important tool to extend shelf-life and maintain quality of fresh fruits and vegetables. Delays between harvesting and cooling or processing can result in direct losses due to water loss and decay and indirect losses such as those in flavor and nutritional quality (Kader and Morris, 1978). The most important parameter for preserving produce quality and inhibiting pathogen development during the postharvest life is an adequate storage temperature (Jacxsens *et al*., 1999, 2002). It is well known that low temperatures slow down plant metabolic processes such as respiration, ethylene production and, in general, enzyme activity.

The best way to maintain the quality of fresh fruits and vegetables is undoubtedly by maintaining an adequate temperature throughout the postharvest handling chain. But as discussed above, a constant and optimum temperature is rarely either attained or maintained. (Nunes *et al.*, 1995) In normal circumstances, vegetables are cooled by air blast cooling or in cold storage. However, this requires large storage surface area if vegetables are to be cooled correctly.

In addition, in many cold storage installations vegetables are stacked in crates with a relatively small quantity of product per crate (Greidanus, 1971). The maintenance of a constant optimal temperature throughout postharvest handling chain (i.e. from the grower to the retail display) is one of the most difficult tasks and is far from being universally attained. Even when transport by truck or sea can provide satisfactory temperatures within the limits of acceptability, the transport time may be too long for short-life products to be transported over long distances (Emond *et al*., 1996). In fact, the fluctuating temperatures often encountered during the handling chain can have a very negative effect on the quality of horticultural crops (Nunes *et al*., 1999); Nunes *et al*., 2001). However, low temperatures may induce chilling injury and compromise produce quality. Correct storage temperature can vary from species to species and cultivar to cultivar. The most frequently used temperature is 4 ◦C, considered the optimal for many vegetables (Jacxsens *et al*., 2002). Because of the difference in the rates of change of permeability and respiration rate with temperature, a film that produces a favourable atmosphere at the optimal storage temperature may cause excessive accumulation of CO2 and/or depletion of O2 at higher temperatures, a situation that could lead to metabolic disorders (Beaudry *et al*., 1992). Results from (Nunes *et al*., 2001) indicated that, even for short periods of time, fluctuating and/or high temperatures during handling might result in rejection of the whole load. Given such facts, it is obvious that something needs to be done in order to improve the conditions endured by horticultural products during postharvest handling in order to reduce losses and provide consumers with products of the best possible quality and safety (Nunes *et al*., 2001). The most important vitamin in fruits and vegetables for human nutrition is vitamin C. More than 90% of the vitamin C in human diets is supplied by fruits and vegetables (Wills *et al.*, 1984).

2.13 QUALITY CHARACTERISTICS OF CARROTS

Quality is a combination of characteristics, attributes or properties that give a commodity value in terms of human food. Quality makes a produce what it is: the combination of attributes or characteristics of a product determining its degree of acceptability. Produce quality requirements refers to market, storage, transport, eating and processing qualities. Post-harvest behaviour and quality of horticultural products, which are mostly perishable, reflect the pre-harvest cultural and environmental conditions to which the produce is exposed. (Olympio and Kumah, 2008).

2.13.1 Total Soluble Solids

Harril, (1998) reported that TSS is also known as Brix. OECD, (1999) also indicated that a refractometer measures TSS as °Brix in 0.1% graduations. Brix is a measure of the percent solids (TSS) in a given weight of plant juice. It is actually a summation of the pounds of sucrose, fructose, vitamins, minerals, amino acids, proteins, hormones, and other solids in one hundred pounds of any particular plant juice (Harril, 1998). Carrots contain 8.5-12.5% soluble solids (Rashidi *et al*, 2010). Water content and soluble solids exert a profound influence on the storage period length, mechanical properties and quality characteristics of fruits and vegetables (Rashidi *et al*, 2010a).

2.13.2 Dry matter

The dry matter (or otherwise known as dry weight) is a measurement of the mass of something when completely dried. It is what remains after all the water is evaporated out of the carrot slice. The dry matter of plant and animal material would be its solids, that is, all its constituents excluding water. Anon. (2012).

2.13.3 Moisture content

Water content or moisture content is the quantity of water contained in a material such as soil, rock, ceramics, fruits and vegetables or wood. Water content can be directly measured using a known volume of the material and drying oven volumetric water content. According to Rashidi et al., 2010, carrots contain 75-88% water.

2.13.4 Appearance/shrinkage

People 'buy with their eyes' and learn to associate desirable qualities with a certain external appearance. A rapid visual assessment can be made on the basis of size, shape, colour, condition (such as freshness) and/ or the presence of defects or blemishes, Wills *et al.,* (1998). Excessive shrinkage is due to: immaturity of the produce; delay before storage; picking produce when hot and then placing hot produce in the cool store; packing produce into dry wooden boxes or cartons; high storage temperatures, including hot spots in the room; low humidities due to insufficient insulation or insufficient coil surface; slow cooling and excessive air circulation. The appearance of many commodities may be marred by surface lesions caused by pathogenic organisms, without the internal tissues being affected, Wills *et al.,* (1998).

2.13.5 Firmness

Fresh-cut fruit firmness is an important quality attribute that can be affected by cell softening enzymes present in the fruit tissue (Varoquaux et al., 1990) and by decreased turgo due to water loss. As fruits mature and ripen they soften, largely because the pectins comprising the middle lamella of cell walls dissolve, Wills *et al.,* (1998). This softening can be estimated subjectively by finger or thumb pressure. However, more objective measurement, yielding a numerical expression of flesh firmness, is possible with a fruit pressure tester (penetrometer). These testers measure the pressure at which flesh yields to the penetration of a standard diameter plunger inserted to a standard depth Wills *et al.,* (1998).

2.13.6 Decay/rot

Wastage of horticultural commodities by microorganisms between harvest and consumption can be rapid and severe, particularly in tropical areas where high temperatures and high humidity favour rapid microbial growth. Wills *et al.,* (1998). Many bacteria and fungi can cause the postharvest decay. Storage rots of carrot (*Daucus carota* L.) caused by *Sclerotinia sclerotiorum* (Lib.) de Bary (watery soft rot) and *Botyrtis cinerea* Pers.:Fr. (grey mold) are significant problems in many carrots producing areas of the world (Rader, 1952; Lockhart and Delbridge, 1972; Goodliffe and Heale, 1975; Kora *et al.*, 2003).

2.13.7 Weight loss

This is reduction in the total mass of a body due to a mean loss of fluid. Anon., 2012. Fresh fruits, vegetables and ornamentals are mostly composed of water, the unique ‘universal solvent’ that is fundamentally important in all life processes.

Water loss equates to loss of saleable weight, and thus constitutes a direct loss in marketing. According to Wills et al., 1998, Loss in weight of only 5 per cent will cause many perishable commodities; even bulky fruit with a low surface area to volume ratio, to appear wilted or shriveled.

2.14 PRE-COOLING

Pre-cooling has been reported as among the most efficient quality enhancements for commercial producers and was found to rank as the most essential of the value-added marketing activities, especially if cold storage facilities are available (Sullivan *et al*., 1996). Research confirms that lowering the respiration rate of fresh vegetables is essential to preserving market quality and the most important technology for lowering respiration rates remains proper pre-cooling of produce within hours of harvest. Proper pre-cooling preserves product quality by: (1) inhibiting the growth of decay producing microorganisms; (2) restricting enzymatic and respiratory activity; (3) inhibiting water loss; and (4) reducing ethylene production. There are different pre-cooling methods and among these, forced-air cooling and hydro cooling were found to be the most effective and economical in preserving optimum quality and increasing market life. Rapid cooling either by hydro cooling alone or in combination with package icing (ice packing) is essential to maintain the quality of leafy vegetables. Hydro cooling by dipping in cold water is simpler, but hydro cooled produce must be kept cool in order to prolong shelf life. Hydro cooling Chinese kale in 4^{o}C water for 5–10 minutes prior to 7^{o}C storage was found to reduce water loss and yellowing and extend shelf life (Kanlayanarat, 2007).

Ice packing is a cheap form of cooling to extend shelf life but has not been widely adopted because growers were seldom in a position to easily access the loose ice and plastic packing containers required, which would lead to additional costs. Furthermore, the effect of ice is transitory; without proper insulating material, it melts quickly and the temperature returns to near ambient (Jiang and Pearce, 2005).

2.15 QUALITY DETERIORATION OF CARROTS

Quality and storage life of fruits and vegetables are reduced by moisture loss, physiological breakdown, and decay. Carrots at high temperature tend to wilt, have poor appearance, and hence a short life. Controlled atmosphere during storage as well as chemical treatments have been used to slow down physiological changes and decays in carrot. Wills *et al*, (1979) reported that lowering the O2 concentration or increasing the Co2 concentration during storage reduced respiration and physiological breakdown of carrots. Using propionate or potassium sobbate during hydro-cooling has reduced postharvest development of black root rot in carrots (Punja & Gaye, 1993). However, because of consumer concern regarding use of chemicals on food development of non-chemical means to maintain carrot quality during storage is needed.

Several methods have been used to reduce moisture loss from fruits and vegetables during storage. Refrigeration has been used extensively to slow metabolism and reduce water loss. Use of jacketed room storage and Filacell systems (Raghavan *et al.*, 1980) increases relative humidity which reduces moisture loss. However, these systems are expensive and not intended for the retail market.

2.15.1 Respiration and ethylene production. Prolonged exposure to ethylene, as low as 0.01 ppm, could cause significant losses of fresh produce. Ethylene easily accumulates in packages, packinghouses, storage areas, and even markets.

All plant tissues produce ethylene, although at varying levels. In markets (wholesale, retail, distribution centers), the main sources of ethylene, in addition to the fresh produce, include ripening fruit, decaying produce, and exhaust gases of vehicles; concentration could reach 0.02-0.06 ppm, which can cause a 10-30% loss in product shelf life (Wills *et al*., 2000). The effect of ethylene is cumulative, so continuous exposure to a low concentration throughout marketing can cause significant harm. The loss of shelf life will be most frustrating for the final consumer, as the loss of quality will not be obvious during marketing and retail. Aside accelerating aging, ethylene increases product susceptibility to decay. Yellowing is found to be controlled by the sugar level (the main energy substrate) rather than ethylene, which explains the poor performance of anti-ethylene agents (e.g. 1-methylcyclopropene) in extending shelf life (O'Hare *et al*., 2001).

2.15.2 Pathological Decay

Vegetables are susceptible to postharvest diseases that render the produce unfit to sell. Postharvest diseases can be spread through field boxes contaminated by soil or decaying produce or both, contaminated water used to wash produce before packing, decaying rejected produce left lying around the packinghouse, and contaminated healthy produce in packages.

Microbial infection can occur both before and after harvest. The infection after harvest can be found at any time between the field and final consumer (Kanlayanarat, 2007).

2.15.3 Mechanical Injury

Vegetables are very susceptible to mechanical injury (physical damage). Tearing and crushing, midrib breakage, and head cracking or bursting are common forms of damage. Physical injuries increase physiological deterioration through browning as a result of oxidation of phenolics substances, and susceptibility to decay. Postharvest rots have been found to be more prevalent in bruised or damaged produce. Mechanical damage also increases moisture loss by as much as 3-4 times more than that of undamaged produce (Bachmann and Earles, 2000).

2.16 PRE-PROCESSING OPERATIONS

Vegetables may be washed with water in three different ways: soaking, washing by agitation, and spraying (Diamante, 2007). Washing vegetables with water can be manual or mechanized, depending upon the scale of operation. Soaking is not in itself an effective means of removing dirt but it is useful as a preliminary treatment to washing by spray or agitation. If the vegetables are agitated in water, the efficiency of the soaking process is greatly enhanced. Washing by means of water spray is by far the most satisfactory method. Vegetables that are heavily contaminated with soil or other objectionable material should first be soaked thoroughly to loosen adhering soil before washing under spray. The efficiency of a spray of water for washing depends upon the pressure of the water, its volume, and also the distance of the spray nozzle from the vegetable to be washed (Diamante, 2007).

2.16.1 Washing and Sanitizing

Washing may be important to remove sap (e.g. mangoes), dirt (e.g. carrots) and debris (e.g. bananas), Wills *et al.,* (1998). Most vegetables are washed in clean water to remove dirt and other debris and surface contaminants. Sanitation is essential to control the spread of diseases from one item to another and limit the pathogen load in wash water or in the packinghouse air. Waterborne microorganisms, including postharvest plant pathogens and agents of human illness, can be rapidly acquired and taken up on plant surfaces (Kader, 2006).

Natural plant surface contours, natural openings, harvest and trimming wounds can be points of entry and provide safe harbor for microbes. Chlorine in the form of sodium hypochlorite (NaOCl) solution (e.g. Chlorox or commercial bleach) or as a dry, powdered calcium hypochlorite can be used in wash water as a disinfectant.

For the majority of vegetables, chlorine in wash water should be maintained in the range of 75–150 ppm (Suslow, 1997; Bachmann and Earles, 2000). The antimicrobial form, hypochlorous acid, is most available in water with a neutral pH (6.5 to 7.5). Concentrations above 200 ppm may injure some vegetables (e.g. leafy greens and celery) or leave undesirable off-flavors. A 100 ppm chlorine solution can be prepared by mixing 4 tablespoons of commercial bleach (5.25% NaOCl) per gallon of water (Bautista and Acedo, 1987). Chlorine is routinely used as a sanitizer in wash, spray, and flume waters used in the fresh fruit and vegetable industry (Beuchat and Ryu, 1997). Antimicrobial activity depends on the amount of free available chlorine (as hypochlorous acid) in water that comes in contact with microbial cells. Hydrogen peroxide (food grade) also can be used as a disinfectant. Concentrations of 0.5% or less are effective for inhibiting development of postharvest decay caused by a number of fungi (Bachmann and Earles, 2000).

2.17 PACKAGING AND PACKING

Packaging should ensure identification, and provide information including variety, weight, number of units, selection or quality grade, producer's name, area of origin, handling instructions and appropriate storage temperature for product display (Lopez Camelo, 2004).

If the produce is packed for handling, waxed cartons, wooden crates or rigid plastic crates are preferable to bags or open baskets, because bags and baskets do not protect the produce when stacked. For domestic marketing plastic plates provide excellent protection for produce and adequate ventilation during handling, cooling, transport and storage. Some plastic plates are collapsible or can be nested when stacked for easier handling when empty (Kitinoja and Kader, 2002).

2.17.1 Storage and Transport

Local produce, often characterized by seasonal production, its small volume and short transport distance, could require less storage facilities and technology. In this case, the lead time between harvesting and customer sale could be limited to less than a day. It is important to know that that effective distribution of the produce is more important than its preservation in storage. However, storage is a strategy for achieving higher returns. The produce can be held temporarily to overcome fluctuations in supply and demand (Lopez Camelo, 2004). Transport to road side stands and product display at road side stands or farmers' market can often result in produce being exposed to direct sunlight, warm or even high temperatures, and low relative humidity levels. Rapid water loss under this condition can cause fruits and vegetables to deteriorate (Suslow, 1997). By providing postharvest cooling before and during transport and a shading structure during display, the produce will last longer.

2.17.2 Loss of Freshness in Produce

The keeping and the preparation of fresh produce after harvest affects its nutritional value in several ways, for example: Dry matter content (the energy supply) is reduced with time as the continuation of living processes within the produce uses up stored food reserves. Vitamin C content decreases with time after harvest, and little may remain after two or three days. The enhancement of produce shelf life and the maintenance of quality will require careful manipulation of the storage environment or conditions (Maalekuu, 2008). Many growers know how to increase yields but do not pay sufficient attention to the quality of the produce, leading to low market value. Many handlers unknowingly contribute to postharvest losses by using common practices or by not using certain practices known to reduce losses and help maintain produce quality and safety.

Each example above is considered an improper practice since it has definite negative effects on fresh produce, leading either to increased waste and losses, quicker quality deterioration, or food safety problems (Kitinoja and Kashmire, 2002). Most of these improper practices and conditions cannot be labeled "technical problems," and they cannot be solved by initiating new research projects or simply by extending existing well-proven technical information. Often, postharvest losses take time to develop, and the specific cause of quality problems may not be fully understood by produce handlers along the chain. Other times, the handler may deliberately choose not to use a practice known to protect produce because of its cost or because consumers perceive the practice as undesirable. On occasion, a lack of reliable supplies, market information, or other infrastructural problems may make changes in handling impractical.

Postharvest losses and changes in quality affect both the volume and perceived value of produce as it moves from the field to its final destination market, and any changes in practices will also have an effect. Part of any potential technical solution, therefore, is a consideration of the socioeconomic, cultural, and institutional constraints facing growers, handlers, and marketers when they attempt to make changes in the way they handle and market horticultural crops (Kitinoja and Kashmire, 2002).

2.18 POSTHARVEST LOSS

Quality deterioration results in partial or total loss of fresh produce. It is predisposed by a number of interacting factors, which may be pre-harvest, harvest and/or postharvest in origin, such as poor crop variety, unfavorable climate, inadequate cultural practices, and lack of harvesting techniques, improper handling, and poor storage conditions. Non-technological factors also contribute to postharvest loss, such as lack of capable human resources, lack of knowledge about technical and scientific technologies, inefficient commercialization and marketing systems, lack of logistical support, and lack of enabling policy for the use and administration of human, economic, technical, and scientific resources. Postharvest losses of vegetables vary with commodity, location, growing season, and other factors such as standards of quality and consumer preferences and purchasing power, which differ greatly among countries and across cultures (Kader and Rolle, 2004). Losses of fresh fruits and vegetables after harvest may reach very high values depending on the species, harvest methods, length of storage, marketing conditions, etc. Losses are particularly high in underdeveloped countries (almost 50%) and most of them are due to pathogen attacks (Wilson and Wisniewski, 1989)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was carried out in the Asante Mampong Municipality. Asante Mampong (7° 4N, 10° 22W) lies about 457.5m above sea level and lies in the transitional agro- ecological zone with the forest of the south and Guinea savannah to the North. Meteorological Station, Mampong, 2001).The vegetation of Mampong Ashanti is the semi-deciduous type with thick-grass cover. However, due to human activities such as bush burning, indiscriminate felling of trees by chain-saw operators and charcoal making the amount of rainfall has declined and has subsequently affected the vegetation of the area. Asante Mampong experiences a bimodal rainfall system. The major raining season starts from March and ends in July, whereas the minor season begins from mid- August and ends in November. There is a long dry spell (that is Harmattan) from November to March. (Meteorological Station, Mampong, 2001). The soils in Mampong are classified as Chromic Luvisol in the FAO-UNESCO classification system (Asiamah, 1998). It belongs to the Bediesi series which is well drained friable, red permeable, have moderate organic matter content and moderate water holding capacity. The soil was derived from the voltarian sand stone. It is good for the cultivation of many vegetables including pepper, carrot, egg plant, many staples and commercial crops such as cocoa, cassava, maize and cowpea. Tillage of the soil can easily be done manually and mechanically.

3.2 Materials

The following materials were used in the study.

Ninety (90) Carrots of 'Tokita' variety were used for the study. Digital weight scale, hand held refractometer, metal sponge, brush, plastic bowls, laboratory mortar and pestle, distilled water, paper tapes, oven, analytical scale, knife, chopping board, decicator, and penetrometer.

3.3 METHODOLOGY

3.3.1 Data collection

Data were taken in three parts, first was field survey, secondly on-field quantitative loss assessment and lastly, laboratory work. Interviews and personal observation were employed both on farmers' farm and the market to gather information on postharvest handling practices.

3.3.1.1 Questionnaire Design

A structured questionnaire was designed for carrot farmers, marketers and consumers to identify the various postharvest handling practices of carrots along the value chain. Information solicited included demographic characteristics of respondents, on-farm practices, means of transportation, packaging, marketing and postharvest treatments applied to harvested carrot roots.

3.3.1.2 Quantitative loss assessment

Losses of carrots were assessed both at the farm gate after harvest and on the market after transportation. On the farmer's farms, the number of roots considered spoilt/unmarketable by the farmers was counted and subtracted from the total number of roots harvested to obtain the marketable produce. At the market, the number of roots considered by traders as spoilt/non-marketable was also counted and subtracted from the total number of roots purchased and transported to the market to obtain marketable roots. On farm loss assessment was done at the various farming communities and the average loss was determined for the municipality. Market loss was assessed in the major marketing centres where wholesalers transport carrots to and from the Asante Mampong municipality. The average losses were calculated as: x±SD.

3.3.1.3 Storage at the laboratory

Fresh carrots cv. "Tokita" was harvested on 11th April from a commercial farmer in the Asante Mampong Municipality, Ashanti Region of Ghana. Carrots were packed in a sack and transported as per farmer practice to the laboratory at the Department of Horticulture, KNUST, Kumasi, where carrots were kept under ambient conditions for study.

3.4 EXPERIMENTAL TREATMENTS

Identified farmer/trader practices during sales were simulated at the laboratory during the study. The treatments were

3.4.1 Control treatment

The roots were left with the soil on it and brought to the laboratory.

3.4.2 Scrapped treatment

The carrots were first washed to remove the soil on it with distilled water. A metal sponge was used to scrape the outer epidermis of the roots and re-washed. The water was allowed to drain off and randomly placed in the replications.

3.4.3 Washed treatment

The carrots were washed with the bare hands with distilled water to remove the dirt on them. It was allowed to drain off excessively before placing it at random in the replications.

3.5 PARAMETERS ASSESSED

3.5.1 Weight loss

Initial weights (g) of all individual roots in all the treatments were taken and subsequently at three days interval until the study were truncated when the roots were adjudged unsalable. An electronic weight device was used. Weight loss was determined as: initial weight –final weight/initial weight×100. Shibairo, (1996).

3.5.2 Moisture content

The moisture content of the samples was determined using an electric oven (Wagtech) and an analytical scale (AAA 100LE). The weight of the petri dish was taken after which a slice of the carrot was added to it and weighed again. The samples were oven dried at a temperature of 105^{o}C and re-weighed after 24 hours (Rashidi *et al*., (2010). Percentage Moisture content was calculated as:

$$\frac{\text{(Fresh weight-oven dried weight)}}{\text{Fresh weight}} \times 100.$$

Where the fresh weight was the weight minus the petri dish before drying and the weight after drying is the weight minus petri dish after drying.

3.5.3 Dry matter content (%)

Dry matter content of carrots was determined for the period of storage using analytical scale (AAA 100LE). Two grams (2g) of fresh carrot root was placed in an electric oven and dried at 105^{o}C for 24 hours (Ryall *et al*., 1982). Dry matter content was calculated as:

$$\frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.5.4 Root Firmness

A hand held penetrometer (Fruit pressure tester (FT 327)) was used to test for flesh firmness of the carrots in every three days till the end of the experiment (Rashidi *et al*., (2010). The samples were firmly held with one hand on a rigid surface. The penetrometer was zeroed and the plunger head depressed at the mid-point of the longitudinal axis of the carrots. A steady downward pressure was applied until the plunger penetrated the flesh of the carrots up the depth mark (half way up) on the plunger. Slow, steady pressure is essential as sharp uneven movements may give unreliable results. Plunger was removed and the reading on the penetrometer dial recorded to one decimal place. The process was conducted on other treatments in each replications and the average calculated.

3.5.5 Total Soluble Solids (TSS) Content

Total Soluble Solids (TSS) was determined using a hand-held refractometer, MT-032. QA supplies, LLC.

Whole roots were sliced with a knife on a chopping board and mashed with laboratory mortar and pestle. A drop of the juice was squeezed onto the prism plate. The reading on the prism scale was noted facing the prism surface to a light source. The prism plate was cleaned with distilled water and wiped dry with a soft tissue before new tests were conducted for other treatments and the average TSS calculated (Harrill, 1998). The results were expressed as ^{0}Brix.

3.5.6 Root Shrinkage (%)

Sensory quality was evaluated by a ten member panel trained to score the quality attributes of stored carrots. Appearance (Wrinkling) was evaluated on a 3 point scale indicated below:

0- No wrinkle

1 - Minor shrinkage (<40% of surface wrinkled)

2 -major shrinkage (>40% surface wrinkle) Simões *et al*, (2009)

3.5.7 Decay/Rot (%)

A ten member panel was trained to score the quality attribute of stored carrots at the laboratory.

Decay/rot was evaluated using a scale as follows:

0=No Rot

1=1-25% Rot

2=26-50% Rot

3=51-75% Rot

4=76-100% Rot

3.5.8 Determination of Shelf life

The shelf life of the carrots was estimated from the time of harvest to the time the carrots were adjudged unmarketable because they were either excessively wrinkled or had the surface showing decay/rot.

3.6 EXPERIMENTAL DESIGN

A Randomized Complete Design (CRD) with three treatments, that is Control treatment, Washed treatment, and Scrapped treatment, and three replications were used.

3.7 STATISTICAL ANALYSIS

The data collected from the field survey and the laboratory work was statistically analyzed using Statistical Package for the Social Scientist (SPSS), version 17 software. The laboratory data were submitted to analysis of variance using Statistix 9 statistical software and least significant difference (LSD) test was applied to distinguish between means that were statistically different (P=0.05) among treatments. The results were presented in tables and charts.

CHAPTER FOUR

4.0 RESULTS

4.1 FIELD SURVEY

This chapter is devoted to the analysis of data gathered from the field survey conducted during the study. These are shown in tables and pie charts covering the demographical data of respondents (farmers, marketers, retailers and consumers) as well as the assessment of postharvest handling practices and losses of carrots in Mampong Municipality.

4.2 Demographical Data of Respondents

Table 4.1 indicates the data pertaining to respondents' demographical characteristics such as gender, educational levels, age and experience in carrots business. Among the fifty (50) respondents interviewed forty-seven (47) were males representing 94% while three (3) were females representing 6%. Majority (46%) of the respondents were aged between 31-40 years, as compared to those below the age of 20 years, representing 2%. For educational level, respondents were sorted out as non-formal, JHS/MS, SHS/VOC and tertiary education. Sixty percent (60%) of them had education up to JHS/MS level. On the other hand, 26% of the respondents did not have any formal education. Twenty eight percent (28%) of the respondents had between 4-6 years' experience in carrot business while 2% had less than one year experience.

Table 4.1: Demographic characteristics of respondents

Characteristics	**Level**	**Frequency**	**Percentages (%)**
Gender	Male	47	94
	Female	3	6
Age group	Below 20 years	1	2
	21-30 years	20	40
	31-40 years	23	46
	41-60 years	6	12
Education	Non-formal	13	26
	JHS/MS	30	60
	SHS/VOC	6	12
	Tertiary	1	2
Experience	Less than 1 year	1	2
	1-3 years	12	24
	4-6 years	14	28
	7-10 years	10	20
	More than 10 years	13	26

4.3 Varieties of Carrots Cultivated

Figure 1 indicates the varieties of carrot cultivated by the respondents. Out of the fifty (50) respondents interviewed forty-eight (48) cultivated Tokita variety only, representing 96% while the remaining two (2) cultivated Amazonia variety only, representing 4%.

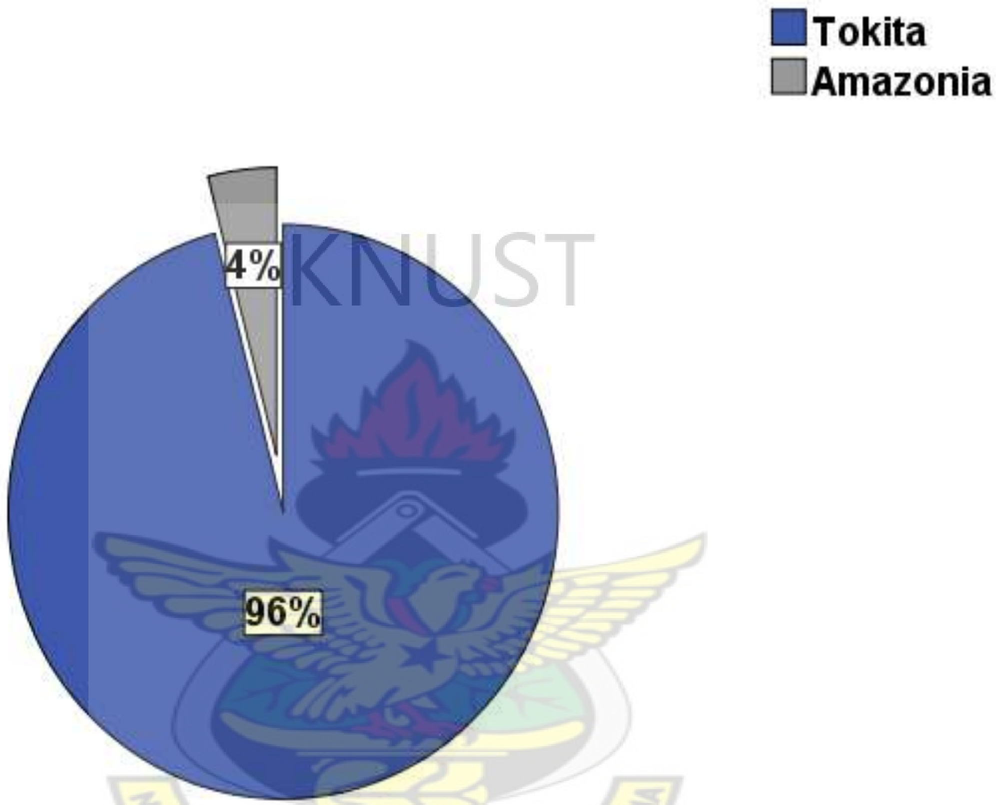

Figure 4.1: Varieties of carrot cultivated by producers

4.4 Time of Harvesting Carrots

Figure 4.2 indicates the time for harvesting carrots. The result showed that, out of the fifty (50) respondents, forty-six (46) harvested carrots in the morning, representing 92% while the remaining 8% harvested carrots in the afternoon.

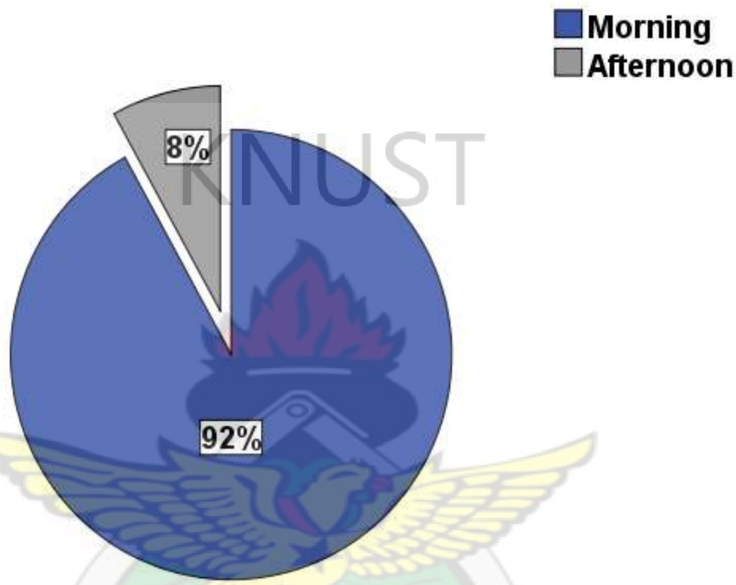

Figure 4.2: Time of harvesting matured carrots

4.5 Methods of Harvesting Carrot

Figure 4.3 shows the methods adopted by respondents for harvesting carrots. Out of the fifty (50) respondents interviewed forty-five (45) harvested carrots by uprooting, representing 90% while the remaining five (5) harvested carrots by digging, representing 10%.

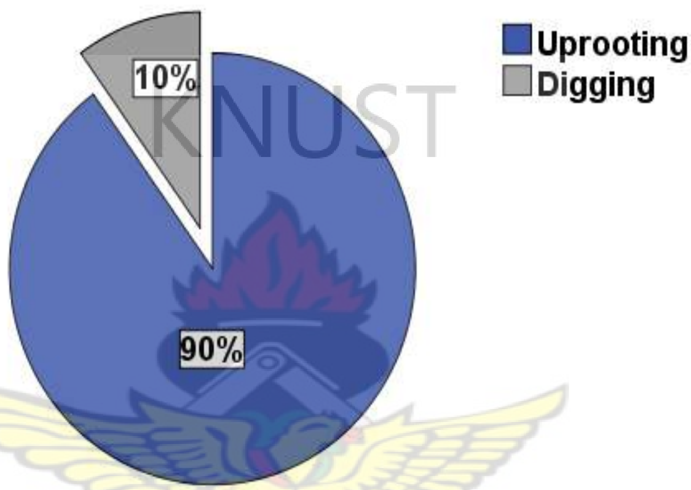

Figure 4.3: Harvesting methods used by carrots farmers

4.6 Sorting and grading after Harvest

Figure 4.4 indicates whether respondents sorted and graded carrots after harvest before selling to marketers. The results revealed that, forty-six (46) of the respondent's sorted and graded carrots before selling to marketers, representing 92%. This was done based on qualities such as shape, size, shrinkage and texture. However, the remaining 8% of the respondents neither sort nor grade carrots before selling to the wholesalers.

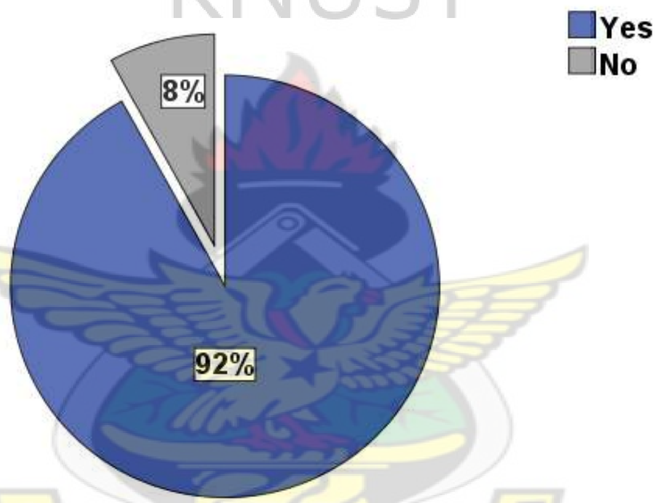

Figure 4.4: Sorting and grading of carrots by farmers

Table 4.2 presents the grading system used in the carrot industry in the Asante Mampong municipality. There were 2 major grading systems. According to the farmers, carrots were graded as “Papa”, “Social”, “Broken”, and “Under”. On the other hand the wholesalers had 5 grades being “Papa”, “Nhyemfra”, “Social”, “Broken”, and “Under”. Whereas Grade 1 was the finest, grade 5 represented the poorest.

Table 4.2. Grading of carrots by farmers and traders

GRADE	FARMERS	MARKETERS
1	Papa	papa
2	Social	Nhyemfra
3	Broken	Social
4	Under	Broken
5	-	Under

Source: field survey, 2012

4.7 Pre-cooling of Carrots after Harvest

According to 96% of the farmers (Fig 4.5) they did not carry out pre-cooling of their harvested carrots. However, 4% of them did pre-cooling after harvest prior to selling to the wholesalers.

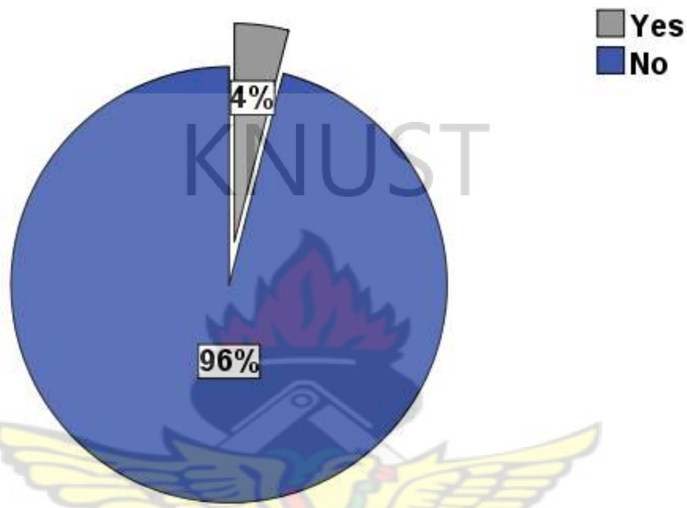

Figure 4.5: Pre-cooling of carrots after harvest

4.8 Marketing of Carrots by producers

Figure 6 indicates the marketing strategies adopted by producers in selling carrots to marketeters. The study revealed that, 8% of the carrot farmers sold their carrots directly to retailers (Fig 4.6). On the other hand 92% sold either to middlemen (68%) or farmer association (28%)

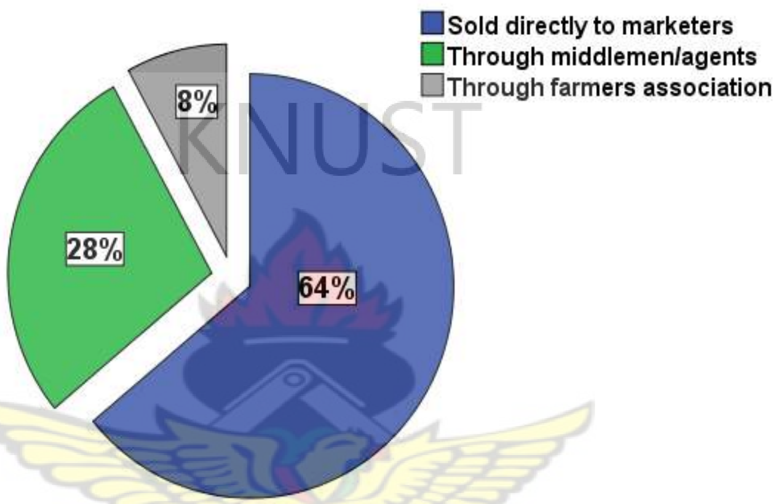

Figure 4.6: Marketing Strategies used by producers

4.9 Transportation of Carrots by Producers

The means of transport used to transport carrots from farm gates to market has been presented on figure 4.7. The study revealed that most (54%) of the respondents reported that they used Kia trucks for transporting their carrots. The next popular means of transport was the use of mini vans (popularly called urvan buses) which was used by 28% of the respondents. The use of taxi cab was common among 18% of the respondents.

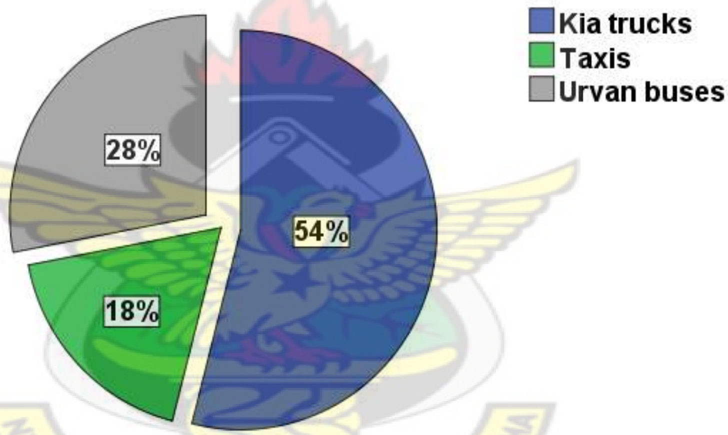

Figure 4.7: Means for transporting carrots

4.10 Sorting and grading of Carrots by wholesalers

Figure 4.8 shows the proportions of carrot seller's practice of grading. Seventy two percent of the carrot sellers reported that they graded and sorted their carrots before selling them. Grading was based on root size whereas sorting was based on degree of wholesomeness and deformities of roots.

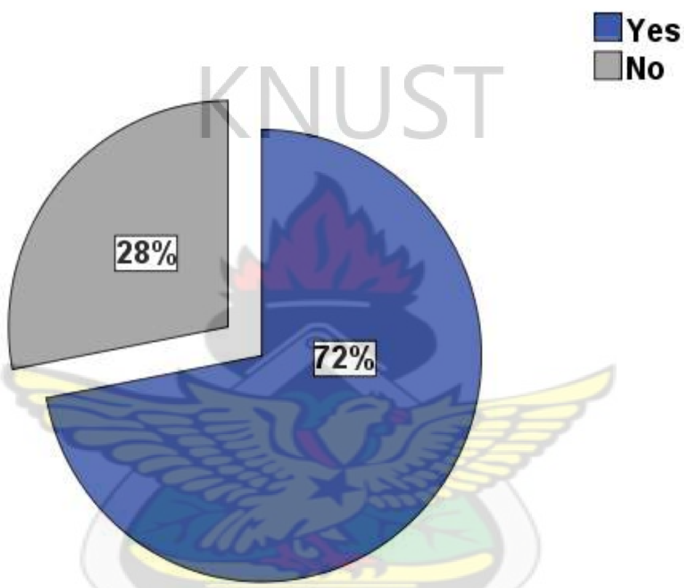

Figure 4.8: Sorting and grading of carrots by wholesalers

4.11 Controlling water loss by retail marketers

Figure 4.9 presents the strategies adopted by retail marketers in controlling water loss from carrots. All the carrot retailers took measures to reduce moisture loss during sales. Majority (76) of the carrot retailers indicated that they sprinkled water on their carrots at the market during sales to minimize moisture loss (evapo-transpiration). On the other hand, 22% of the retailers reported they covered their carrots from the direct impact of sunlight. The covering material used was a piece of clean cloth. Two percent (2%) of them however, placed their carrots in polyethylene bags.

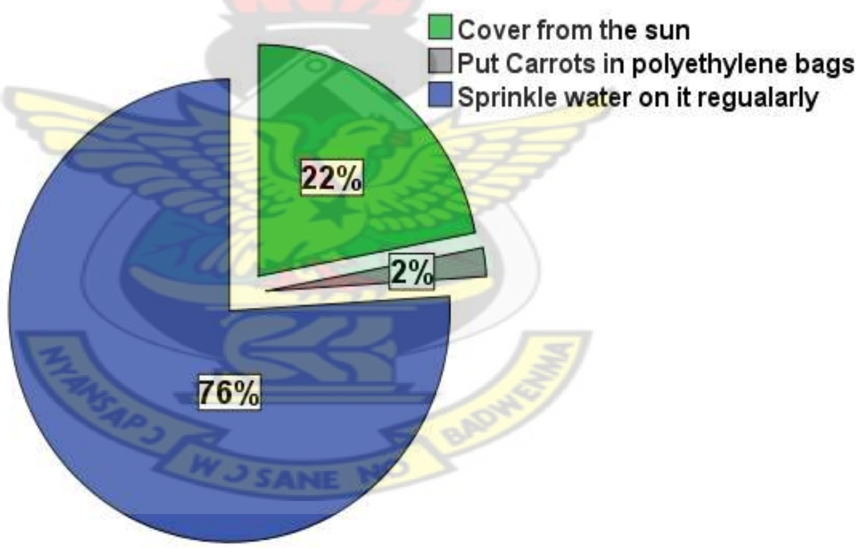

Figure 4.9: Controlling water loss during sales

4.12 Method of washing and sanitizing Carrots

Retailers processed carrots into baby carrots ready to be eaten by consumers. Eighty four percent (84%) used silver sponge to wash the carrots, 14% used brush to wash, and whiles 2% used their bare hands to wash the carrots.

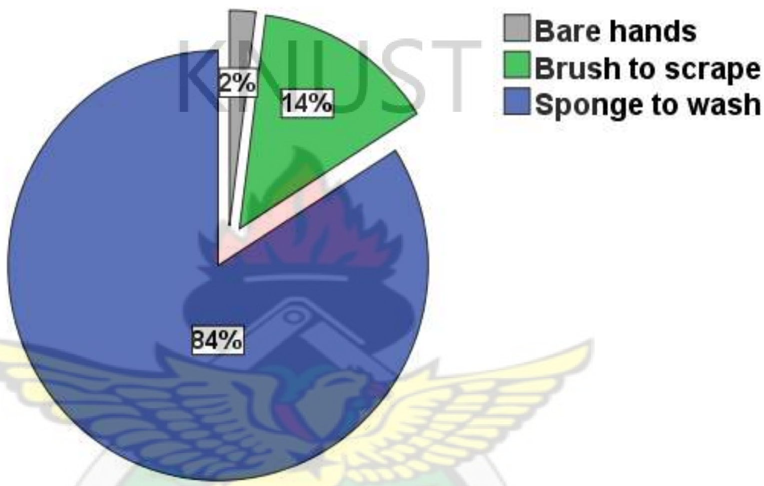

Figure 4.10: Methods of washing and sanitizing Carrots

4.13 Source of Carrots to Consumers

The source of carrots to consumers as reported by the respondents is presented in figure 14. 58% said they buy their carrots from retail market, 40% indicated buying carrots from hawkers, whereas 2% bought carrots from farmers.

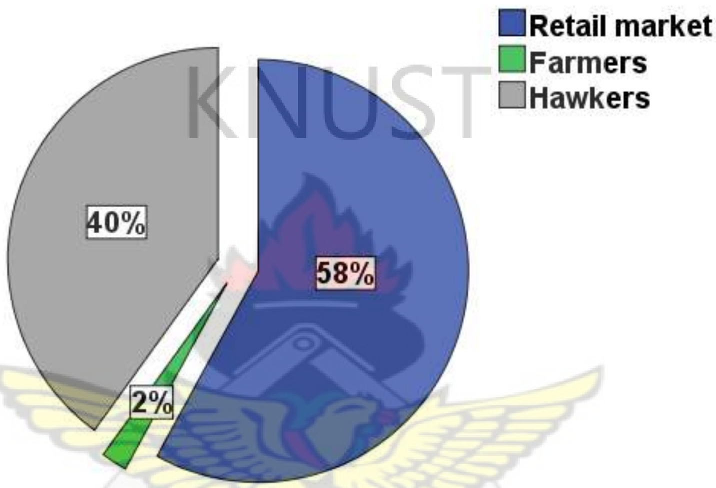

Figure 4.11: Source of carrots for consumers

4.14 Quality factors considered by Consumers before buying Carrots

Consumers used some quality factors in buying carrots for consumption. Most of the respondents (56%) bought carrots based on its firmness, 40% bought carrots based on its appearance (shrinkage) whiles 4% used colour as an indicator to buy carrots.

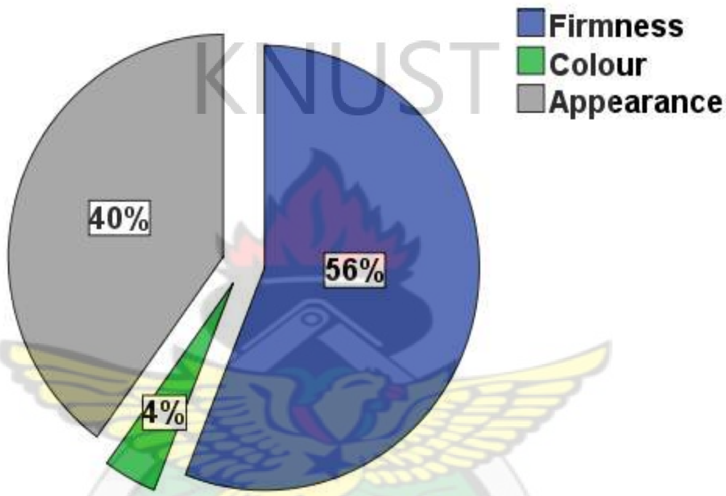

Figure 4.12: Factors considered by consumers before buying carrots

4.15 Methods of storing Carrots by Consumers

Majority (92%) of the of the respondents preferred storing carrots in the refrigerator. 6% stored carrots using other methods, and 2% stored carrots in cupboards as presented in figure 17.

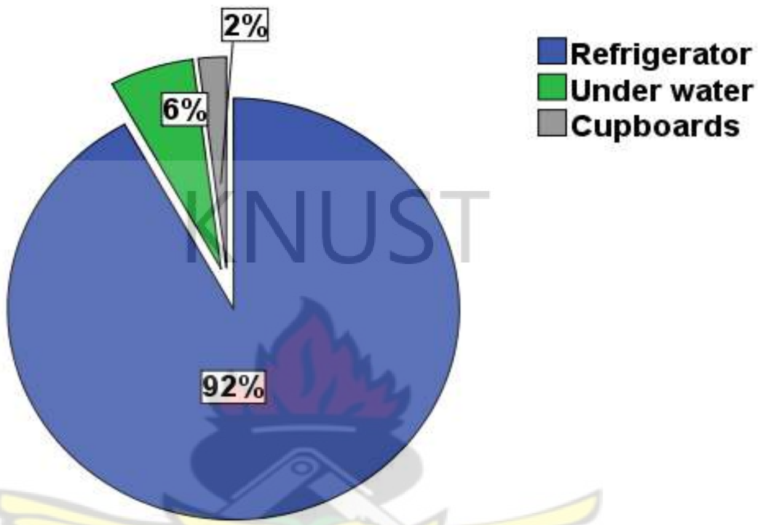

Figure 4.13: Methods of storing carrots by consumers

4.16 Quantitative assessment of Postharvest losses in Carrots

4.16.1 Farm gate loss assessment

Quantitative losses observed on carrots at the farm gate during the study were presented in Table 4.3. During the assessment it was observed that postharvest losses varied between 2.17% and 6.28% among the selected farms.

Table 4.3 Quantitative losses of carrots at the farm gate

Farms	Total roots harvested	Quantity rejected (lost)	Percentage (%) Loss
Kyirimfaso	29841	1875	6.28
Nkwanta	24354	1034	4.25
Bobin	23087	842	3.65
Adidwan	26676	579	2.17
Abuontem	37390	2102	5.62
Konkoma	31437	1191	3.79
Average Loss (%)	**-**		**4.29±1.48**

4.16.2 Causes of loss of carrots at the farm gate

The nature of the quantitative losses at the farm gate has been presented in Table 4.4. The quantitative losses were in the form of cracks, sunburns, discolorations, rot, nematode infested and undersized roots.

Table 4.4 Causes of loss at the farm gate

NATURE OF LOSS	CAUSES (FARMERS RESPONSES)
Cracks/Split	Heavy soils, over fertilization and high solar radiation
Discolorations/Sunburn	Exposure of un-harvested roots to sunlight
Nematode infestations	Nematodes in the soil
Rot/ decay	Fertilizer application coupled with too much watering and high solar radiation
Under development/Undersized	Overcrowding, feeding of the leaves by insects (crickets)

4.17.1 Market loss assessment

Quantitative losses at the market ranged between 1.45% and 10.11 %. (Table 4.5)

Table 4.5 Quantitative losses of Carrots at the market

Destination (Markets)	Total roots transported	Quantity rejected (Lost)	Percentage (%) Lost
Asante Mampong	6680	97	1.45
Abinkyi	20291	1837	9.05
Bantama	10661	1078	10.11
Ejura	22900	1221	5.33
Average Loss (%)	**-**		**6.49±3.93**

4.17.2 Causes of loss of carrots at the market

Table 4.6 indicates the causes of loss observed at the market after transport of carrots to the various wholesale markets. The nature of the loss as indicated by the respondents was that, rotten/softness of the carrots was as a result of heat buildup along the chain, from the farm till it got to the markets. However they said some farmers did not sort out cracked and nematode infested and under developed roots from the bagged roots.

Table 4.6. Causes of loss at the market

NATURE OF LOSS	CAUSES(TRADERS RESPONSES)
Softness/ rot	Heat
Cracks, nematode infested and under developed	Improper sorting by farmers

4.18 Shelf life of carrots

The perception of retailers of the shelf life of the carrots they sold has been presented on Table 4.7. According to the respondents, (54%) said when carrots are prepared by scrapping; the shelf life was between 7-14 days. On the other hand, the shelf life reduces to 7 days when the carrot peel is scrapped as reported by 94% of the retailers.

Table 4.7 Shelf life of carrots according to the survey

Shelf life	Not scrapped	Scrapped
7 days	46%	94%
7-14 days	54%	6%

4.19 Effect of processing Method on quality of carrots

4.19.1 Weight loss

Percentage weight loss of carrots stored and studied over the period of the experiment was shown in Table 4.8. Initial weights of carrots were taken on the first day. On the 3rd day the scrapped roots had lost about 26% of its weight, the control with 24% loss in weight, and the washed roots 21% weight loss. Weight loss on the fifth day was as follows, scrapped 14%, control 16%, and washed 16%.

Table 4.8 Weight loss of carrots

TREATMENTS	DAY 1 (%)	DAY 2 (%)	DAY 3 (%)	MEANS
Control	0	26.170 A	16.000 A	14.0566
Scrapped	0	24.477 AB	14.133 A	12.87
Washed	0	21.753 B	16.061 A	12.6046
LSD	0	3.5559	2.7891	-
CV (%)	0	7.37	9.07	-

4.19.2 Firmness

The firmness of the carrots ranged between 6.97N and 7.37N (Table 4.9) at the onset of the study. The study showed similar firmness irrespective of the treatment of days 1 and 3. However, on the 5th day the Control (not scrapped), 8.00N roots were significantly softer than the washed (8.87N) which was similar to the Scrapped (8.00N)

Table 4.9 Firmness of Carrots

TREATMENTS	DAY 1 (N)	DAY 3 (N)	DAY 5 (N)	MEANS
Control	7.3333 A	8.0000 A	8.0000 AB	7.7777
Scrapped	7.3667 A	7.1333 A	7.0000 B	7.1666
Washed	6.9667 A	7.2000 A	8.8667 A	7.6778
LSD	1.1477	2.4532	1.0841	-
CV (%)	7.95	16.49	6.82	-

4.19.3 Total Soluble Solids (TSS)

The Total Soluble Solids of the carrot roots in the various replications were determined and the results presented in Table 4.10. It ranged between 4.17 ^{0}Brix and 12.27 ^{0}Brix. There were no significant differences among treatment means.

Table 4.10 Total Soluble Solids of Carrots

TREATMENT	DAY 1 (^{0}Brix)	DAY 3 (^{0}Brix)	DAY 5 (^{0}Brix)	MEANS
Control	4.1667 A	7.9333 A	12.267 A	8.1223
Scrapped	4.3000 A	10.333 A	10.200 A	8.2777
Washed	4.1667 A	6.6667 A	10.067 A	6.9668
LSD	0.4709	6.7417	2.6270	-
CV (%)	5.60	40.60	12.12	-

4.19.4 Shrinkage

As presented in Table 4.11, there was no significant difference among the treatments from Day 1 to Day 5.

Table 4.11 Shrinkage of Carrots

TREATMENT	DAY 1 (%)	DAY 3 (%)	DAY 5 (%)	MEANS
Control	0	1.0667 A	1.6000 A	0.8889
Scrapped	0	1.2667 A	1.8667 A	1.0445
Washed	0	1.0667 A	1.8000 A	0.9556
LSD	0	0.3263	0.4212	-
CV (%)	0	14.41	12.01	-

4.19.5 Moisture content

The results of Moisture content among the treatments showed no significant difference (Table 4.12). It ranged between 76.06% and 86.96%.

Table 4.12 Moisture Content of Carrots

TREATMENTS	DAY 1 (%)	DAY 3 (%)	DAY 5 (%)	MEANS
Control	86.580 A	81.533 A	82.170 A	83.4277
Scrapped	86.890 A	80.250 A	76.060 A	81.0667
Washed	86.963 A	85.597 A	78.500 A	83.6867
LSD	4.1461	6.2474	6.6644	-
CV (%)	2.39	3.79	4.23	-

4.19.6 Dry matter content

The dry matter content of the stored carrots was determined and the results presented in Table 4.13. It ranged between 13.033% and 23.933%.

Table 4.13 Dry matter content of stored carrots

TREATMENTS	DAY 1 (%)	DAY 3 (%)	DAY 5 (%)	MEANS
Control	13.433 A	18.467 A	17.833 A	16.5777
Scrapped	13.133 A	19.733 A	23.933 A	18.9333
Washed	13.033 A	14.400 A	21.533 A	16.3222
LSD	4.1509	6.2551	6.6303	-
CV (%)	15.74	17.83	15.73	-

4.19.7 Decay/rot

As shown in Table 4.14, there was no significant difference in decay on the 1st and 3rd day. However, significant differences were observed on the 5th day between control treatment and the other two treatments. The extent of decay in the roots on day 3 ranged between 3.33 and 11.67%. By the 5th day, the scrapped roots had as much 56.67% decay similar to the washed. However, the control, which was neither scrapped nor washed, had significantly lower decay.

Table 4.14 Decay of Carrots

TREATMENTS	DAY 1 (%)	DAY 3 (%)	DAY 5 (%)	MEANS
Control	0	3.3333 A	25.000 B	9.4444
Scrapped	0	11.667 A	56.667 A	22.778
Washed	0	8.3333 A	53.333 A	14.9999
LSD	0	9.9895	16.979	-
CV (%)	0	64.29	18.89	-

4.19.8 Shelf life of carrots in storage

Shelf life of the carrots stored at the laboratory at room temperature for the study was determined. The Carrot roots were considered unmarketable when decay appeared on them or had become excessively wrinkled. The average storage life for the controlled roots was 5 days, that of the washed roots was 4 days and the scrapped roots was 3 days, (Table 4.15).

Table 4.15 Shelf life of carrots in storage at the laboratory

TREATMENT	SHELF LIFE (DAYS)
Control	5 A
Washed	4 B
Scrapped	3 C
LSD	0.8632
CV (%)	10.45

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 DEMOGRAPHIC DATA OF RESPONDENTS

Among the carrot farmers, 94% were males, 6% were females. The high involvement of males in the production of carrots could be due to the labour intensiveness involved in the production. On the other hand, women are traditionally known to be predominant in marketing activities than farming since carrot farming activities such as planting, watering, weeding and harvesting was found to be tedious. Majority of the respondents fell between ages 31-40. This may be due to the fact that people of this age group are energetic and therefore have competitive advantage in the production of carrots.

Majority of the respondents have had quite a number of experiences in the production of carrots, with 4-6 years recording highest. Therefore it was expected that they would have the skill to produce good quality carrots. However, in this study it was observed that most of the farmers did not use appropriate postharvest handling practices relating to transportation and pre-cooling.

5.2 VARIETIES OF CARROT CULTIVATED

The survey revealed that 96% cultivates Tokita variety of carrots, with 4% cultivating Amazonia. According to the respondents, their choice of Tokita variety was due to its high yield and ready market. Wholesalers were ready to buy no matter the quantity supplied by producers. This enhances profitability resulting in improved standard of living of farmers. Carrot varieties vary in their susceptibility to breakages.

In general, Nantes types are more susceptible to breakage than Western Red and Imperator types. There are also differences among Nantes varieties in resistance to breakage.

The Japanese Kuroda varieties have proved to be highly susceptible to breakage. Farmers should therefore be careful in the variety of carrot they grow.

5.3 TIME OF HARVESTING CARROTS

Ninety-two (92%) of carrot farmers in the Asante Mampong municipality harvested their carrots in the morning, eight (8%) harvest in the afternoon. Harvesting in the morning was preferred much to the afternoon and evening. The reasons for the early morning harvesting, according to the farmers, were that buyers arrived early in the morning to purchase carrots. Also early harvesting was conducive since by then the sun has not risen by then and much work could be done before getting tired. In hot weather, farmers should harvest during cool times of the day. Harvesting early in the morning will reduce dehydration and reduce the time for carrots to cool down. High temperatures accelerate the rate at which disease-causing fungi and bacteria grow.

5.4 HARVESTING METHODS

Farmers harvest carrots using bare hands to uproot and sometimes dig with cutlass when the soil is too compact. In all, 90% indicated harvesting by uprooting with 10% doing it by digging. During harvesting; vegetables are bruised and broken as a result of harvesters using cutlasses or hard soil pans which could lead to infection and subsequent rots.

Bachmann & Earles, (2000) reported that, postharvest rots have been found to be more prevalent in bruised or damaged produce. Mechanical damage also increases moisture loss by as much as 3-4 times more than that of undamaged produce. Since most farmers harvested by forcibly uprooting the tuber, it could result in higher levels of broken and bruised roots if not harvested with care.

This would therefore result in higher postharvest losses as observed in this study (Table 4.3). Higher postharvest losses of tuber could reflect in higher economic losses for all along the value chain. Farmers should therefore harvest with care.

5.5 SORTING AND GRADING AFTER HARVEST

Majority of the farmers and marketers does sorting and grading of the carrots into grades and sold those produce based on physical characteristics such as size, shape colour/appearance and texture. 96% of farmers in the municipality does sorting and grading as against 72% of marketers who sort and grade their carrots before selling, whereas 8% of farmers does no sorting or grading as against 28% of marketers who does no sorting or grading.

This according to them normally happens during the off season when carrots are scarce. According to Bautista & Acedo, (1987), sorting is done to separate poor produce from good produce, and further classify the good produce based on other quality parameters, such as size.

5.6 GRADING SYSTEM USED IN THE CARROT INDUSTRY

In other to distinguish between the qualities of carrots harvested and to be sold, farmers and wholesalers in the Asante Mampong municipality has develop local names to identify their carrots. The farmers had four grading systems namely, “Papa”, “Social”, “Broken”, “Under”, where “Papa” represents grade 1 which was the finest and “Under” grade 4, which was the poorest. Wholesalers on the other hand had five grading systems; “Papa”, “Nhyemfra”, “Social”, “Broken”, and “Under”. “Papa” was grade 1 and “Under” grade 5. “Nhyemfra” was a mixture of “Papa” and “Social”. The mixture increases the profit margin of the wholesalers.

5.7 PRE-COOLING

Only 4% of carrot farmers in the Asante Mampong municipality pre-cool their produce before selling to marketers. Pre-cooling was done by packing bagged carrots under trees whiles awaiting transportation to the market. 96% of the farmers said they do not have any facility for such activity. Kader and Morris (1970), reported that, delays between harvesting and cooling or processing can result in direct losses due to water loss and decay and indirect losses such as those in flavor and nutritional quality. Carrots were packed as soon as they were harvested and kept in the sun awaiting transportation. This increases heat buildup and thus result in the softening and rot of the roots after transportation. Pre-cooling is therefore very needful to reduce postharvest losses as most of the loss observed was due to softening and rots. Harvested carrots should therefore not be kept exposed to the sun. Shading will reduce dehydration (Appiah *et al*., 2012). Heated carrots will lose their quality and dehydrate more quickly.

5.8 MARKETING OF CARROTS BY FARMERS

Farmers in the Asante Mampong municipality had marketing channels in selling their carrots. 64% sold their carrots directly to wholesalers, 28% sold carrots through middlemen, whereas 8% sold carrots through farmer based association. The farmers pre-arrange with the wholesalers before harvesting, any delay or prolong holding of the carrot on the farm could affect the quality. Since majority of the farmers sold directly to wholesalers, it could affect their profit margin since prices sold to retailers was higher than that of the wholesalers. According to Kader and Morris, 1978 delays between harvesting and cooling or processing can result in direct losses due to water loss and decay and indirect losses such as those in flavor or nutritional quality.

5.9 TRANSPORTATION

According to the survey, two main means of transportation to the main wholesale market in the municipality was by vehicles and carrying on the head. Transportation to other marketing centers was by vehicles such as, KIA trucks, urvan buses and taxis. These vehicles had no cooling systems, thus no temperature regulation and therefore cause heat buildup which might be the main cause of the rot and softening of the carrots. The road network from the farms to the municipal market was undulating and therefore vehicle were reluctant to ply the roads. However roads leading to marketing centers in Kumasi and Ejura were good. Due to the bad nature of the roads from the farm, there were delays in reaching the market which could lead to bruises and breaks, which is a predisposing factor to rot/decay.

Postharvest rots have been found to be more prevalent in bruised or damaged produce.

Mechanical damage also increases moisture loss by as much as 3-4 times more than that of undamaged produce (Bachmann and Earles, 2000).

Carrots should therefore be transported carefully to avoid excessive bouncing and shaking in bins and sacks, to reduce bruising and splitting. In hot weather, cover the carrots with a tarpaulin during transport. If packed and transported without cooling, wilting and other deteriorative processes rapidly set in (Jiang and Pearce, 2005). However, dirty and contaminated field boxes are to be avoided. Do not pack damaged, over mature or diseased carrots in the same packaging as healthy carrots.

5.10 SORTING AND GRADING BY WHOLESALERS

The study showed that, 72% of the wholesalers sorted and graded carrots to retailers, 28% of them did neither sort nor grade carrots before selling to retailers.

Sorting is done to separate poor produce from good produce, and further classify the good produce based on other quality parameters, such as size (Bautista & Acedo, 1987). This prevents extensive rotten since rotten carrots will contaminate the good ones. Grading increases profit as fine carrots attracts good prices and consumers. Wholesalers therefore need education to understand the need to always carry out sorting and grading.

5.11 METHODS OF CONTROLLING WATER LOSS

Retailers process carrots for sale by scrapping the back to make it appealing and ready to eat. In an attempt to conserve its moisture and maintain its texture, 76% said they sprinkle water on the carrots during sales, 22% cover the carrots using a piece of cloth with 2% covering carrots with plain polyethylene bags. The use of polyethylene bags could cause heat buildup, rots and fermentation. To minimize scaling, it is important that carrots do not become dehydrated at any stage in the harvest–postharvest chain. Shorter and gentle washing may leave the skin layer intact and keep washed carrots wet. Wet hessian bags over the top of bulk bins will help retain moisture, if no cool room is available. Post-harvest moisture loss causes carrots to become shriveled (Hurschka, 1977), lose their bright orange appearance, and become susceptible to post-harvest decay (Van den Berg and Lentz, 1966), 1973).

5.12 PROCESSING OF CARROTS

Retailers processed carrots into baby carrots for consumers using various methods. Majority (84%) used metal sponge to wash dirt on carrots, 14% used brush to scrape and 2% used their bare hands to wash. The metal sponges remove the outer epidermises which expose the carrots to pathogens. Report by Li & Barth, 1998 indicates that, Baby carrots which are prepared by peeling the outer layer of the carrot roots are susceptible to a variety of physiological changes that reduce their quality. Clean water is essential as fungal and bacterial levels may otherwise build up. Wills *et al*. (1998). Retailers should therefore add food disinfectants (5ml of clorax) to the water use in washing as recommended by MOFA, (2008).

5.13 SHELF LIFE OF CARROTS

Ninety-four (94%) of the retailers said, scrapped carrots remained wholesome or marketable for a maximum of seven days as against 54% who claimed that carrots stays wholesome for an average of fourteen days, if not processed (not scrapped). On the other hand, six percent (6%) indicated that scrapped carrots stay wholesome for an average of 14 days as against 46% who said carrots could stay for 7 days if not scrapped or washed. (Table 4.7)

The laboratory studies however revealed that, the control treatment had an average storage life of 5 days (Table 4.14); the washed roots had 4 days; whereas the scrapped roots had 3 days average storage life. The study showed that the untreated (raw/control) had significantly higher shelf life than the washed, which also lasted a day longer than the scrapped roots. This however does not support claims made by the retail marketers that the unscrapped could last for 14 days and the scrapped roots for 7 days. The main problems that limit the shelf life of baby carrots to 4-5 days are; high respiration rate (RR), development of off-flavours, acidification, loss of firmness, discoloration and microbial spoilage (Barry-Ryan & O'Beirne, 2000; Barry-Ryan, Pacussi & O'Beirne, 2000). In the present study, the loss was mainly decay due to microbial spoilage. This could be as a result of creation of wounds with scrapping and the use of contaminated water. To extend the shelf life of carrots however, marketers and consumers may use a food disinfectant in washing or store in a refrigerator.

5.14 SOURCES OF CARROTS TO CONSUMERS

According to the consumers, they obtain carrots from the retail market, farmers and hawkers. 58% bought carrots from the retail market, 40% bought from hawkers, and 2% bought from the farmers. The higher percentage of the respondents who bought from the retail market may be that higher number of the carrots is readily available for sale by retailers to people who need carrots for various uses at home or restaurants. People who buy baby carrots from hawkers are mainly those who are ready to eat it. According to Li & Barth, 1998 the consumption of carrots has steadily increased in popularity in the last few years, particularly baby carrots which is one of the most popular products. Farmers do not normally sell their carrots directly to consumers, according to the survey, and that may have accounted for the low percentage of consumers who source carrots from them.

5.15 QUALITY FACTORS CONSIDERED BY CONSUMERS BEFORE BUYING CARROTS

When buying carrots, consumers look out for certain quality attributes. In all, 56% considered firmness as a way to determining quality, 40% use its appearance, and the remaining 4% use colour. Soft and decaying roots are instantly rejected by consumers as spoilt. Work done by Wiley, 2004, revealed that, the appearance of a fresh-cut fruit or vegetable is the attribute most immediately obvious to the consumer, and strongly affects the decision to buy.

In most vegetables, mass losses of 5% or higher can produce wrinkling and a consequent decline in consumer acceptance (Pantastico *et al*., 1979).

5.16 STORAGE OF CARROTS BY CONSUMERS

Majority of the consumers interviewed indicated, that they store carrots in the refrigerator. This could be attributed to the fact that carrots can stay wholesome and fresh under low temperature for quite a long time. Work done by Hardenburg *et al*., 1986, revealed that, under ideal conditions of 0 ºC and 98-100% relative humidity, fresh carrots (*Daucus carota* L.) can be stored for up to 4-5 months. The ideal conditions, for best keeping quality, are precooling and storage at 0 °C and 95 to 100% relative humidity.

5.17 QUANTITATIVE LOSS OF CARROTS AT THE FARM GATE AND MARKET

Loss at the farm gate was 4.29±1.48%, whiles loss at the market was 6.49±3.93%. Market loss ranged between 1.45% and 10.11% and that of the farm gate ranged between 2.17% and 6.28%. The high difference of percentage loss to traders may be due to the poor handling of the produce and the lack of pre cooling facilities, transportation problems etc.

Wilson and Wisniewiki, 1989., stated that Losses of fresh fruits and vegetables after harvest may reach very high values depending on the species, harvest methods, length of storage, marketing conditions etc. also Kader and Morris (1978) indicated that delays between harvesting and cooling or processing can result in direct losses due to water loss and decay and indirect losses such as those in flavor and nutritional quality.

As observed in the study, postharvest handling of carrots by farmers took lesser time than the marketers who had to transport overnight, offload and assemble for sale, this may have accounted for the grater loss at the market than the farm gate. In carrots, mass loss and the occurrence of disease in the root are the principal causes of postharvest loss during storage and commercialization (Oliveira *et al*., 200

5.18 CAUSES OF LOSS AT THE FARM GATE AND MARKET

Causes of loss at the farm gate as given by the farmers were due to soil factors, environmental factors, bad cultural practices and lack of knowledge about technical and scientific technologies. The bacteria are found principally in soil, and the disease becomes apparent under conditions of high soil temperature and moisture. Affected carrots become a mushy and slimy mass of tissue, an unpleasant odour is present. That of the market was attributed to injuries during harvesting, transportation and storage period. Producers and marketers when given the needed training and resources for good handling practices would help reduce loss in quality and quantity. According to Kader and Rolle (2004) quality deterioration results in partial or total loss of fresh produce. It is predisposed by a number of interacting factors, which may be pre-harvest, harvest and or postharvest in origin, such as poor crop variety, unfavorable climate, inadequate cultural practices, and lack of harvesting techniques, improper handling, and poor storage conditions.

5.19 CHANGES IN QUALITY ATTRIBUTES OF CARROTS IN STORAGE

5.19.1 Weight loss

There was a significant loss in weight between the scrapped (26%) and washed roots (21%) on the 3rd day, the control treatment however recorded 24% loss in weight. The significant percentage weight loss in the scrapped roots may be due to excessive evapo-transpiration since the outer epidermis was removed. Li & Barth (1998) reported that baby carrots, which are prepared by peeling the outer layer of the carrot roots, are susceptible to a variety of physiological changes that reduce their quality.

Post-harvest moisture loss causes carrots to become shrivelled (Hurschka, 1977), lose their bright orange appearance, (and become susceptible to post-harvest decay (Van den Berg and Lentz, 1966), 1973). An 8% weight loss is reported to make carrots unsalable (Robinson *et al*., 1975). To reduce weight loss in processed carrots, retailers can display baby carrots in enclosed transparent plastic containers to reduce excessive evaporation during sales.

5.19.2 Decay

The result showed significant difference in the treatments on the fifth day. The scrapped carrots had much decay followed by washed, with the control having the least decay; this may probably be due to the easy access of pathogens through the injuries. This was in line with work done by Li & Barth, 1998, who reported that peeled carrots are susceptible to a variety of physiological changes that reduce their quality.

Postharvest decays of fruits and vegetables account for significant levels of postharvest losses. If distilled water is not used for washing, it could also introduce microbial contaminants. It is estimated that about 20–25% of the harvested fruits and vegetables are decayed by pathogens during postharvest handling even in developed countries (El-Ghaouth *et al*., 2004; Droby, 2006; Zhu, 2006; Singh and Sharma, 2007). Processed carrots should be treated with disinfectants during processing to inhibit the entry of pathogens which cause rot. Farmers should also harvest carrots at optimum maturity as carrots are more susceptible to decay and rot when over-matured.

5.19.3 Firmness

The washed roots remained firmer on the fifth day, followed by the control. The scrapped treatments however had lost its firmness. This could be as a result of the rotten/decay nature of the scrapped roots. Huxley *et al*., 2004 reported that during storage of carrots, quality may decline as a result of decay, loss of flavor, and texture and development of bitterness. It may also be due to excessive loss of water from the roots, this confirms the work done by Caron *et al*., 2003 who reported that, high rates of transpiration affects produce appearance by wrinkling and altering the texture of its skin; among other effects. To maintain the firmness of carrots however, consumers should prevent excessive water loss.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

From the result of this study, it was observed that majority of the carrot farmers did not do pre-cooling and carrots were normally harvested and bagged at the same time in the sun whiles awaiting transportation to the market. This practice results in heat build-up in the sacks and predisposed the roots to decay which were found to be the main cause of root losses at the market. Losses at the farm gate were mainly in the form of undersized roots, nematode infested roots, cracked roots and constituted about 4.28% whiles that on the market was 6.49%. The relatively higher loss at the market was due to the length of time the carrots stayed with marketers before they are completely sold out. Work done at the laboratory did not support claims by retail marketers on carrot storage life. The control treatment was observed to have longer shelf life (5 days) than the washed (4 days) and scrapped (3 days) roots. To reduce losses however, farmers should practice pre-cooling by packing bagged carrots under shade to remove field heat before transportation. Wholesale marketers should offload bagged carrots on arrival to allow fresh air to circulate in the produce to prevent decay/rot. Carrot roots should be washed or scrapped when ready to use or store in a refrigerator by consumers, otherwise it should be left untreated for relatively longer storage life.

6.2 RECOMMENDATIONS

- Farmers should provide postharvest cooling before and during transport and a shading structure during display by marketers, to extend the shelf life of the produce.

- Systematic sorting or grading coupled with appropriate packaging and storage, by both farmers and marketers will extend shelf life, maintain wholesomeness, freshness, and quality, and substantially reduce losses and marketing costs.

- A comprehensive training on farming practices, agrochemical usage should be given to carrot farmers in the Asante Mampong municipality by the Ministry of Food and Agriculture, to enhance their know how to help reduce loss due to soil borne nematodes.

- Retail marketers and Consumers should leave carrots untreated when storing under room temperature to extend its shelf life.

- Marketers should offload produce soon on arrival to eliminate heat buildup which is the main cause of rot/decay.

- Baby carrots should be packaged in transparent poly-bags to enhance its appeal to consumers and extend its storage life.

- Further studies should be carried out in other Districts/Municipalities to assess loss and also come out with possible ways of reducing it.

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APPENDIX

PROJECT QUESTIONNAIRE

ASSESSMENT OF POSTHARVEST HANDLING OF CARROTS (*Daucus carota L.)*

A CASE STUDY IN THE ASANTE MAMPONG MUNICIPALITY

FARMERS

1. Age. <20 years [ ] 20-30 years [ ] 31-40 years [ ] 41-50 years
2. Sex. male [ ] female [ ]
3. Level of Education. Non-formal [ ] JHS/MS [ ] SHS/VOC [ ] Tertiary [ ]
4. How many years have you been cultivating carrots? <1year [ ] 1-3years [ ] 4-6years [ ] 7-10years [ ] >10 years [ ]
5. What cultivar do you grow? Tokita [ ] New Kurada [ ] Amazonia [ ] Bahia [ ]
6. Why that cultivar. Availability [ ] longer shelf life [ ] High yield [ ] Disease resistant [ ]
7. How do you harvest the Carrots? Uprooting [ ] digging [ ] others [ ]
8. What tool do you use in harvesting? Cutlass [ ] hoe [ ] Bare hands [ ]
9. When is Carrot ready for harvesting? 2.5months [ ] 3months [ ] 4months [ ]
10. At what time of the day do you harvest Carrots? Morning [ ] afternoon [ ] evening [ ]
11. Why do you harvest at that time. Convenience [ ] protect produce [ ] to meet market [ ]
12. Do you do pre cooling after harvest? YES [ ] NO [ ]
13. Do you wash Carrots after harvest? YES [ ] NO [ ]
14. How long do you store the Carrots before selling to marketers? Same day [ ] 2-3 days [ ] 4-5 days [ ]
15. Are Carrots sorted and graded before selling? YES [ ] NO [ ]
16. If yes, indicate the basis for that. Shape [ ] size [ ] colour [ ] texture [ ]

17. How is marketing done? Sold directly to marketers [ ] through middlemen/agents [ ]
    Through farmers association [ ]
18. How much does a bag of carrots sold? GHC..................................

TRADERS/ WHOLESALERS

19. Source of Carrots. Farm [ ] wholesale market [ ]
20. How far is it away from you? Specify..
21. Are carrots sorted and graded before purchase. YES [ ] NO [ ]
22. If yes, indicate the basis for it. Size [ ] shape [ ] colour [ ] texture [ ]
23. How long are Carrots kept by the farmer before purchase? Immediately after harvest [ ]
    1day [ ] 2-3 days [ ] 4-5 days [ ]
24. How many bags are you able to buy in a week? 1-5 bags [ ] 6-10 bags [ ] above 10 bags [ ]
25. How are Carrots assembled after purchase? Sacks [ ] baskets [ ] others [ ]

TRANSPORTATION

26. Type of vehicles used to transport carrots. Kia trucks [ ] taxis [ ] urvan buses [ ]
    Bicycles [ ]
27. How many bags of Carrots do you transport per trip? ....
28. Are carrots transported alone? YES [ ] NO [ ]
29. If no, specify the other produce...
30. What is the nature of road plied during transportation? First class [ ] second class [ ]
    Third class [ ]

31. At what time of the day do you transport Carrots? Morning [ ] afternoon [ ] evening [ ]

32. How long does it take to transport Carrots to sales point? 1 hour [ ] 2-5 hours [ ]

    6-12 hours [ ] 13-24 hours [ ]

33. How are Carrots offloaded on arrival? Carried in baskets [ ] throw and catch[ ] in bags[]

34. Are some Carrots damaged during transportation? YES [ ] NO [ ]

35. What is the nature of damage? Softness [ ] breaks [ ] bruises [ ]

36. What happens to the damaged Carrots? Discarded [ ] sold at a reduced price[ ] others[ ]

STORAGE

37. Where do you keep the Carrots after offloading? Heaped outside [ ] packed in a store room [ ] others [ ]

38. Do you wash Carrots after transportation? YES [ ] NO [ ]

39. Do you sort and grade before selling to retailers/consumers. YES [ ] NO [ ]

40. How long do you keep the Carrots before selling to retailers/consumers? Same day[ ]

    2-5 days [ ] 6-10 days [ ]

41. How much do you sell a bag of carrots to retailers? GHC.......................................

RETAILING

42. Source of Carrots. Farm [ ] Market [ ]

43. Are Carrots sorted and graded before purchase. YES [ ] NO [ ]

44. If yes, indicate the basis for it. Size [ ] shape [ ] colour [ ] texture [ ]

45. Do you wash Carrots after purchase? YES [ ] NO [ ]

46. If yes, how is it done? Under running tap [ ] water in a bowl [ ] other [ ]

47. If water in a bowl, how often do you change the water? ....

48. What material do you use in washing? Bare hands [ ] brush to scrape [ ] Sponge to wash [ ]

49. Why do you scrape? To remove dirt [ ] to make it appealing [ ] others [ ] specify.............

50. What effect do you see after scraping? Bruises [ ] cuts [ ] breaks [ ]

51. If you don't scrape, how long does it last? 1 week [ ] 2-3 weeks [ ] over 4 weeks [ ]

52. If you scrape, how long does it last? 1 week [ ] 2-3 weeks [ ] over 4 weeks [ ]

53. Is there any chemical treatment done to carrots apart from washing? YES [ ] NO [ ]

54. How do you package Carrots for sale to consumers? In polyethylene bags [ ] Tie whole carrots [ ] other [ ] (Specify)..

55. How do you prevent water loss in carrots during sales? Cover from the sun [ ] Put carrots in polyethylene bags [ ] sprinkle water on it regularly [ ]

CONSUMERS

56. Do you often use carrots at home? YES [ ] NO [ ]

57. Where do you buy the carrots Retail market [ ] Farmers [ ] Hawkers [ ]

58. What do you look out for as quality when buying carrots? Firmness [ ] colour [ ] appearance [ ] size [ ] shape [ ]

59. When do you reject carrot as spoilt? Soft [ ] greenish [ ] other (specify)...

60. How do you process carrots for storage. Cut into pieces [ ] whole [ ] other [ ] (specify)..

61. Do you wash carrots before storage? YES [ ] NO [ ]

62. Where do you store the carrots? Refrigerator [ ] polyethylene bags [ ] other (specify)..

63. How long does the carrot keep after purchase? 1week [ ] 2weeks [ ] 3weeks [ ] 4weeks [ ]

64. What are the changes you observe after storage? Softness [ ] Change in taste [ ] Colour change [ ] Breaks [ ]

65. What is the best storage method for carrots over time? Refrigeration [ ] Polyethylene bags [ ] other (specify)..

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Completely Randomized AOV for DM1

Source	**DF**	**SS**	**MS**	**F**	**P**
trt	2	0.2600	0.13000	0.03	0.9705
Error	6	25.9000	4.31667		
Total	8	26.1600			

Grand Mean 13.200 CV 15.74

Homogeneity of Variances	**F**	**P**
Levene's Test	2.36	0.1755
O'Brien's Test	1.05	0.4070
Brown and Forsythe Test	0.84	0.4776

Welch's Test for Mean Differences

Source	**DF**	**F**	**P**
trt	2.0	0.02	0.9789
Error	3.4		

Component of variance for between groups -1.39556
Effective cell size 3.0

trt	**Mean**
CONTROL	13.433
SCRAPING	13.133
WASHED	13.033

Observations per Mean 3
Standard Error of a Mean 1.1995
Std Error (Diff of 2 Means) 1.6964

Completely Randomized AOV for DM3

Source	**DF**	**SS**	**MS**	**F**	**P**
trt	2	46.587	23.2933	2.38	0.1737
Error	6	58.813	9.8022		
Total	8	105.400			

Grand Mean 17.533 CV 17.86

Homogeneity of Variances	**F**	**P**
Levene's Test	1.97	0.2196
O'Brien's Test	0.88	0.4634
Brown and Forsythe Test	1.12	0.3862

Welch's Test for Mean Differences

Source	**DF**	**F**	**P**
trt	2.0	1.50	0.3640
Error	2.7		

Component of variance for between groups 4.49704
Effective cell size 3.0

trt	**Mean**
CONTROL	18.467
SCRAPING	19.733

WASHED	14.400
Observations per Mean	3
Standard Error of a Mean	1.8076
Std Error (Diff of 2 Means)	2.5563

Completely Randomized AOV for DM5

Source	**DF**	**SS**	**MS**	**F**	**P**
trt	2	56.660	28.3300	2.57	0.1560
Error	6	66.080	11.0133		
Total	8	122.740			

Grand Mean 21.100 CV 15.73

Homogeneity of Variances	**F**	**P**
Levene's Test	2.47	0.1649
O'Brien's Test	1.10	0.3924
Brown and Forsythe Test	0.83	0.4799

Welch's Test for Mean Differences

Source	**DF**	**F**	**P**
trt	2.0	2.26	0.2427
Error	3.3		

Component of variance for between groups 5.77222
Effective cell size 3.0

trt	**Mean**
CONTROL	17.833
SCRAPING	23.933
WASHED	21.533
Observations per Mean	3
Standard Error of a Mean	1.9160
Std Error (Diff of 2 Means)	2.7097

Completely Randomized AOV for FIRMNESS1

Source	**DF**	**SS**	**MS**	**F**	**P**
trt	2	0.29556	0.14778	0.45	0.6588
Error	6	1.98000	0.33000		
Total	8	2.27556			

Grand Mean 7.2222 CV 7.95

Homogeneity of Variances	**F**	**P**
Levene's Test	2.50	0.1620
O'Brien's Test	1.11	0.3882
Brown and Forsythe Test	0.78	0.5014

Welch's Test for Mean Differences

Source	**DF**	**F**	**P**
trt	2.0	0.79	0.5199
Error	3.7		

Component of variance for between groups -0.06074
Effective cell size 3.0

trt	Mean
CONTROL	7.3333
SCRAPING	7.3667
WASHED	6.9667

Observations per Mean 3
Standard Error of a Mean 0.3317
Std Error (Diff of 2 Means) 0.4690

Completely Randomized AOV for FIRMNESS3

Source	DF	SS	MS	F	P
trt	2	1.3956	0.69778	0.46	0.6503
Error	6	9.0467	1.50778		
Total	8	10.4422			

Grand Mean 7.4444 CV 16.49

Homogeneity of Variances	F	P
Levene's Test	3.00	0.1248
O'Brien's Test	1.33	0.3315
Brown and Forsythe Test	0.41	0.6817

Welch's Test for Mean Differences

Source	DF	F	P
trt	2.0	1.14	0.4116
Error	3.6		

Component of variance for between groups -0.27000
Effective cell size 3.0

trt	Mean
CONTROL	8.0000
SCRAPING	7.1333
WASHED	7.2000

Observations per Mean 3
Standard Error of a Mean 0.7089
Std Error (Diff of 2 Means) 1.0026

Completely Randomized AOV for FIRMNESS5

Source	DF	SS	MS	F	P
trt	2	5.23556	2.61778	8.89	0.0161
Error	6	1.76667	0.29444		
Total	8	7.00222			

Grand Mean 7.9556 CV 6.82

Homogeneity of Variances	F	P
Levene's Test	3.36	0.1048
O'Brien's Test	1.50	0.2973
Brown and Forsythe Test	0.84	0.4778

Welch's Test for Mean Differences

Source	DF	F	P
trt	2.0	12.73	0.0407
Error	2.8		

Component of variance for between groups 0.77444
Effective cell size 3.0

trt	Mean
CONTROL	8.0000
SCRAPING	7.0000
WASHED	8.8667

Observations per Mean 3
Standard Error of a Mean 0.3133
Std Error (Diff of 2 Means) 0.4431

Completely Randomized AOV for TSS1

Source	DF	SS	MS	F	P
trt	2	0.03556	0.01778	0.32	0.7378
Error	6	0.33333	0.05556		
Total	8	0.36889			

Grand Mean 4.2111 CV 5.60

Homogeneity of Variances	**F**	**P**
Levene's Test	0.23	0.8040
O'Brien's Test	0.10	0.9058
Brown and Forsythe Test	0.06	0.9464

Welch's Test for Mean Differences

Source	DF	F	P
trt	2.0	0.32	0.7444
Error	3.9		

Component of variance for between groups -0.01259
Effective cell size 3.0

trt	Mean
CONTROL	4.1667
SCRAPING	4.3000
WASHED	4.1667

Observations per Mean 3
Standard Error of a Mean 0.1361
Std Error (Diff of 2 Means) 0.1925

Completely Randomized AOV for TSS3

Source	DF	SS	MS	F	P
trt	2	20.8089	10.4044	0.91	0.4504
Error	6	68.3200	11.3867		
Total	8	89.1289			

Grand Mean 8.3111 CV 40.60

Homogeneity of Variances F P

Test	F	P
Levene's Test	2.03	0.2128
O'Brien's Test	0.90	0.4551
Brown and Forsythe Test	0.26	0.7777

Welch's Test for Mean Differences

Source	DF	F	P
trt	2.0	0.69	0.5577
Error	3.7		

Component of variance for between groups -0.32741
Effective cell size 3.0

trt	Mean
CONTROL	7.933
SCRAPING	10.333
WASHED	6.667

Observations per Mean 3
Standard Error of a Mean 1.9482
Std Error (Diff of 2 Means) 2.7552

Completely Randomized AOV for TSS5

Source	DF	SS	MS	F	P
trt	2	9.1289	4.56444	2.64	0.1505
Error	6	10.3733	1.72889		
Total	8	19.5022			

Grand Mean 10.844 CV 12.12

Homogeneity of Variances F P

Test	F	P
Levene's Test	1.60	0.2767
O'Brien's Test	0.71	0.5275
Brown and Forsythe Test	0.46	0.6514

Welch's Test for Mean Differences

Source	DF	F	P
trt	2.0	2.25	0.2481
Error	3.1		

Component of variance for between groups 0.94519
Effective cell size 3.0

trt	Mean
CONTROL	12.267
SCRAPING	10.200
WASHED	10.067

Observations per Mean 3
Standard Error of a Mean 0.7591
Std Error (Diff of 2 Means) 1.0736

Completely Randomized AOV for days3wl

Source	DF	SS	MS	F	P
trt	2	29.7909	14.8954	4.70	0.0591
Error	6	19.0067	3.1678		

Total 8 48.7976

Grand Mean 24.133 CV 7.37

Homogeneity of Variances	**F**	**P**
Levene's Test	1.89	0.2316
O'Brien's Test	0.84	0.4777
Brown and Forsythe Test	0.32	0.7409

Welch's Test for Mean Differences

Source	**DF**	**F**	**P**
trt	2.0	4.17	0.1119
Error	3.7		

Component of variance for between groups 3.90921
Effective cell size 3.0

trt	**Mean**
CONTROL	24.477
SCRAPING	26.170
WASHED	21.753

Observations per Mean 3
Standard Error of a Mean 1.0276
Std Error (Diff of 2 Means) 1.4532

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Completely Randomized AOV for days5wl

Source	DF	SS	MS	F	P
trt	2	7.2267	3.61333	1.85	0.2361
Error	6	11.6933	1.94889		
Total	8	18.9200			

Grand Mean 15.400 CV 9.07

Homogeneity of Variances	F	P
Levene's Test	2.29	0.1827
O'Brien's Test	1.02	0.4167
Brown and Forsythe Test	0.52	0.6165

Welch's Test for Mean Differences

Source	DF	F	P
trt	2.0	2.15	0.2671
Error	2.9		

Component of variance for between groups 0.55481
Effective cell size 3.0

trt	Mean
CONTROL	16.000
SCRAPING	14.133
WASHED	16.067

Observations per Mean 3
Standard Error of a Mean 0.8060
Std Error (Diff of 2 Means) 1.1399

Completely Randomized AOV for decay1

Source	DF	SS	MS	F	P
trt	2	0.00000	0.00000	M	M
Error	6	0.00000	0.00000		
Total	8	0.00000			

Grand Mean 0.0000 CV M

WARNING: The total sum of squares is too small to continue.
The dependent variable may be nearly constant.

Completely Randomized AOV for decay3

Source	DF	SS	MS	F	P
trt	2	105.556	52.7778	2.11	0.2022
Error	6	150.000	25.0000		
Total	8	255.556			

Grand Mean 7.7778 CV 64.29

Homogeneity of Variances	**F**	**P**
Levene's Test	2.82	0.1367
O'Brien's Test	1.25	0.3505
Brown and Forsythe Test	0.80	0.4921

Welch's Test for Mean Differences

Source	**DF**	**F**	**P**
trt	2.0	2.60	0.1971
Error	3.7		

Component of variance for between groups 9.25926
Effective cell size 3.0

trt	**Mean**
CONTROL	3.333
SCRAPING	11.667
WASHED	8.333

Observations per Mean 3
Standard Error of a Mean 2.8868
Std Error (Diff of 2 Means) 4.0825

Completely Randomized AOV for decay5

Source	**DF**	**SS**	**MS**	**F**	**P**
trt	2	1816.67	908.333	12.58	0.0071
Error	6	433.33	72.222		
Total	8	2250.00			

Grand Mean 45.000 CV 18.89

Homogeneity of Variances	**F**	**P**
Levene's Test	2.50	0.1625
O'Brien's Test	1.11	0.3889
Brown and Forsythe Test	0.75	0.5120

Welch's Test for Mean Differences

Source	**DF**	**F**	**P**
trt	2.0	23.47	0.0078
Error	3.7		

Component of variance for between groups 278.704
Effective cell size 3.0

trt	**Mean**
CONTROL	25.000
SCRAPING	56.667
WASHED	53.333

Observations per Mean 3
Standard Error of a Mean 4.9065
Std Error (Diff of 2 Means) 6.9389

Completely Randomized AOV for mc1

Source	**DF**	**SS**	**MS**	**F**	**P**
trt	2	0.2484	0.12421	0.03	0.9717
Error	6	25.8393	4.30654		

Total 8 26.0877

Grand Mean 86.811 CV 2.39

Homogeneity of Variances	**F**	**P**
Levene's Test	2.41	0.1707
O'Brien's Test	1.07	0.4004
Brown and Forsythe Test	0.87	0.4650

Welch's Test for Mean Differences

Source	**DF**	**F**	**P**
trt	2.0	0.02	0.9813
Error	3.4		

Component of variance for between groups -1.39411
Effective cell size 3.0

trt	**Mean**
CONTROL	86.580
SCRAPING	86.890
WASHED	86.963

Observations per Mean 3
Standard Error of a Mean 1.1981
Std Error (Diff of 2 Means) 1.6944

Completely Randomized AOV for mc3

Source	**DF**	**SS**	**MS**	**F**	**P**
trt	2	46.744	23.3722	2.39	0.1724
Error	6	58.668	9.7780		
Total	8	105.412			

Grand Mean 82.460 CV 3.79

Homogeneity of Variances	**F**	**P**
Levene's Test	1.98	0.2190
O'Brien's Test	0.88	0.4628
Brown and Forsythe Test	1.11	0.3886

Welch's Test for Mean Differences

Source	**DF**	**F**	**P**
trt	2.0	1.52	0.3618
Error	2.7		

Component of variance for between groups 4.53141
Effective cell size 3.0

trt	**Mean**
CONTROL	81.533
SCRAPING	80.250
WASHED	85.597

Observations per Mean 3
Standard Error of a Mean 1.8054
Std Error (Diff of 2 Means) 2.5532

Completely Randomized AOV for mc5

Source	DF	SS	MS	F	P
trt	2	56.755	28.3773	2.55	0.1579
Error	6	66.762	11.1270		
Total	8	123.516			

Grand Mean 78.910 CV 4.23

Homogeneity of Variances	F	P
Levene's Test	2.49	0.1632
O'Brien's Test	1.11	0.3899
Brown and Forsythe Test	0.85	0.4725

Welch's Test for Mean Differences

Source	DF	F	P
trt	2.0	2.23	0.2451
Error	3.3		

Component of variance for between groups 5.75011
Effective cell size 3.0

trt	Mean
CONTROL	82.170
SCRAPING	76.060
WASHED	78.500

Observations per Mean 3
Standard Error of a Mean 1.9259
Std Error (Diff of 2 Means) 2.7236

Completely Randomized AOV for shrink1

Source	DF	SS	MS	F	P
trt	2	0.00000	0.00000	M	M
Error	6	0.00000	0.00000		
Total	8	0.00000			

Grand Mean 0.0000 CV M

WARNING: The total sum of squares is too small to continue.
The dependent variable may be nearly constant.

Completely Randomized AOV for shrink3

Source	DF	SS	MS	F	P
trt	2	0.08000	0.04000	1.50	0.2963
Error	6	0.16000	0.02667		
Total	8	0.24000			

Grand Mean 1.1333 CV 14.41

Homogeneity of Variances	F	P
Levene's Test	2.00	0.2160
O'Brien's Test	0.89	0.4591
Brown and Forsythe Test	0.17	0.8503

Welch's Test for Mean Differences

Source	DF	F	P
trt	2.0	0.85	0.4954
Error	3.8		

Component of variance for between groups 0.00444
Effective cell size 3.0

trt	Mean
CONTROL	1.0667
SCRAPING	1.2667
WASHED	1.0667

Observations per Mean 3
Standard Error of a Mean 0.0943
Std Error (Diff of 2 Means) 0.1333

Completely Randomized AOV for shrink5

Source	DF	SS	MS	F	P
trt	2	0.11556	0.05778	1.30	0.3396
Error	6	0.26667	0.04444		
Total	8	0.38222			

Grand Mean 1.7556 CV 12.01

Homogeneity of Variances	**F**	**P**
Levene's Test	3.56	0.0956
O'Brien's Test	1.58	0.2806
Brown and Forsythe Test	0.70	0.5330

Welch's Test for Mean Differences

Source	DF	F	P
trt	2.0	M	0.0000
Error	M		

Component of variance for between groups 0.00444
Effective cell size 3.0

trt	Mean
CONTROL	1.6000
SCRAPING	1.8667
WASHED	1.8000

Observations per Mean 3
Standard Error of a Mean 0.1217
Std Error (Diff of 2 Means) 0.1721

Completely Randomized AOV for shelflife

Source	DF	SS	MS	F	P
trt	2	3.92000	1.96000	10.50	0.0110
Error	6	1.12000	0.18667		
Total	8	5.04000			

Grand Mean 4.1333   CV 10.45

Homogeneity of Variances	F	P
Levene's Test	0.70	0.5319
O'Brien's Test	0.31	0.7430
Brown and Forsythe Test	0.12	0.8930

Welch's Test for Mean Differences

Source	DF	F	P
trt	2.0	8.46	0.0382
Error	3.9		

Component of variance for between groups   0.59111
Effective cell size   3.0

trt	Mean
control	5.0000
scrapped	3.4000
washed	4.0000

Observations per Mean   3
Standard Error of a Mean   0.2494
Std Error (Diff of 2 Means) 0.3528

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LSD All-Pairwise Comparisons Test of DM1 by trt

trt	Mean	Homogeneous Groups
CONTROL	13.433	A
SCRAPING	13.133	A
WASHED	13.033	A

Alpha   0.05   Standard Error for Comparison 1.6964
Critical T Value 2.447   Critical Value for Comparison 4.1509
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of DM3 by trt

trt	Mean	Homogeneous Groups
SCRAPING	19.733	A
CONTROL	18.467	A
WASHED	14.400	A

Alpha   0.05   Standard Error for Comparison 2.5563
Critical T Value 2.447   Critical Value for Comparison 6.2551

There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of DM5 by trt

trt	Mean	Homogeneous Groups
SCRAPING	23.933	A
WASHED	21.533	A
CONTROL	17.833	A

Alpha 0.05 Standard Error for Comparison 2.7097
Critical T Value 2.447 Critical Value for Comparison 6.6303
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of FIRMNESS1 by trt

trt	Mean	Homogeneous Groups
SCRAPING	7.3667	A
CONTROL	7.3333	A
WASHED	6.9667	A

Alpha 0.05 Standard Error for Comparison 0.4690
Critical T Value 2.447 Critical Value for Comparison 1.1477
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of FIRMNESS3 by trt

trt	Mean	Homogeneous Groups
CONTROL	8.0000	A
WASHED	7.2000	A
SCRAPING	7.1333	A

Alpha 0.05 Standard Error for Comparison 1.0026
Critical T Value 2.447 Critical Value for Comparison 2.4532
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of FIRMNESS5 by trt

trt	Mean	Homogeneous Groups
WASHED	8.8667	A
CONTROL	8.0000	AB
SCRAPING	7.0000	B

Alpha 0.05 Standard Error for Comparison 0.4431
Critical T Value 2.447 Critical Value for Comparison 1.0841
There are 2 groups (A and B) in which the means
are not significantly different from one another.

LSD All-Pairwise Comparisons Test of TSS1 by trt

trt	Mean	Homogeneous Groups
SCRAPING	4.3000	A
CONTROL	4.1667	A
WASHED	4.1667	A

Alpha 0.05 Standard Error for Comparison 0.1925
Critical T Value 2.447 Critical Value for Comparison 0.4709

There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of TSS3 by trt

trt	Mean	Homogeneous Groups
SCRAPING	10.333	A
CONTROL	7.9333	A
WASHED	6.6667	A

Alpha 0.05 Standard Error for Comparison 2.7552
Critical T Value 2.447 Critical Value for Comparison 6.7417
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of TSS5 by trt

trt	Mean	Homogeneous Groups
CONTROL	12.267	A
SCRAPING	10.200	A
WASHED	10.067	A

Alpha 0.05 Standard Error for Comparison 1.0736
Critical T Value 2.447 Critical Value for Comparison 2.6270
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of days3wl by trt

trt	Mean	Homogeneous Groups
SCRAPING	26.170	A
CONTROL	24.477	AB
WASHED	21.753	B

Alpha 0.05 Standard Error for Comparison 1.4532
Critical T Value 2.447 Critical Value for Comparison 3.5559
There are 2 groups (A and B) in which the means
are not significantly different from one another.

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LSD All-Pairwise Comparisons Test of days5wl by trt

trt	Mean	Homogeneous Groups
WASHED	16.067	A
CONTROL	16.000	A
SCRAPING	14.133	A

Alpha 0.05 Standard Error for Comparison 1.1399
Critical T Value 2.447 Critical Value for Comparison 2.7891
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of decay3 by trt

trt	Mean	Homogeneous Groups
SCRAPING	11.667	A
WASHED	8.3333	A
CONTROL	3.3333	A

Alpha 0.05 Standard Error for Comparison 4.0825
Critical T Value 2.447 Critical Value for Comparison 9.9895
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of decay5 by trt

trt	Mean	Homogeneous Groups
SCRAPING	56.667	A
WASHED	53.333	A
CONTROL	25.000	B

Alpha 0.05 Standard Error for Comparison 6.9389
Critical T Value 2.447 Critical Value for Comparison 16.979
There are 2 groups (A and B) in which the means
are not significantly different from one another.

LSD All-Pairwise Comparisons Test of mc1 by trt

trt	Mean	Homogeneous Groups
WASHED	86.963	A
SCRAPING	86.890	A
CONTROL	86.580	A

Alpha 0.05 Standard Error for Comparison 1.6944
Critical T Value 2.447 Critical Value for Comparison 4.1461
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of mc3 by trt

trt	Mean	Homogeneous Groups
WASHED	85.597	A
CONTROL	81.533	A
SCRAPING	80.250	A

Alpha 0.05 Standard Error for Comparison 2.5532
Critical T Value 2.447 Critical Value for Comparison 6.2474
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of mc5 by trt

trt	Mean	Homogeneous Groups
CONTROL	82.170	A
WASHED	78.500	A
SCRAPING	76.060	A

Alpha 0.05 Standard Error for Comparison 2.7236
Critical T Value 2.447 Critical Value for Comparison 6.6644
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of shrink3 by trt

trt	Mean	Homogeneous Groups
SCRAPING	1.2667	A
CONTROL	1.0667	A
WASHED	1.0667	A

Alpha 0.05 Standard Error for Comparison 0.1333
Critical T Value 2.447 Critical Value for Comparison 0.3263
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of shrink5 by trt

trt	Mean	Homogeneous Groups
SCRAPING	1.8667	A
WASHED	1.8000	A
CONTROL	1.6000	A

Alpha 0.05 Standard Error for Comparison 0.1721
Critical T Value 2.447 Critical Value for Comparison 0.4212
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of shelflife by trt

trt	Mean	Homogeneous Groups
control	5.0000	A
washed	4.0000	B
scrapped	3.4000	C

Alpha 0.05 Standard Error for Comparison 0.3528
Critical T Value 2.447 Critical Value for Comparison 0.8632
There are 2 groups (A and B) in which the means
are not significantly different from one another.

PLATES

Plate 1: Discolored roots

Plate 2: Rotten root

Plate 3: Cracked roots

Plate 4undersized roots

Plate 3: Nematode infested roots

Plate 6: Marketable roots

Plate 7: Harvesting and bagging on the farm

Plate 8: Bagged carrots awaiting transportation

Plate 9: Bagged carrots packed in urvan bus

Plate 10: Carrots displayed at the market for sale

Plate 11: Processing of carrots for sale