



THE UNIVERSITY OF ZAMBIA

**The Relationship Between Pre- harvest treatments
on the Post- harvest Quality and Shelf life of
Improved Mango (*Mangifera indica*) Cultivars**

Dissertation submitted in partial fulfillment of requirements for the award of
the BACHELOR'S OF SCIENCE DEGREE OF AGRICULTURAL
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DEDICATION

To my late wife, Linda Chikola Paulino Chilembo, may her soul rest in peace and God's hands and to my children Elina, Paulino and Violet for having been so understand during the time I spent at school away from home. To my late mother-in-law, Mrs. Paulino Chikola, may her soul rest in the love of God.

To my sister Anna Chilembo Lombe and my brother -in- Mr. L. Lombe for taking care of Violet all these years I have spent in school. I say to Anna keep up with this kind of understanding and love you have for mankind.

To my father and mother, Mr. Chilembo Tafuna Patson and Violet Yumba Chilembo for bring me up.

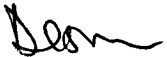
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APPROVAL

The undersigned herewith certifies that this dissertation entitled 'The Relationship Between Pre- harvest treatments on the Post- harvest Quality and Shelf life of Improved Mango (*Mangifera indica*) Cultivars' was not previously presented for the award of a degree, and the work contained herein were carried out by CHILEMBO S. DANNY under my supervision. The dissertation hereby submitted to the School of Agricultural Sciences in partial fulfillment of requirements for the award of the Bachelor's degree of Agricultural Sciences in Crop Science is accepted.

Approved by



M. Mataa (PhD)

ABSTRACT

A study was conducted at the University of Zambia farm, Liempe, during the 2001/2002 agricultural season to determine the optimum harvest stage of mango (*Mangifera indica* Linn.) and secondly to evaluate the effects of chemical pesticides treatments during the preharvest period on the fruit shelf life. It included fieldwork and laboratory quality analysis. Two improved mango cultivars; Kent and Sabre were used, to test for, fruit skin and pulp colour, firmness, fruit weight loss and total soluble solids. Mango trees used were about 38 years old. These were sprayed with chemical pesticides at three- week intervals and the first application was done on 15th August 2001. Fruit were harvested at three harvests - 136, 141 and 146 days after fruit set (DAFS). To test the effect of storage on fruit quality, for each harvest fruit were subjected to storage in shade under ambient conditions and analysed for quality every 5 days starting on the day of harvest. A split-plot design with three factors replicated four times was used. The main plot was the variety and the split plots were maturity stage and storage duration.

To determine the effect of pre- harvest chemical control of pest and diseases on shelf life of mango, fruits were subjected to routine insecticide and fungicide sprays every three weeks; samples were collected from sprayed and non- sprayed trees (controls) at 136, 141, and 146 days after fruit-set (full maturity). Average storage conditions were temperature 23-27°C, relative humidity of 65-75%, and normal atmospheric pressure and air composition counts of diseased or insect damaged fruit were recorded every five days for thirty days. In the first study, total soluble solids were highest in second harvest date (The fruit total soluble solids (TSS) at the three harvest age were 8.13%, 11.52% and 8.15% respectively). Fruit skin and pulp colour were significant different at the three harvest dates and fruit firmness was found to decrease as the fruit matures and had decreased by about 17.2% and in storage decreased by about 54.6%. In storage skin and pulp colour increased by 41.5% and 49.00% respectively. Total soluble solids increased by about 100% within ten in storage. There was significant reduction in fruit mass for both cultivars. Kent had loss in weight of about 24.5% and for Sable cultivar it was 19.4%. Treated fruits were found to have 12.5 % of decayed fruits while for untreated fruits recorded total of 53.3% of decayed fruits within thirty days. At the end of storage time the treated fruits were found to have soluble solids of 18.00% and firmness of 3 (40%) whereas untreated fruits had soluble solids (TSS) and firmness of 11.52% and 5 (100% soft) respectively. The preharvest

treatments had significant influence on the internal quality and shelf life of mango improved cultivars. The pre harvest chemical application on mango fruits extended shelf life.

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Chapter 1

INTRODUCTION

The mango (*Mangifera indica* Linn.) belongs to the family Anacardiaceae, which also includes fruit, trees like Bindjai (*Mangifera cacasía*), Horse mango (*Mangifera foetida*), Marula (*Sclerocarya birrea*), Gardaria (*Bouea gandaria*) and Cashew nut (*Anacardium occidentale*). Mango is a crop native to the Southern Asia, particularly around the Burma/Eastern India border region, a tropical to sub-tropical monsoon area in the Himalayan foothills. It spread early to Malaya, eastern Asia and eastern Africa. It is one of the fruit tree crops that have been grown in India for more than 4,000 years. Bor (1984) reported that the mango grows wild in the forests of India especially in hilly areas in the northeast. In many areas mango has become naturalised. The Portuguese and Arab traders introduced mango to Zambia in the last part of the 19th century (Mumba, 1976).

Mango is consumed fresh in large quantities exceeding any other fruit, (Schroeder, 1989). Generally mango is found all over Zambia. Zambia provides favourable conditions for the production of mangoes. Many of the trees however, produce low quality fruits due to a number of reasons, such as poor pests and diseases control. In many areas the fruit is consumed locally and the period in which this fruit is consumed is not more than one-month due to poor shelf life. It is known that some regions of Zambia produce fruit that is sold on the formal market, but a larger proportion of the fruit brought to the market goes to waste due to poor harvest time and poor pre-harvest treatments (Hamaamba, 1976).

Vamoer (1976) reported that protein-calorie deficiency, anaemia, vitamin deficiency especially of vitamin A and B₂ (riboflavin) and parasitic infections are widespread and the most serious disorders related to nutrition in Zambia. It is known that the mango fruit contains appreciable amounts of vitamin A and C, which are of great physiological significance (Vamoer, 1976; Purselove, 1988). From reports it is estimated that a serious level of vitamin A deficiency exists in about 15% of the Zambian population (Vamoer, 1976; Javaid, 1976). This vitamin A and C deficiency is observed seasonally. So preserving mango fruit at the right time harvest, using non-expensive equipment, the mango fruit could be made available throughout the year to alleviate the vitamin A and C. Most of the local mango varieties produce fruit almost at the same time and this makes the mango orchards business not profitable as the prices offered for the commodity at

this time are very low and do not encourage the investment into the mango production. Uppal (1976) outlined prominent areas where the mango fruit is growing in Zambia and these areas are the Eastern, Luapula, Northern and Western provinces. The fruiting season, - October to March is, different from the other mango producing countries and it makes Zambian mangoes a valuable commodity. The period coincides with the period of high demand for mango fruits on the European market. Due the climatic weather that Zambia has, it is possible for Zambia to produce high quality mango fruits that could be exported. The actual population of mango trees, and annual production as with other fruit in Zambia is not known. However, the bulk of the trees are under subsistence growers

Mango production is increasing among small-scale farmers and commercial farmers. The high price offered for mangoes in the Departmental shops or stores clearly is one indicator for the demand of it (Mataa and Nalumino, 2000). Most of these mangoes in established stores come from other countries like South Africa. There is need to extend the mango available season through the introduction of varieties that are very early and late maturing. When grown under the local production practices it appears the yields and the quality of improved mango cultivars, are poor due to pests and diseases Post-harvest quality greatly depends on the pre-harvest treatments given to crop. The title of the study was the effects of the preharvest treatments on shelf life and internal quality of improved mango cultivars.

The overall objective of the study was to improve post harvest quality of mango fruits. Specifically it evaluated

- (1) the effect of the degree of maturity/ storage on the harvest on sensory (external) and compositional (internal) fruit quality.
- (2) The relationship between chemical insect/pest control measures on the shelf life of mango fruits

The results of this study may contribute to the reducing of post harvest loses that are currently been experienced, in mango production. This finding suggests that the chemical fungicide and insecticide pre harvest treatments might be useful for extending the marketing life of mangoes.

Chapter 2

LITERATURE REVIEW

Classification

Mango fruit is a fresh drupe, a simple fruit derived from a single carpel where the mesocarp tissue become thick and fleshy, variable in size from 2.5-30 cm long, in shape from rounded to ovoid-oblong and some times laterally compressed, and in colour with vary mixture of green, yellow and red. The edible mesocarp varies in thickness, texture and flavour from soft, free of fiber, sweet and juicy to fibrous and turpentine- flavored; endocarp thick, woody and fibrous, and maybe free from mesocarp or with fibre extending into it (Purseglove, 1988). Mango fruit takes between two and four months to mature depending on the variety and locality. It has a smooth fairly thick skin (Cobley, 1965).

Many authors have reviewed mango (*Mangifera indica* Linn.) cultivation in different parts of the world (Singh, 1968;). The main production areas are India, Florida, Egypt, Natal, East African coasts and West Indies (Hill and Waller, 1990). Mango belongs to a family Anacardiaceae, a family of tropical trees or shrubs having the resinous bark and bearing alternate leaves. The family also includes the cashew nut (*Anacardium occidentale*), and Pistachio nut (*Pistacca vera*), and the poison ivy of the United States of America. In India, there are species of mango that grow wild in the forest and it is from these wild mango trees that the cultivated forms were taken. The cultivated ones yield fruits that are superior to the wild type, which are stringy and full of turpentine and poison (Purseglove, 1988 and Bor, 1984). Most of the mango trees in Africa and tropical Asia grow either wild or semi wild, although they may have been deliberately planted; but in parts of Asia there are plantation (Hill and Waller, 1990). The genus *Mangifera* is an indigenous to Southeast Asia, and mango (*Mangifera indica*) is the most important species of the genus. India was the first country to cultivate mango as a fruit crop, but currently, it is grown commonly throughout the Tropical areas of the world and about 69 species in this genus *Mangifera* are known in the Southeast Asia (Eiadthong, et al, 2000). Mango is decidedly the most popular fruit among millions of people in the Orient, particularly, where it is considered to be the choicest of all the indigenous fruits. It occupies relatively the same position in the tropics as is enjoyed by the apple in the temperate region (Purseglove, 1988). There are many cultivars

grown all over the world. However, most of them are not cultivated on commercial scale. Most of them are localized in particular areas (Nagy, 1980). The nomenclature of mango has been complicated due to the existence of synonyms where the same mango cultivar has different names in different places (Nagy, 1980). Eiadthong, et al. (2002) used RELP to classify mango and reported 69 species of *Mangifera* genus that is based on the genetic characteristics. And it has been agreed that mango taxonomy is sometimes ambiguous and a more reliable system based on the molecular biology is needed for modern taxonomy. Fortunately mango cultivars are either classified be pulpy or juicy cultivars.

Although mango has been grown in Zambia for many years and is found all over the country there have been very little published works on Zambia (Javaid, 1976, Mumba 1976). Mataa and Nalumino (2000) have outlined the need for research work in mango production in Zambia. A few local and improved mango cultivars have been grown at research stations and some commercial farmers and Mufulira, but no detailed information is available.

Chemical and nutritional composition

Young fruits are astringent acidic and rich in vitamin C, whereas ripe mangoes are sweet rich in pro-vitamin A and highly aromatic. The chemical composition of the fruits varies with cultivars (Burton, 1984). Mango contains carbohydrates, organic acids, proteins and amino acids, pigments, pectic substances, polyphenols, vitamins, fatty acids and odoriferous compounds (Singh, 1991). The principal chemical composition of the mango fruit is water -80-95%, sugar-15% (varies from 10-20%, as soluble solids. The total soluble solids in mango mainly comprises free sugars which glucose, fructose and sucrose. Other sugars like xylose and arabinose have been detected at vary stages of ripening of mango (Nagy, 1980). Sugar content at edible stage of ripening is given as 15,3g/100g for fresh weight and 90g/100g for dry weight; protein 0.5%. The edible portion of mango fruit of improved cultivars is 60-75 percent by weight.

Climatic influence and soil requirement

Optimum mango production occurs mainly in the tropics with a long dry season (Parker 1976). Mangoes are grown at an elevation from sea level up to 1200 m in the tropics. The optimum elevation is 600m and lower (Purseglove, 1988). The optimum growth temperature ranges from 24-27°C. A rainfall of 750-1900mm is generally desirable. The tree is fairly sensitive to frost.

Heavy rains during flowering and fruit-ripening periods are harmful. In general, dry weather and a cloudless sky during flowering and fruit ripening are considered essential for good crops (Kochhar, 1986) Temperature is a very important factor in mango production. Pantastico (1975) and Nagy *et al.* (1980) have noted that for most fruits and vegetables, the higher the temperature during the growing period, the earlier the time of harvest. Among fruits, warm days and cool nights during growth and ripening are necessary for development. The temperature in the tropics does not vary much; between the day and night. During the month of October to January the average daily room temperatures were $25.1 \pm 2^{\circ}\text{C}$. Even during ripening temperatures plays very important role. If temperature is more than 35°C in storage spoilage set-in (Singh, 1992).

Many authors like that of Lakshminarayana (1970) have reported the effects of light on the quality of fruits at harvest and have noted that duration, intensity and quality of light were important in this aspect. Mango is daylight neutral. Mango will grow in almost any well-drained soil whether sandy, loam or clay, but heavy, wet soils must be avoided. A pH between 5.5 and 7.5 is preferred. They are somewhat tolerant of alkalinity. For good growth mangoes needs a good deep soil to accommodate their extensive root systems. Very fertile soils with adequate supplies of water throughout the year may result in luxuriant vegetative growth and poor cropping (Singh, 1968). They require a dry period at flowering to prevent fungal diseases and also to reduce competition from vegetative growth

Preharvest treatments

Popenoe *et al.*, (1958) defined the pre-harvest treatments as any kind operations done on the crop before harvest. Chien (1997) reported that the post-harvest quality of horticultural crops is closely influenced by various pre-harvest factors, including environment and cultural practices. Seasonal growing temperatures, light condition, amount of rainfall and irrigation, mineral nutritional status and fertilization, pest management and the maturity stage at the time of harvest can directly or indirectly affect the post-harvest quality, storage life, susceptibility of the crop to disorders and diseases. Many authors including Chien (1997), Pantastico (1975) and Mathooko, *et al.*, (2002) agree that in many horticultural crops, quality does not improve after harvest, therefore the best quality of the crop is at harvest. Field management practices, such as pest management, soil fertility, and water management play a very important role in determining the quality attributes such as size, colour, flavour, texture and the nutritional value of these

horticultural products. The heavy loss incurred in mango production in Zambia and elsewhere may be attributed to pre-harvest conditions. For example, superficial scald is a serious physiological disorder in certain cultivars of apples (*Malus domestica* Brokh), pears (*Pyrus communis* L.), and many other fruits. The occurrence of scald is closely associated with several pre-harvest conditions, such as seasonal growing temperatures, light condition, and the amount of rainfall. Fruit canopy position, irrigation, and fertilization can affect the severity of these disorders. Mineral nutrition plays a very important role, mineral elements such nitrogen and calcium have a profound effect on firmness, ethylene production, respiration, storage life, ripening, and the decay of diverse fruits and vegetables, drainage, and ringing. Mineral nutrients must be well managed, if not they will have a negative impact on the fruit quality. Kevin, et al., (1997), reported that peaches and nectarine grown under Californian conditions, did not respond to higher amount of nitrogen (more than 2.6% to 3.6% leaf nitrogen). High nitrogen levels were reported not to increase the fruit production and soluble solid concentration and delay the maturation. Crop load is an aspect of importance in pre-harvest management. There is a tendency in some fruit crops to bear a heavy at one time and a small crop on some other times. Heavy crop normally results in small sized fruits. Fruit let thinning is known to increase the size of the fruits and at the same time reducing the yield. Hence, the importance of balancing fruit size and fruit yield.

Maturity

Maturity has been defined as the stage of development where the plant is capable of shifting from vegetative to reproductive growth. However, in the field of agriculture, maturity is seen as a stage of development superimposed on the plant or plant parts relative to human needs (Mathooko, et al., 2002).

Horticultural maturity.

Horticultural maturity for a number of crops varies widely with the plant produce involved. Depending on which parts of the plant are required, they are harvested at different times. Other plant parts are harvested at seedling stage e.g. cauliflower, or partially developed fruits e.g. cucumber, etc. Therefore, horticultural (harvestable) maturity can occur throughout the developmental cycle, with the precise time varying with the product in question (Mathooko, et

al., 2002). Horticultural maturity for a number of crops occurs over a relatively wide time frame. Many crops however, have relatively short, precise time of harvest and exceeding this period results in the quality or product loss. The timing and duration of this period of harvestable maturity can be modulated by a number of factors such as cultivars, which can have significant influence. Environmental conditions during the plant growth and development can also have pronounced effects on the timing and length of the period of harvestable maturity. Environmental induced alterations in the maturation time periods, accounts for substantial loss of food crop. Harvesting at the correct stage of maturity is essential for optimum quality and often for the maintenance of this quality after harvest. The manner in which the crop will be harvested will also influence harvestable maturity. Optimum harvestable maturity is not a fixed point in the developmental cycle of the plant or plant part and varies; depending on the criteria utilised to determine it. With most crops, optimum maturity is determined by specific physical and/or chemical characteristics of the plant or plant part to be harvested. (Mathooko, et al., 2002; Kiya, 2002).

Measurements of maturity.

Physical attributes such as size, colour or texture are commonly used to determine crop maturity (Kiya, 2002). Maturity criteria based on physical characteristics can be made either subjectively (sensory evaluation) or objectively (numerical measurements) of maturity. The index of horticultural maturity usually involves some expression of the stage of development or maturation and requires some characteristics known to change as the fruit and vegetables matures. Experienced growers commonly determine harvest date based on a subjective assessment of the crops' physical characteristics that is calendar date that is based on time of flowering or planting. In this study the flowering and fruit-setting time were used as criteria for maturity determination. These are probably not very good as they are dependent on the seasonal climates (Mathooko, et al., 2002). Commodity shape and size may be used in some instances to decide on maturity, for example some cultivars of banana become less angular in cross-section as development and maturation progresses (Mathooko, et al., 2002). Analytical assessment of maturity requires using standard instruments to measure some physical characteristics that known to change in relation to maturity of product. Water content can be measured easily by weighing the product before and after drying under certain conditions like temperature of 105°C,

and total soluble solids (TSS) can be determined by use of a refractometer or hydrometer. Flesh firmness is commonly used to determine the maturity of several fruits, since as the fruit matures there is some dissolution of middle lamellae of the cell wall resulting in softening (Gerasopoulos and Richard, 1997). Acidity may be readily measured by titration. Moreover, it is acid component most closely linked with aging of fruit tissues as determined by softness and deformation parameters (Sasson and Monselise, 1977). The conversion of starch to sugar can be used as an index of maturity in some products. Optimum measurements maybe also used to assess the maturity of many crops. Colour changes for many fruits are associated with ripening and may be used to determine the optimum maturity for harvest. Respiratory behaviour can be used to determine or assess maturity especially for climacteric fruits. Commercial maturity can be related to the rise in respiration in fruits. Green-life which is the time from harvest of the fruit to the on-set of ripening is a concept usually used to indicate the degree of physiological immaturity at the time of harvest and also useful expression of potential storage life.

Maturity indices of Mango

Depending on what the fruit will be used for, the harvest of the mango fruit can start at any time when the fruit is very small up to point when the fruit is full matured. Mango is a highly perishable fruit. Mango for overseas exports or long storage demands for longer post harvest life (<http://www.tropical-seed.com/tech-forum/fruit-anon/mango-ph.html>). Harvestable maturity in mango plays an important role in the capacity required for the fruit storage and the overall quality of the fruit when ripen. The recommended stage of maturity will depend on the storage time required and the shipment time; there is however, a clear distinction between physiological and commercial maturity. For Florida-type varieties like the Kent and Zill and for other varieties like Sabre, the following categories applied:

Fully mature: outgrow shoulders, formation of a depression with ridges at the stem end, firm, and green. This fruit has reached physiological maturity, if left on the tree, it will be ripen naturally; if harvested, it will ripe to excellent quality. *Half mature*: shoulder in line with the stem with slight ridged edges, firm, and green. This fruit has reached full physiological maturity, but has reached commercial maturity. If left in the tree, it will develop to full physiological maturity: if removed from the tree, it will begin and complete the ripening processes. *Immature*: shoulders below the stem insertion with ridges absent, firm, and green.

This fruit is maturity not mature physiological or commercially. It will not ripen properly if harvested. Other characteristics have been suggested as maturity indices but tent not to be used in commercial operations because of inconsistency in the application. These include the total soluble solids (TSS), acid, and starch content; specific gravity; pulp colour; and weight. Mangoes normally take 80 to 120 days between fruit set and the physiological maturity, depending on the variety, location, and production conditions. Basing harvest on the time interval has been difficult with mango because individual trees will flower and set fruit over several weeks; the mango fruits on one tree are therefore of different ages (<http://www.tropical-seeds.com/tech-forum/fruits-anon/mango-ph.html>). Nagy (1980) also reported that the mango fruit is usually harvested in physiological mature but unripe stage, 15 weeks to 16 weeks from fruit setting. Unfortunately, insufficient data are available on all the commercial varieties. In Zambia, Mumba (1971) reported that mangoes starts ripening at the end of October in Mpulungu, Mbala and Nchelenge districts and continues to be available in various parts of the country, until the end of January when the Central and Southern province mangoes become ripe and he (Mumba) described the stage of harvesting as when the area around the stalk turns from green to pale yellow in colour. The harvest time and yield within genetic limitation depending on climate, vigour, age as well as 'on' and 'off' year habit (Singh, 1992)

Post harvest physiology

Post-harvest physiology has been defined as the division of plant physiology that deals with the functional processes in plant material after it has been harvested (Mathooko, et al., 2002). Post-harvest physiology is concerned with the plant or plant parts that are handled and marketed in living state including seed, vegetable, fruits, cut flowers, potted plants, nursery plants and edible fungi (Mathooko, et al., 2002). The quality of fruits and vegetables cannot be improved, after harvest but it can be preserved. Good quality is obtained when harvesting is done at the proper stage of maturity and proper ways of harvesting (Anon, 1975). The fruits and vegetables harvest too soon may remain green for long time but are of poor quality. And fruits and vegetables that are delayed in harvest may be susceptible to decay, resulting in poor quality (Nagy, 1980).

Quality factors

In harvested plant products, quality is a composite of those characteristics that differentiate individual units of the product and have significance in determining the unity's acceptability to the user (Mathooko, *et al.*, 2002). There are two forms of components of quality, which are nutritional and sensory. Nutritional components are used on the products that are to be consumed. Sensory criteria used include appearance, texture, aroma and taste.

Size: The size of the harvested product has a significant influence on the consumer appeal, handling practices, storage potential, market selection and final use. The size of the fruits can be determined using the width of the fruit and fruit weight

Shape and form. Has to conform within the average of a given species and cultivars. *Shape* (the outline of the product) and *form* (the arrange of the product) these are important factor of overall quality. In the study the shape was monitored as a ratio between the length and the width of the fruit.

Colour: The colour of an agricultural product probably contributes more to the assessment of the quality than any other single factor. Consumers have developed distinct correlation between colour and the overall quality of the product. For tomato it is usually red, banana and mangoes should be yellow or green. Colour is a function of light striking the product. Colour change may be due to either degradative or synthetic processes, or both. While colour is used as a criterion to assess the general quality of mango products, quality and colour do not necessarily correlate closely with each other and they cannot be used solely as criterion for quality (Mathooko, *et al.*, 2002). The pulp of many fruit becomes edible before the green colour has completely disappeared from skin. A number of preharvest and post harvest factors may affect the colour of harvested products for example cultivar may have tremendous effect in on the colour and/or colour stability after harvest. Moisture content, season, weather, improper handling, chilling injury and physical damage, can affect the colour of the fruit. Can be assessed visually (subjectively) or objectively using equipments like colorimeter (Hunter-laboratory colometer) expressing various lines of colour brightness, redness or yellowness

Condition and absence of defects

The general assessment of conditions may include general visible quality parameters such as colour, shape and freedom from defects. The defects can be classified as being due to:

1. Biological factors – pathological, entomological, zoological.
2. Physiological factors – physiological disorders nutrition imbalance and product immaturity.
3. Environmental factors – climate and weather, soil and water supply.
4. Mechanical damage. Arising out of cultural and harvesting practices
5. Presence of extraction matter – growing medium, vegetable matter, and chemical residue
6. Genetic aberrations. Can be transient or heritable

Taste: The most dominant chemical sensation are sweet, sour, and bitter, are of particular importance in post harvest quality of products with saltiness being seldom a factor of flesh produce. Sweetness and sugar and sourness from organic acids are dominant component in the taste of many fruits. Maturity, cultivars and degree of ripeness are likely to have an impact on the taste of many products as cultivars, irrigation and fertilization (Mathooko, et al., 2002).

Texture: Texture is comprised of those properties of a product that can be appraised by touch or visually. The internal textural properties of the plant products are due to the composition of the cells and the cell wall. Turgor pressure is an extremely important parameter affecting texture in many fleshy products. Product maturity has a significant bearing to the textural properties of the product. The handling and storage conditions to which many products are exposed after harvest may also significantly alter their textural properties. The loss of water due to improper control of relative humidity to which the product is exposed results in serious textural quality losses. Exposure of the product to chilling temperatures may result in textural alteration. Agronomical practices such as nutrition and irrigation may affect product texture (Mathooko, et al., 2002 and Pastistico, et al., 1975).

Nutritional value: Although the nutritional value of harvested commodities cannot be seen it is important in determining quality. The main nutrients of value are vitamin C and fruits and vegetables are the sole source of vitamin C to most people.

Harvesting and handling of mango

Harvesting of the product is the most important step or stage in post harvest of mango and many other crop products. Harvest starts the post harvest management process (Pastistico, et al., 1975). Harvesting the product should be done when the temperatures are low or during the cooler part of the day. When the temperatures are low, the respiration rate is low and that extends the shelf

life of the product. Respiration is one of the metabolic processes that represent the entirety of many chemical activities that occur in the cell and as such it is a very important process in the post harvest handling of the harvested products. The higher the respiration rate the lower the product shelf life. Respiration has a direct effect on the quality of product. In the study done mango fruits cultivars Kesar and Amrapali it was found that ripening of fruits at controlled temperature (22-25°C) significantly reduced the physiological loss in weight, and damage in fruit and increased the time required for ripening. Quality of ripe fruits in terms of higher level of total soluble solids (TSS) vitamin-C and total sugars and lower level of acidity was also highest in this treatment. The process of fruit ripening could be slowed down by retarding pre-climacteric activities of catalase, peroxidase and PME enzymes and rate of respiration and ethylene production (<http://www.actahort.org/books/291/291-53.htm>). Harvest the mango should be done properly. Because of some unique characteristics (like alternate fruit bearing, fruits on the same tree maturing and ripening at different times) of mango, growers have difficulties in deciding when to harvest the mango fruits for maximum storage life while maintaining fruit quality.

Chapter 3

MATERIALS AND METHODS

Experimental Site

The study was conducted during the 2001/02 agricultural seasons at University farm Liempe, Lusaka. The mango orchard used was established in the early 1960's. It is located about 25km, East of Lusaka. It lies between latitudes 15° 27'S and 15°24'S and between longitudes 20° 27'E and 20° 28'E, at an elevation of 1140 m above sea level.

The climate in this region, where the farm is, is a tropical continental type with three distinct seasons: A wet season from November to April; a cold dry season from May to July and a hot dry season from August to October. In this region the mean annual temperature falls in the range of 18-24°C except in major river valleys (Mulokela, 1995). Soil texture is clayey with sandy clay loam topsoil, with soil pH (CaCl₃) ranging from 3.8 to 4.7 and soil acidity reducing with increase in soil depth, and with medium nutrient status. According to USDA soil classification taxonomy are referred to as typic rhadoustalf or kandiustalf.

Plant materials

Mature trees of about 38 years old of improved (grafted) cultivars of mango were used Kent and Zill (monoembryonus type). Sabre is a Polyembryonus type and is from Israel and is medium season varieties while the Zill is an early season variety (Aron, et al., 1997; Singh, 1992). Kent and particularly Zill are susceptible to mildews and intolerant of high humidity and produce fruits of high colour and regular form. Sabre tolerates excess moisture. In the previous year (2000), these mango trees were subjected to regenerative pruning after a severe fire devastated the orchard. They had however, shown significant recovery during the test year. The study started on 7th August 2001 and continued until January 2002. The parameters measured were the fruit size rate, mass, skin and, pulp colour, firmness, total soluble solids, shelf life (storability). The harvest dates were 7th January, 12th January and 17th January 2002 and the ages of the fruits at those harvest dates were 136 day, 141 days and 146 days from fruit set respectively.

Orchard Management

Plant protection (spraying)

The trees were sprayed to a run-off with chemical fungicides and insecticides at three weeks interval. Since the trees were relatively big, a tractor mounted boom sprayer was used to spray. The knap-sack sprayer was used for spot spraying where necessary. The common diseases and insect pests in the orchard were anthracnose (*Colletotrichum gloeosporioides* Penz), Powdery mildew (*Oidium mangiferae*) and fruit black spot (*Xanthomonas compestris*). Anthracnose is common in the moist wet season and characteristic damage caused included leaf spotting, blossom blast, wither tip, dieback, fruit anthracnose and fruit rot. Powdery mildew (*Oidium mangiferae*) infects leaves and fruits, forming superficial blotches often purplish with a white bloom (Parker, 1976). The insect pests sprayed against were fruit flies (*Ceratitidis spp* or *Dacus spp*) that cause soft rot of the fruits; mango scale insects (*Aulacasyis tuberculasis*) extract juice from the plant and cause yellow and red discoloration on the fruit. Mango seed weevil (*Sternochetus mangiferae*) was the most serious insect pest in the mango orchard at Liempe farm and yearly caused a lot of damage to mango fruits.

To control these pathogenic diseases and insect pests the following formulations were used Fundazol or Benelate WP (active ingredient Benomy-Benzindazole 500g/kg) @ 40 gm/10 litres of water, Zoom BS (Carbendazin 50% w/w) @ 45 gm/15 litres of water and Avigard E (Mercapthothion-organophosphate 500gm/litre) 30 ml/10 litres of water and karate 2 ED (Hambdacyhalrothrin) @ 30 ml/10 litres of water. Each tree received about of 30 litres of the chemical tank mix at very spraying and a total of eight sprays were applied and throughout the study about of 240 litres of each chemical water mixtures was used. The application of these chemicals was done as per recommendation of the chemical manufacturer.

Fruit growth

Ten fruits on each tree (experimental unit) were selected and tagged. These ten fruits on each tree were randomly spread over skirt area. Fruit size, length and width were recorded every 3 weeks, fruit growth monitoring in terms of length (Polar) and width (Equatorial) of the fruit was done on these fruits. A veneer caliper took these measurements. The measurements were taken

and recorded. The first measurement was done on the 6th October 2001 at 3 weeks, at 50%-100% anthesis.

For the effect of insect and disease control on the shelf life, another set of trees were randomly selected and were not sprayed with chemical fungicides or insecticides. Routine weeding was done around every tree under consideration. This was done as a protection measure against bush fire and for orchard hygiene (plant protection) as well as for identification of the experimental units. The size of the tree determined the size of the basin. In line with plant protection all branches were removed and any fruit that dropped from the tree on their own, were picked and thrown away from the orchard. Orchard hygiene was strictly maintained at all times.

Harvesting

Fruits were harvested at three harvest dates. The decision to begin harvesting was based on the steady fruit growth. The fruits were harvested from the farm and transported to the main campus, University of Zambia, for laboratory analysis at harvest and subsequent one at day 5 and day 10. For diseases and insect pests infestation monitoring five fruits were picked from each tree at every three weeks. At 16 weeks after fruit-setting the increase in the diameter was steady and almost no change in the diameter was observed during the next three weeks and this period was taken as the time when the fruit was approaching maturity. The harvest dates were the 7th January 2002 (when the fruits were 136 days old), 12th January 2002 (fruits were 141 days old) and 17th January 2002 (fruits were 146 days old). Harvesting was done by hand. The fruit was twisted sharply sidewise or up wards, during harvest care was taken not to allow the fruit dropping to the ground. The pedicel was trimmed short enough to keep it from puncturing other fruit. The picker climbed the trees and using collecting bags put in the harvested mango fruit. At each of these harvest dates, twenty fruits from each of the treated trees were picked, ten fruits for external and internal quality analysis and the other ten fruits for shelf life analysis. Ten fruits per tree were picked from the controls. The time taken from the harvest to start of the laboratory analysis was about one hour.

Fruit handling

The ten fruits were harvested, to monitor the diseases development and the infection of the insect pests. They were cut longitudinally using a very sharp knife and the cross sections of the fruit were

carefully examined for signs and symptoms of diseases and the presence of any insect and this operation was done in the field. All fruits were washed under the tap water and rinsed in the distilled water. The washed fruit sample was later placed on the standing trays. All fruits were weighed using the electronic weighing scale, and weights of individual fruits were recorded. Three fruits were analyzed for external and internal on the day of harvest, five days after harvest, and the last four fruits were analysed 10 days after harvest. At each analysis the fruits the following determined fruit mass, skin colour, pulp colour, firmness and total soluble solids. Another set of ten fruits from each tree was kept for shelf life analysis. In this study observations were done between those fruits that received pre-harvest chemical fungicide/insecticide treatment and those that received no pre-harvest chemical treatment. All the fruits were subjected to same conditions like temperature, relative humidity and shaded light during storage. During the study in the storage any decay or insect damaged fruits were removed from the set and count as decayed or diseased. The mean maximum and minimum daily temperatures (26.7°C and 23.4°C respectively) were recorded using maximum and minimum thermometer in the storeroom, throughout the study period (Appendix, 3).

Fruit Skin colour

The skin colour of the fruit sample was monitored visually and used in the assessment of both the internal and external quality of the mango fruit. The colour change from pure green to yellow/orange was observed from the blossom end of the fruit. Care was taken to avoid confusion where reddening or colour change associated with excessive fruit exposure to sunlight. The rating for skin colour changes was 1-5. The higher the rating value was the more advanced was the colour of the fruit skin. Rating of 1 meant that the fruit skin colour was green and no colour change towards yellow/orange. Rating of 2 value meant that the fruit skin colour had advanced 25% in colour change towards the yellow colour and the 75% of the fruit surface area was still green. The rating value of 3 was given to fruit that was showing 50% colour change towards the yellow/orange colour. The rating value of 4 was given when only 25% of the fruit surface area was still showing some green colour (75% of the skin was yellow/orange) and rating value of 5 was scored when very little or no green colour was visible.

Fruit Firmness

Due to lack of a penetrometer, a hand system was used. This was subjectively done using the human hand to apply pressure on the fruit, placed between the forefinger and thumb. The ratings used were from 1 to 5, based on ability of the indentation to appear/disappear after pressure removal. Firmness was rated as one or hard (fruit does not yield under finger pressure), 2 or firm (fruit does not yield ready to finger pressure), 3 or firm-ripen (fruit yields ready to finger pressure), 4 or soft ripe (fruit uniformly soft this is stage usually preferred) and 5 or overripe (soft and mushy not a desirable eating stage).

Fruit Pulp colour

This is another indicator that is be used for determining the fruit maturity. As the fruits ripen the pulp colour changes from white (cream) to orange/yellow. At each analysis, after weighing, fruit samples were sliced longitudinally using a sharp knife to about 1 - 2 cm from the seed, on either side of the fruit. The pieces were observed under full light and scored for colour.

Scoring done subjectively using the visual judgment to describe the colour of the pulp and the ratings were based on the transition of the pulp colour from white/cream to yellow/orange. The rating was 1 - 5. Rating 1 (to yellow colour 100% white/cream colour), rating 2 (25% colour change to yellow, or 75% white/cream colour), rating 3, (50% colour change to yellow, 50% white/cream), rating 4, (75%of pulp has deep yellow colour, 25%) and rating 5, (almost 100% pulp has deep yellow colour to yellow).

Total soluble solids.

This parameter aspect of fruit quality and maturity index was determined using the refractometer (Model). The results were expressed as degree Brix or percent soluble solids. Using a sharp knife, the fruit samples were sliced longitudinally to about 1 - 2 cm from the seed, and these slices from either side of the seed, were squeezed onto the lens of the refractometer and the total soluble solids read from the eyepiece.

Shelf life

Fruit firmness and proportion of normal non-diseased fruits were determined every five days for one-month storage. 'Kent and Sabre' mangoes were harvested at three different dates of five days

interval from the University of Zambia farm, Liempe. The harvesting of mangoes was based on the marked decline in diameter increase of the fruit. Fruits were harvested and transported to school of Agricultural sciences, Crop science department plant protection laboratory. The harvest dates were 02nd January, 07th January, 12th January and 17th January 2002, which are represented by 131, 136, 141, and 146 days after fruit set. After cleaning and washing the fruits were placed on plastic racks. Each rack had 3 trays placed at 50cm. These trays had a 1cm mesh and allowed free air to circulate. Two sets of fruit samples were kept and observed in the storeroom. One set of the fruit samples was from treated trees while the other set was from trees that were not sprayed (control). The average ambient temperature ranging from about 23.0 to 27.0°C, relative humidity of about 65-75% and atmospheric air with partially shaded light. In each set, there were ten fruits at start of the storage duration's period. This meant that twenty fruits per cultivars were harvested, every five days. Both sets of fruit samples were treated in the same manner. Every five days a check was made on the fruit samples in both sets and any fruit from any set that showed signs or symptoms of diseases, or decays or insect damages was removed. This observation was done for a period 30 days from the harvests. The scale used was 1 - 5. 1 was for clean fruit and 5 was for fruits that were more than 50% infected as either too soft sunken fruit skin, spotted skin, decayed (watery) skin and holes in the skin. The results expressed as a percentage of the clean fruits. To make this determination standard the signs and symptoms for anthracnose, powdery mildew and brown soft rot diseases were considered. The change in weight was calculated as the loss in the weights of the fruit sample and expressed as percentage of the initial weight.

Experimental design and data analyses

A split-plot design with three factors replicated four times was used. The three factors were the cultivars (as main plot), harvest date (as split plot) and storage duration (as split plot). The data were subjected to analysis of variance to examine if there were any significant differences among treatments. The separation of the means was by the Duncan's multiple range (Little and Hills, 1987). For the shelf life evaluation a t-tests was used. The complete statistical package superanova was used to analysis the data. Differences were considered significant at $p \leq 0.05$

Chapter 4

RESULTS

Fruit quality characteristics of different of cultivars

Fruit growth

Cumulative growth was measured as the width (diameter -mm) of the fruit and was expressed as fruit shape and related it to fruit mass. Fruit growth followed a normal sigmoid curve but Kent was larger than Sabre (Figure 1). The fruit mass for Kent cultivar was significantly higher than that Sabre cultivar 476.4 grams and 160.7 gram respectively (Table 1).

Fruit skin colour

Skin colour for both cultivars Kent and Sabre were the same that was 2.70 and 2.88 respectively (Table 1).

Fruit firmness

There was no significant difference in fruit firmness between the two mango cultivars at harvest. However, there was a reduction in fruit firmness for both cultivars due to age, with Kent having 2.93 value for firmness and Sabre having 2.77 value for firmness, (Table 1).

Fruit total soluble solids.

Percentage of total soluble solids (TSS) pooled over the three harvest dates were significantly different in both cultivars Sabre mango fruit had higher percentage of total soluble solids of 14.75% than Kent with 14.37% (Table 1).

Fruit weight

The effects of cultivar on the fruit weight loss were highly significant. Sabre mango fruit had experienced higher weight loss of 9.67% than Kent mango fruit that had a loss of 4.62% (Table 1).

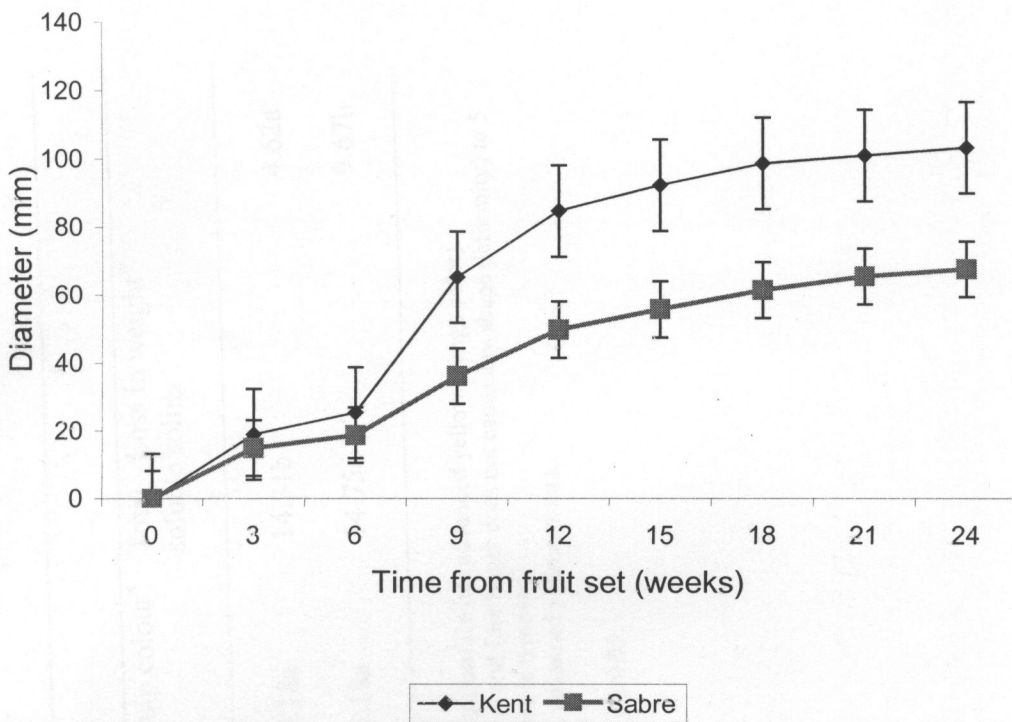


Figure 1: Fruit growth curves (mm) of the mango cultivars (Kent and Sabre)..

Table 1. Fruit quality characteristics of fully ripe Sabre and Kent mango fruits (*Mangifera indica*) determined at harvest. Data was pooled for the three harvests at 136, 141 and 146 days after fruit set (n = 10).

Variety	Fruit quality factors				
	Fruit weight (g)	Skin colour ^z	Firmness ^y	Pulp colour ^x	Total Loss in weight ^w soluble solids
Kent	476.4a	2.70a	2.93a	3.18a	14.31b
Sabre	160.7b	2.88a	2.77a	3.18a	14.75a

^zSkin color was ranked visually from 1 (full green over) to 5 (more than 75% of the fruit skin surface has advanced yellow orange color).

^yFirmness was ranked from 1 (application of moderate pressure to fruits held between thumb and fore finger does not cause any shape deformity) to 5 (applications of finger pressure causes shape deformity that does not disappear after pressure is removed).

^xPulp color was ranked visually from 1 (full green) to 5 (more than 75 % of the skin has an advanced yellow color).

^wChange in weight of fruit during storage expressed as a percentage of initial fruit weight.

^vMeans within each column followed by the same letter were not significantly different at $p \leq 0.05$.

Fruit quality characteristics of fully ripe mango fruits (Mangifera indica) relative to harvest age

Fruit Mass

Harvest date (degree of maturity) exerted significant effect on fruit mass. Fruit weight increased with age. Fruits harvested at 141 days old were significantly heavier than those harvested at 136 and 146 days old. No differences were observed among fruit from the three different harvest dates in weight loss (Table. 2).

Table 2. Fruit quality characteristics of fully ripe mango fruits (*Mangifera indica*) determined by harvest age. Data (n= 10) was pooled for two varieties (Sabre and Kent).

Fruit age at harvest		Fruit quality factors				
(Days after fruit set)	Fruit weight (g)	Skin color ^z	Firmness ^y	Pulp color ^x	Total soluble solids	Loss in weight ^w
136	303.48b ^v	2.78b	2.22c	2.71c	13.50c	7.26a
141	345.80a	2.86b	2.84b	3.20b	15.61a	6.37a
146	306.93b	3.32a	3.43a	3.64a	14.55b	7.95a

^z Skin color was ranked visually from 1 (full green over) to 5 (more than 75% of the fruit skin surface has advanced yellow orange color).

^y Firmness was ranked from 1 (application of moderate pressure to fruits held between thumb and fore finger does not cause any shape deformity) to 5 (application of finger pressure causes shape deformity that does not disappear after pressure is removed).

^x Pulp color was ranked visually from 1 (full green) to 5 (more than 75 % of the skin has an advanced yellow color).

^w Change in weight of fruit during storage expressed as a percentage of initial fruit weight.

^v Means within each column followed by the same letter were not significantly different at $p \leq 0.05$.

Fruit Firmness

All the harvest dates were significantly different from each other with the 146 days from fruit setting being the highest relative to the other two harvest dates. The fruit firmness at harvest decreased with fruit maturation, by 52.2% for Kent and 39.4% for Sabre (Table 2).

Fruit Pulp Colour

The effects of the harvest date on the fruit pulp colour are shown on table 2. The fruit pulp colour for all the three-harvest date was statistically different from each other. Colour increased with fruit maturation. Fruit harvested at 146 days after fruit set had the highest colour (3.32).

Fruit Total Soluble Solids

The effects of the harvest date on the fruit total soluble solids were highly significant, with the Sabre mango cultivars having the higher percentage (14.8%) of total soluble solids than Kent (14.4%) The total soluble solids percentage for the fruits harvested at 141 days after the fruit set (DAFS) was significantly higher than the other two fruit ages at 136 days and 146 days. Total solid increased in fruits as they mature up to a point then declines. Fruits harvested at 136days had average total soluble solids of 13.50%. Fruit harvested at 141 days old were found to have an average of total soluble solids of about 15.6%, while those fruits harvested at 146 days had on average of about 14.6% of total soluble solids. The differences in percentage fruit total soluble solids between the fruits of 141 days old (harvest date) and the other two fruit ages of 136 and 146 days after fruit set (harvest date) was 90.6% (Table 2).

Effects of storage durations on fruit quality characteristics.

Fruit Mass

The effects of the Storage duration on the fruit mass were significant (Table 3). Fruit mass at day 0 (136 days old) and day 5 (141 days old) in storage were not significantly different from each other, but the loss in fruit weight at day 10 (146 days old) in storage was statistically different from the other two storage times. Lost in weight at 10 days in storage was about 10% (Table 3).

Fruit Skin Colour

The influence of storage duration on the fruit skin colour was highly significant, with all the three storage duration times having fruit skin colour scores significantly different from each other. Day 0 had a low skin colour score of 1.6. Day 5 had the skin colour score of 2.9 and day 10 had skin colour score of 4.0 (Table 3).

Fruit Firmness

There was a highly significant reduction in the fruit firmness while in storage. All the three storage duration times were significantly different from each other. Ten days in storage score value was 4.2. At harvest and five days losses in fruit firmness were in storage 1.5 and 2.9 respectively (Table 3).

Fruit Pulp Colour

Storage duration advanced fruit pulp colour was significantly. All the three duration times were significant different from each other. The fruit pulp colour at harvest was 2.55, after five days it advanced 3.19 and at ten days to days it rose to 3.81 (Table 3).

Fruit Total Soluble Solids

The percentage of the fruit total soluble solids increased significantly while in storage and all the three-storage duration times were significant different form each other. There was an increase in the percentage of total soluble solids from day 0 to day 5 of about 74%. From day 5 to day 10 it was 14% (Table 3).

Table 3. Changes in fruit quality characteristics of fully ripe mango (*Mangifera indica*) fruits subjected to storage under shaded-ambient conditions. Data (n= 10) was pooled for two varieties (Sabre and Kent).

Storage duration ^u	Fruit quality factors					
	Fruit weight (g)	Skin color ^z	Firmness ^y	Pulp color ^x	Total soluble solids	Loss in weight ^w
0	339.96a	1.55c	1.46c	2.55c	9.26c	5.28a
5	326.88a	2.88b	2.92b	3.19b	16.09b	17.30b
10	294.68b	3.95a	4.17a	3.81a	18.31a	5.99a

^z Skin color was ranked visually from 1 (full green over) to 5 (more than 75% of the fruit skin surface has advanced yellow orange color).

^y Firmness was ranked from 1 (application of moderate pressure to fruits held between thumb and fore finger does not cause any shape deformity) to 5 (application of finger pressure causes shape deformity that does not disappear after pressure is removed).

^x Pulp color was ranked visually from 1 (full green) to 5 (more than 75 % of the skin has an advanced yellow color).

^w Change in weight of fruit during storage expressed as a percentage of initial fruit weight.

^v Means within each column followed by the same letter were not significantly different at $p \leq 0.05$

^u numbers of days in storage

Fruit weight

The effects of Storage duration on the fruit weight content were highly significant. Five days in storage the fruit experienced a higher loss in fruit weight of about 17.30% than ten days in storage where a loss of 5.99% in weight was noted (Table 3).

Interaction of cultivar and harvest date on fruit quality of mango (Mangifera indica) fruits harvested at various maturity stages.

Fruit Mass

The effects of cultivars and harvest dates (degree of maturity) on the fruit mass are shown in Table 4. The fruit masses for Kent and Sabre cultivars at three different fruit ages 136, 141, and 146 days after fruit set were similar.. But there was a significant difference in fruit mass between Kent and Sabre. (Table.4).

Fruit skin colour, firmness and pulp colour

The effects of interaction of cultivars and harvest date were shown not to be significant, yet this kind of interaction was supposed to be significant on fruit skin and pulp colour and firmness (Table 4).

Fruit Total Soluble Solids

The effects of interaction of cultivars and harvest date (degree of maturity) were highly significant on the fruit total soluble solids. The Sabre mango cultivar had a higher percentage of the fruit total soluble solids than Kent cultivar. At the age of 136 days after fruit set Sabre had total soluble solids of 13.82% while Kent had 13.18%. At 141 days after fruit set the percentage of total soluble solids was 18.31% in Sabre while in Kent the total soluble solids was 14.97% and at the age of 146 days Sabre had 16.09% and Kent had 14.93% (Table 4).

Table 4. Interaction of cultivar and harvest date on fruit quality of mango (*Mangifera indica*) fruits harvested at various maturity. Data (n= 10) was pooled for two varieties (Sabre and Kent).

Variety	Fruit quality factors						
	Fruit age at harvest	Fruit weight (g)	Skin colour ^z	Firmness ^y	Pulp colour ^x	Total soluble Solids (%)	
	(Days after fruit set)						
Kent	136	439.20a ^v	2.36a	2.36a	2.75a	13.18d	
	141	534.40a	2.75a	2.83a	3.19a	14.97c	
	146	455.60a	3.25a	3.59a	3.64a	14.93c	
Sabre	136	167.00b ^v	2.17a	2.71a	2.67a	13.82d	
	141	165.80b	2.96a	2.84a	3.21a	18.31a	
	146	158.40b	3.50a	3.28	3.68a	16.09b	

^z Skin color was ranked visually from 1 (full green over) to 5 (more than 75% of the fruit skin surface has advanced yellow orange color).

^y Firmness was ranked from 1 (application of moderate pressure to fruits held between thumb and fore finger does not cause any shape deformity) to 5 (application of finger pressure causes shape deformity that does not disappear after pressure is removed).

^x Pulp color was ranked visually from 1 (full green) to 5 (more than 75 % of the skin has an advanced yellow color).

^w Means within each column followed by the same letter were not significantly different at p ≤ 0.05.

Interaction of cultivars and storage durations on fruit quality characteristics of fully ripe mango fruits (Mangifera indica) determined at various storage durations

Fruit mass

The effects of the interaction of variety and storage duration were not significant on fruit mass analysed by the analysis of variance (Table 5).

Table 5. Interaction of variety and storage duration on fruit quality characteristics of fully ripe mango (*Mangifera indica*) fruits determined at various storage durations. Each datum was an average of 10 samples.

Variety	Fruit quality factors						
	Fruit in storage	Fruit weight (g)	Skin color ^z	Firmness ^y	Pulp color ^x	Total soluble Solids (%)	Loss in weight ^w
	(Days in storage)						
Kent	0	498.30a	1.52c	1.44d	1.12c	8.33d	0.01a
	5	477.80a	2.71b	2.92c	2.26b	16.22b	4.12ab
	10	453.00a	3.84a	4.42a	4.17a	18.54a	9.71c
Sabre	0	181.60a	1.58c	1.48d	1.98b	10.20c	10.57c
	5	164.00a	3.00b	2.92c	3.46a	15.96b	16.47d
	10	136.30a	4.04a	3.92b	4.12a	18.08a	7.27bc

^z Skin color was ranked visually from 1 (full green over) to 5 (more than 75% of the fruit skin surface has advanced yellow orange color).

^y Firmness was ranked from 1 (application of moderate pressure to fruits held between thumb and fore finger does not cause any shape deformity) to 5 (application of finger pressure causes shape deformity that does not disappear after pressure is removed).

^x Pulp color was ranked visually from 1 (full green) to 5 (more than 75 % of the skin has an advanced yellow color).

^w Change in weight of fruit during storage expressed as a percentage of initial fruit weight.

^v Means within each column followed by the same letter were not significantly different at $p \leq 0.05$.

Fruit Skin Colour

Effects of interaction of variety and storage duration on the fruit skin colour were highly significant. At harvest (the start of the storage duration) the fruit skin colour scores were statistically not different from each other. The colour advanced towards the accepted bright yellow colour from the green colour by 149.67% in Kent and 155.69% in Sabre that was day 0 (at harvest) to day 10 (after harvest) (Table 5).

Fruit Firmness

Effects of interaction of the cultivars and storage duration on the fruit firmness were significant. At day 0 the score was lower (1.44 for Kent and 1.48 for Sabre) and at day 5 the score value for Kent and Sabre were 2.92. At 10 days it increased to higher scores 4.41 for Kent and 3.92 for Sabre. Fruit firmness reduced from harvest to day 5 in storage by about 100% for Kent and about 97.3% for Sabre. From day 5 to day 10 the reduction in firmness was recorded as 51% for Kent and 34% for Sabre had better eating quality than Kent after 10 days in storage (Table.5).

Fruit Pulp Colour

Effects of interaction of cultivars and storage duration were highly significant on fruit pulp colour. Colour advanced from day 0 to day 10 in storage by about 272.32% for Kent mango fruits and 108.08% for Sabre mango fruits (Table 5).

Fruit Total Soluble Solids

The effects of interaction of cultivars and storage duration on the fruit total soluble solids were significant. The total soluble solids increased from the day 0 to day 5 after harvest. And from day 5 to day 10 the total soluble solids increased. At day 0 in storage, the percentage of the total soluble solids was 8.33% for Kent and 10.23% for Sabre cultivar. At day 5 the percentage of total soluble solids were 16.22% and 15.96% for Kent and Sabre cultivars respectively. At day 10 the percentages for total soluble solids Kent had 18.54% and Sabre had 18.08% (Table 5).

Fruit weight

The loss of the fruit weight was significant. Both mango cultivars experienced a lot of loss in weight Most of fruit weight losses were noted more in at five days in storage (Table 5).

Interaction of harvest date and storage duration on fruit quality characteristics of fully ripe mango fruits (Mangifera indica) determined at various storage durations

The effects of interaction of the degree of maturity with storage duration on fruit mass, skin and pulp colour and firmness were not significant. The changes noted were normal ones that are brought about as a result of differences in cultivars and storage times. The loss in fruit weight was not significant at all dates of harvest and storage duration interaction (Table 6).

Table 6. Interaction of harvest date and storage duration on fruit quality characteristics of fully ripe mango (*Mangifera indica*) fruits determined at various storage durations. Each datum was an average of 10 samples.

Fruit age at harvest		Fruit quality factors						
(Days after harvest)	Fruit weight (g)	Skin color ^z	Firmness ^y	Pulp color ^x	Total soluble Solids (%)	Loss in weight ^w		
136	0	319.44bc	1.04e	1.04g	1.89e	8.13e	7.20ab	
	5	298.38c	2.25d	2.27d	3.45c	15.10c	1.62a	
	10	292.59c	2.34cd	3.53b	3.78bc	17.27b	7.22ab	
141	0	372.60a	1.50	1.47fg	2.52d	11.52d	5.29ab	
	5	359.50ab	2.83e	2.75cd	2.84d	16.70b	11.29b	
	10	303.12c	4.17a	4.28a	3.84b	18.62a	10.32b	
146	0	327.85abc	2.04d	1.88ef	3.25c	8.19e	5.28ab	
	5	304.72c	3.58b	3.73bc	4.14ab	16.42bc	6.29ab	
	10	288.32c	4.34a	4.69a	4.53a	19.04a	6.31ab	

^z Skin color was ranked visually from 1 (full green over) to 5 (more than 75% of the fruit skin surface has advanced yellow orange color).

^y Firmness was ranked from 1 (application of moderate pressure to fruits held between thumb and fore finger does not cause any shape deformity) to 5 (application of finger pressure causes shape deformity that does not disappear after pressure is removed)

^xPulp color was ranked visually from 1 (full green) to 5 (more than 75 % of the skin has an advanced yellow color). ^wChange in weight of fruit during storage expressed as a percentage of initial fruit weight.

^vMeans within each column followed by the same letter were not significantly different at $p \leq 0.05$.

Fruit Total Soluble Solids

Harvest date and storage duration exerted significant effects on fruit total soluble solids as shown in Table 6. Generally the percentage of the total soluble solids increased from the day 0 to day 5 and from day 5 to day 10 at each harvest age. From 136 days after fruit set (DAFS) the percentage of the total soluble solids increased from 8.13% to 15.10% and then to 17.27% at day 10. For 141 DAFS the total soluble solids percentage increased from 11.52% to 16.70% and then increased to 18.12%. For the 146 DAFS it was from 8.15% to 16.42% and at day 10 the percentage of total soluble solids was 19.04% (Table 6).

The effect pre harvest chemical sprays on fruit Shelf life.

The pre harvest chemical fungicides and insecticides spraying on mango (*Mangifera indica* Linn) fruits was found to be highly significant on extending the shelf life and in reducing the post harvest losses. A total of eight sprays were done. The first spray was done on the 15th August 2001. The spraying as a pre-harvest treatment significantly increased the shelf life of the mango fruits by 15 days, (Table 7) under the ambient room temperatures and relative humidity and the number of fruits decaying during the post-harvest storage was significantly reduced. No fungal decay and/or diseased fruits were observed during the first twenty days in storage of mango fruits that were pre harvest treated with the chemical fungicides and insecticides. The decay of mango fruits that received no chemical fungicides and insecticides during the pre harvest period was observed within the first five in storage the intensity increased as storage duration increased. The numbers of decayed fruits at the end of the storage period were 1.25 fruit and 5.33 fruits for treated and untreated (control) respectively. The storage period was thirty days. In terms of post harvest losses 12.5% for the sprayed and 53.3% for control were obtained in 35 days, (Figure 2). This meant that the preharvest chemical treatments on mango trees and fruits would reduce the current post harvest losses by about 40-41% and this suggest that mango orchard as a business would increase the profits by the same margin. The pre harvest chemical treatment eliminated the invasion of fungi, bacteria insects and other organisms that cause high post harvest losses in horticultural products. The application of chemical fungicides and insecticides slowed down the attack of fresh produce by the microorganisms. The relatively high temperatures that prevailed in the storeroom greatly suppressed the development of the decay causing microorganisms.

Table 7. Number of fruits observed for decay in the storeroom from treated and untreated trees

Treatments			Number of fruits in storage ^x							
			Day 0 ^y	Day 5	Day 10	Day 15	Day 20	Day 25	Day 30	Final number
Sprayed	Kent ^w	131 ^z	10	10	10	10	10	10	10	10
Sprayed	Kent	136	10	10	10	10	10	10	9	9
Sprayed	Kent	141	10	10	10	10	10	9	8	8
Sprayed	Kent	146	10	10	10	10	9	8	7	7
Sprayed	Sabre ^w	131	10	10	10	10	10	9	9	9
Sprayed	Sabre	136	10	10	10	10	9	9	9	9
Sprayed	Sabre	141	10	10	10	10	10	10	9	9
Sprayed	Sabre	146	10	10	10	10	10	10	9	9
Unsprayed	Kent	131	10	9	9	9	8	7	7	7
Unsprayed	Kent	136	10	10	8	7	5	5	3	3
Unsprayed	Kent	141	10	10	9	8	6	4	4	4
Unsprayed	Kent	146	10	10	10	8	5	1	1	1
Unsprayed	Sabre	131	10	10	10	10	9	8	7	7
Unsprayed	Sabre	136	10	10	10	9	8	5	3	3
Unsprayed	Sabre	141	10	10	10	10	8	6	3	3
Unsprayed	Sabre	146	10	10	10	10	8	6	3	3
	Total	160	159	156	151	135	117	99		101
	Means	8.9	8.8	8.7	8.4	7.5	6.5	5.5		5.6

^zNumber of days at harvest (Fruit age).

^yNumber of days in storage after harvest.

^xTen mango fruits were kept in storage and formed datum for fruit loss.

^wMango cultivars considered in the study.

At 131 days after fruit set all the ten fruits of Kent cultivars were in good eating condition after 30 days in storage. At 136 days old nine fruits of Kent cultivar were found to be good after the storage period. Fruits harvested at 141 and 146 days old were noted to have had eight and seven fruits of Kent cultivar that were found to be good for eating after the storage time of thirty days respectively. And this worked to be 15% loss of fruits as through decay. As for fruits obtained from trees of Kent cultivar that were unsprayed with chemicals had the following number of fruits that were found to be good for eating at the end of the storage time, at 131 days old, 136 days old, 141 days old and 146 days old six, two, three and zero respectively and this came to be 63% loss of fruits. As for sabre cultivar fruits obtained from sprayed and unsprayed trees harvested at 131 days old, 136 days old, 141 days old and 146 days old the number of good and sound fruits were 9 (sprayed) and 7 (unsprayed), 9 (sprayed) and 3 (unsprayed), 10 (sprayed), and 5 (unsprayed) and 10 (sprayed) and 3 (unsprayed) respectively. In terms of losses in percentage for sprayed it was about 10% and of about 52.5% for unsprayed fruits. More post harvest fruit losses were noted in Kent cultivar than it was with Sabre cultivar.

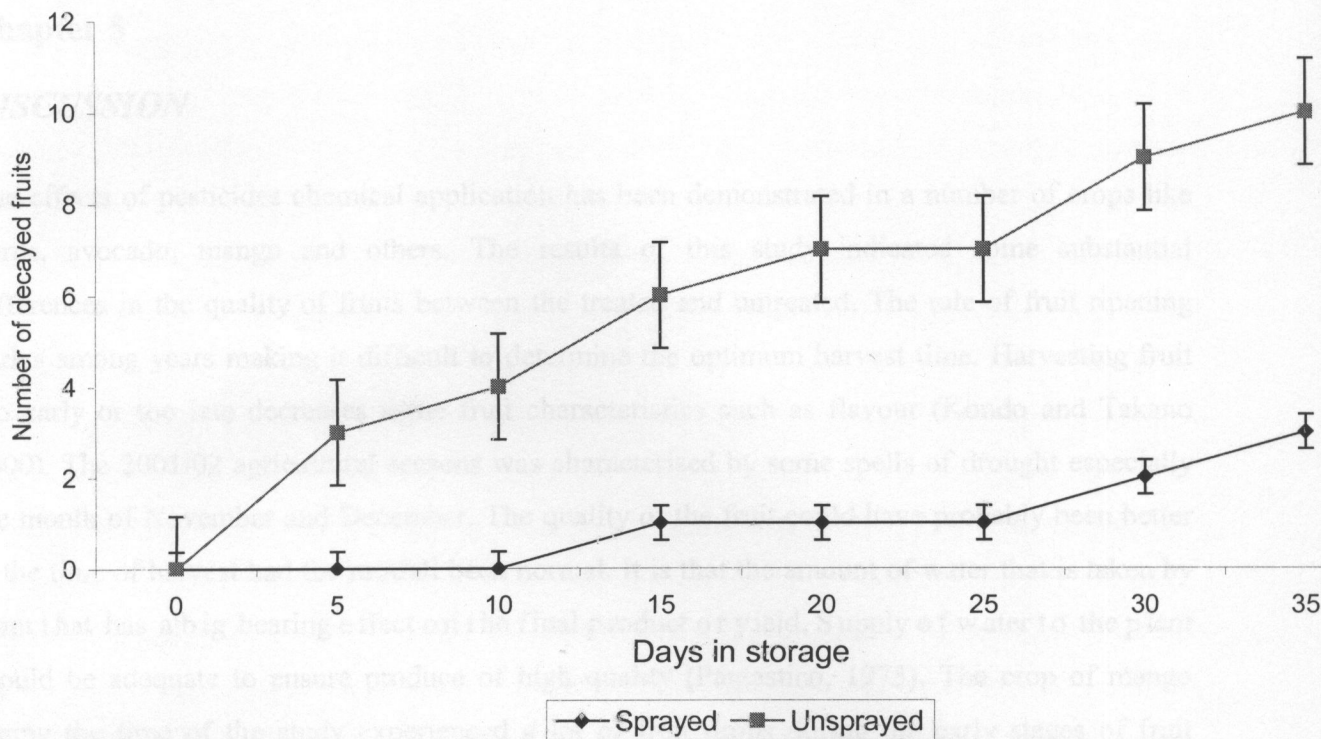


Figure 2: Number of normal and decayed mango fruits of Kent and Sabre in sprayed and unsprayed treatments.

Chapter 5

DISCUSSION

The effects of pesticides chemical application has been demonstrated in a number of crops like citrus, avocado, mango and others. The results of this study indicated some substantial differences in the quality of fruits between the treated and untreated. The rate of fruit ripening varies among years making it difficult to determine the optimum harvest time. Harvesting fruit too early or too late decreases some fruit characteristics such as flavour (Kondo and Takano 2000). The 2001/02 agricultural seasons was characterised by some spells of drought especially the month of November and December. The quality of the fruit could have probably been better at the time of harvest had the rainfall been normal. It is that the amount of water that is taken by plant that has a big bearing effect on the final product or yield. Supply of water to the plant should be adequate to ensure produce of high quality (Pantastico, 1975). The crop of mango during the time of the study experienced a lot of fruit drops during the early stages of fruit development and this was probably due to water deficit. It is evident that the palatability and the taste of fruit are closely associated with the amount and type of chemical constituents and the physical nature of the commodity at the time of harvest. Post harvest manipulations can only affect metabolic transformation of the chemical compounds that are already present. Pantastico (1975), observed that one of the most dramatic effects of chemical sprays was that of lead arsenate applied post bloom on grapefruit in Florida and reported that spraying produced a 30 to 40% reduction in acidity and increased non-reducing sugars and total flavenoid content of the juice. This same response to chemical spraying was also reported from South Africa following calcium arsenate application on 'Valencia' oranges (Manicom, 1991). Pantastico (1975), pointed out that extensive use of the chemicals in spraying the fruit trees had detrimental effects on the quality. The soluble solids decreased and acidity increased. The effects of cultivars, harvest days and storage time on the external and internal quality of mango were significant. Different combination of these three factors produced different effects on the measured parameters. As single factors, their effects were in most cases highly significant on the parameters that were observed. The results obtained are similar to those reported by Harlan and Bianco (1977), working the compositional changes in muskmelons during development and in response to

ethylene treatment. Although the fruits were bigger than the mango fruits, the results obtained in this study, for changes in percentage of fruit growth, fruit skin colour, fruit pulp colour, fruit firmness and total soluble solids are in general agreement with that study on muskmelons. The fruit growth monitored during the study was in line with the proposed mango phenological cycle (Robert, 1991). At maturity, the fruit maintained a constant weight, volume, length and the width. During the ripening process a fruit passes through a series overt changes in colour texture and flavor indicating that compositional changes are taking. The colour of the skin and pulp of mango fruit is reported to increase as the fruit matures and ripens (Pantastico et. al., 1975). With fruits consumed by humans, colour changes that occur during the ripening period are often used as an index to degree of ripeness and also to identify commodities. The timing of harvest for some fruits may be determined by using colour. Thus colour change during ripening and storage are of primary importance (Mathooko et al., 2002). Alteration of colour of fruits normally involves the loss of chlorophyll and / or either the synthesis /degradation of other pigments such as carotenoids and anthocyanins and/or the unmasking of those pigments formed earlier in development of fruits. The timing rate, and extent of changes in fruit colour vary widely between different species and cultivars of the same species. The timing of colour change can be associated relative to the time of harvest or to the actual ripening of the fruits (Mathooko et al., 2002).

Sabre cultivar developed the yellow- green colour much earlier than Kent cultivar, but was late in developing the bright yellow color. The skin colour changes advanced from 2.6 (51.4% colour change to yellow) at the first harvest to 3.6 (72% colour change) at the third harvest. The first harvest was done at 136 days from flowering and the third one was done at 147 from flowering. These results are similar with what has been reported on mango varieties like Alphonso and Pairi that the skin colour breaks from green to yellow colour usually takes place 108 - 125 days after fruiting (Lodh.1970). In my study carried at the Liempa farm the optimum harvest time occurred at 141 days from flowering or 113 days from fruiting and it was that time when the skin colour change from dark green to olive green and the pulp colour from white pale yellow (or cream). Kent fruits at all harvests were firmer than the sabre fruits, and there was decrease in fruit firmness in both cultivars with increase in harvest maturity. Fruit harvested earlier were firmer than those ones harvested at later stages. The texture of the fleshy fruit is affected by the composition of their cell wall and cellular constituents and their degree of hydration. The loss of

fruit firmness is associated with the increase in soluble pectic (during maturation and ripening) and decline in insoluble protopectic (Mathooko, et al., 2002). During this time, fruit become soft. Softening is one of the most significant quality alteration associated with the ripening of fleshy fruits. Alteration in fruit texture often affects both the edibility and the length time the fruit may be held. The loss of fruit firmness was quicker in sabre fruits than it was with the Kent fruits. For marketing purposes firmness is important. At maturity (harvest) fruits should be firm for easier transportation but soften sufficiently when ripe. The effect of storage on fruit firmness was highly significant and all fruits lost their firmness due to their degree of maturity. Mango fruits in both cultivars at harvest were firmer than at the end of the storage time. And their differences in firmness may be explained by difference in their chemical composition. The loss of fruit firmness is reported to increase with increase in temperature and is closely associated with the amount of calcium in the cell wall (Blankenship, et al., 1997). The amount of fruit total soluble solids is known to increase as the fruit matures and ripens (Pantastico, et al., 1975). The concentration of total soluble solids at first harvest (136 DAFS) that is 8.33% for Kent and 10.22% for Sabre was lower than that of the second harvest (141 DAFS), that is 16.24% for Kent and 18.31% for Sabre, this indicates that the amount of soluble solids is affected by the stage of fruit maturity. And the lower amount of soluble solids could be associated with the premature elimination of photo assimilate from the leaves (source) to fruit (sink). The reduction in the amount of soluble solids at the 146 days harvest could associate to breakdown of carbohydrates into relatively simpler substances. From the analysis the second harvest appeared to have the best time to harvest the mangoes and gave a highest overall mean total soluble solids of 15.8% along with the colour change the fruit from the first harvest to the third harvest which showed a marked progression in the development skin colour. Fruits harvested at 146 days old were expected to be heavier than those harvested earlier but experienced some losses due to thefts

Chapter 6

CONCLUSION AND RECOMMENDATIONS

The degree of maturity of at harvest in mango plays an important role in marketing, handling, storage and overall quality of the fruit. From the results obtained in this study at Liempa farm, it can be concluded that, the Pre-harvest chemical treatment at three weeks interval of spraying starting at blooming or flowering, results in producing fruits with superior external and internal qualities and extension shelf life and reduction in the post harvest losses. In my study a reduction of 40.8% was achieved, (53.3% and 12.5% post harvest losses where experienced for unsprayed and sprayed fruits respectively). These post harvest losses in mango production depended on the environmental conditions and cultural practices and the time of harvest. To achieve a better external and internal quality of mango fruit under the climatic conditions like the ones that prevail in Zambia, the recommended stage of fruit maturity at harvest will depend on the market and time required for storage and the purposes to which the crop produce will subjected to. The degree of maturity of the fruit wills the final quality of the fruit. Stage of maturity and storage duration are important factors that affect the quality and shelf life of mangoes. For better quality and reduction in the post harvest losses these two factors must be handled with care. The three weeks interval preharvest tree spray proved to have significant the reduction of post harvest decays and it may be recommended that for the next study should begin much earlier, starting January chemical spraying of the tree at two months interval up to earlier July and thereafter increase the frequency to once at three weeks interval. The optimum time (maturity) of harvest could be between 136 and 146 days from fruit setting. This recommendation is subject to another study to be repeated to confirm. Those farmers must be able to note the time of flowering of mangoes in the respective locations. More research work should be done to exactly determine the date of flowering especially individual flowers on the inflorescence.

Chapter 7

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Chapter 8

APPENDICES

Appendix 1a: ANOVA for pooled means of fruit mass for cultivars

Source	DF	S/square	M/squares	F. value	Probability
Replicate	3	65.47	21.82	0.00	
Factor A	1	1794126.27	1794126.27	116.83	0.001
Error	3	46.069.81	15356.61		
Factor B	2	25556.23	12778.12	11.34	0.000
AB	2	37560.25	18780.05	16.66	0.000
Factor C	2	375610.10	12405.25	11.01	
AC	2	2481.80	17.31	0.02	0.234
BC	4	34.62	1624.16	1.44	
ABC	4	1792.47	448.12	0.04	
Error	48	54101.57	1127.12		
Total	71				

Coefficient of variation 10.34%

Appendix 1b ANOVA for pooled means of fruit skin colour for Kent and Sabre mango cultivars

Source	DF	S/square	M/squares	F. value	Probability
Replicate	3	1.660	0.388	1.710	0.334
Factor A	1	0.570	0.570	2.520	0.210
Error	3	0.680	0.226		
Factor B	2	15.680	7.987	55.430	0.000
AB	2	0.420	0.210	1.460	0.242
Factor C	2	69.460	34.728	24093.00	0.000
AC	2	0.150	0.077	0.540	0.197
BC	4	0.910	0.226	1.570	
ABC	4	0.230	0.054	0.400	
Error	48	6.920	0.144		
Total	71				

Coefficient variation of 13.63%

Appendix 1c: ANOVA for pooled means of fruit firmness of Kent and Sabre mango cultivars

Source	DF	S/square	M/squares	F. value	Probability
Replicate	3	2.070	0.690	1.440	0.336
Factor A	1	0.420	0.425	0.880	
Error	3	1.440	0.481		
Factor B	2	15.840	7.921	50.570	0.000
AB	2	0.280	0.148	0.910	
Factor C	2	88.030	44.015	281.000	0.000
AC	2	1.100	0.548	3.500	0.304
BC	4	1.250	0.313	2.000	0.109
ABC	4	1.390	0.348	2.222	0.000
Error	48	7.520	0.157		
Total	71				

Coefficient of variation of 13.66%

Appendix 1d: ANOVA for pooled means of fruit pulp colour for Kent and Sabre cultivars

Source	DF	S/square	M/squares	F. value	Probability
Replicate	3	1.08	0.360	0.222	
Factor A	1	0.00	0.00	0.000	
Error	3	4.95	1.649		
Factor B	2	10.460	5.231	11.550	0.00
AB	2	0.080	0.0039	0.090	
Factor C	2	19.05	9.5230	2.030	0.000
AC	2	31.34	15.668	34.610	0.00
BC	4	1.140	0.284	0.63	
ABC	4	2.250	0.561	1.24	0.306
Error	48	21.73	0.453		
Total	71				

Coefficient of variation of 10.50%

Appendix 1e: ANOVA for pooled means of fruit total soluble solids for Kent and Sabre mango cultivars

Source	DF	S/square	M/squares	F. value	Probability
Replicate	3	37.380	10.460	8.000	0.060
Factor A	1	2.680	2.680	2.050	0.247
Error	3	3.920	1.307		
Factor B	2	53.490	26.744	26.680	0.000
AB	2	13.100	6.551	6.530	0.030
Factor C	2	1066.570	533.283	531.980	0.000
AC	2	20.690	10.043	10.020	0.000
BC	4	33.050	8.261	8.240	0.000
ABC	4	13.010	3.252	3.240	0.019
Error	48	48.120	1.002		
Total	71				

Coefficient of variation of 6.88%

Appendix 1f: ANOVA for the pooled means of fruit weight loss for Kent and Sabre mango cultivars.

Source	DF	S/square	M/squares	F. value	Probability
Replicate	3	50.15	16.717	3.600	0.000
Factor A	1	477.66	477.66	160.00	0.001
Error	3	8.98	2.985		
Factor B	2	30.08	15.041	0.520	
AB	2	90.96	45.379	1.560	0.221
Factor C	2	354.15	177.065	6.070	0.004
AC	2	1473.37	718.685	24.640	0.000
BC	4	171.02	42.755	1470	0.0277
ABC	4	253.08	63.777	2.170	0.0860
Error	48	1399.89	29.160		
Total	71				

Coefficient of variation 5.85%

Factor A	Mango cultivars
Factor B	Harvest date (Fruit age).
Factor C	Storage duration
AB, AC, and BC	Interactions

Appendix 2: Effects spraying on fruit decay in storage.

TRT ^y	Cultivars	131 ^z	136 ^z	141 ^z	146 ^z	TOTAL	MEANS
Sprayed	Kent	10.0	9.0	8.0	7.0	34.0	8.5
Sprayed	Sabre	9.0	9.0	10.0	10.0	38.0	9.5
Mean		9.5	9.0	9.0	8.5	36.0	9.0
Unsprayed	Kent	6.0	2.0	3.0	0.0	11.0	2.75
Unsprayed	Sabre	7.0	3.0	5.0	3.0	18.0	4.5
Means		6.5	2.5	4.0	1.5	14.5	3.625
Sprayed	9.5a ^y	9.0a	9.0a	8.5a	36.0a	9.00a	
Unsprayed	6.5b	4.0b	2.5b	1.5b	14.5b	3.62b5	

Calculated t.value is 4.8595 and t. table value is 3.707. Significantly different.

^yMeans within each column followed by the same letter were not significantly different at $p \leq 0.05$

^zHD number of days after fruit set at harvest

Appendix 3 Daily maximum and minimum room temperatures² in the storeroom

DATE	Maximum	Minimum	Mean
01/01/02	26.0°C	25.0°C	25.5°C
02/01/02	32.0°C	30.0°C	31.0°C
03/01/02	31.0°C	31.0°C	31.0°C
04/01/02	26.0°C	26.0°C	26.0°C
05/01/02	32.0°C	21.0°C	26.5°C
06/01/02	31.0°C	21.0°C	26.0°C
07/01/02	31.0°C	23.0°C	27.0°C
08/01/02	31.0°C	21.0°C	26.0°C
09/01/02	27.0°C	24.0°C	25.5°C
10/01/02	29.0°C	22.0°C	22.5°C
11/01/02	29.0°C	29.0°C	29.0°C
12/01/02	25.0°C	25.0°C	25.0°C
13/01/02	29.0°C	24.0°C	26.5°C
14/01/02	28.5°C	27.0°C	27.8°C
15/01/02	22.0°C	22.0°C	22.0°C
16/01/02	25.0°C	23.0°C	24.0°C
17/01/02	29.0°C	20.0°C	24.5°C
18/01/02	29.0°C	21.0°C	25.0°C
19/01/02	26.0°C	21.0°C	23.5°C
20/01/02	27.0°C	22.0°C	24.5°C
21/01/02	24.0°C	24.0°C	24.0°C
22/01/02	21.0°C	21.0°C	21.0°C
23/01/02	23.0°C	23.0°C	23.0°C
24/01/02	26.0°C	21.0°C	23.5°C
25/01/02	27.0°C	20.0°C	23.5°C
26/01/02	27.0°C	21.0°C	24.0°C
27/01/02	26.0°C	21.0°C	23.5°C
28/01/02	27.0°C	23.0°C	25.0°C
29/01/02	29.0°C	25.0°C	27.0°C
30/01/02	27.0°C	23.0°C	25.0°C

²Temperature readings taken every day at 12.00 hours AM