EFFECT OF ALOE *(Aloe vera)* LEAF EXTRACT COATING ON QUALITY AND SHELF LIFE OF MANGO (*Mangifera indica* L.) FRUITS AT TWO CONTROLLED TEMPERATURE LEVELS

SOPHIA OCHIKI

A Thesis Submitted to the Graduate School in Partial Fulfillment of the Requirements for the Award of Master of Science Degree in Horticulture of Egerton University

EGERTON UNIVERSITY

JANUARY, 2015

DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not been submitted before in any institution for any other award.

Signature …… Date...……..……..

SOPHIA OCHIKI

KM14/2852/10

RECOMMENDATION

This Thesis has been submitted with our approval as University supervisors.

Signature: …… Date……

DR. ROBERT MORWANI GESIMBA, Ph.D.

Department of Crops, Horticulture and Soils

Egerton University,

P. O. Box 536-20115, EGERTON

Signature: …….. Date ……..…….

DR. JOSEPH WOLUKAU, Ph.D.

Department of Crops, Horticulture and Soils,

Egerton University,

P. O. Box 536-20115, EGERTON

COPYRIGHT

DEDICATION

This work is dedicated to my parents Mr. Charles and Mrs. Priskilah Ochiki, my daughter Hope Bitengo, my brothers and sisters.

ACKNOWLEDGEMENT

I would like to thank Almighty God for his providence and guidance throughout this study. He is the giver of knowledge and life without him this could have not been a success.

I want to thank Dr. Robert Gesimba and Dr. Joseph Wolukau for their guidance and support throughout the course of this study. Thank you for your encouragement and assistance for the time I felt like giving up.

I am grateful for the support received from the department of Crops, Horticulture and Soils of Egerton University, National Council of Science Technology and Innovation for the financial support without which this work would not have been a success. Appreciation goes to Stephen, Everline and Karanja of Egerton University.

To my family: Dad, mum, Zephaniah, Grace, Jones, Ruth, Obadiah, Anne, Elijah, Harrison, Job, Ezra and my brother in-law Sam thank you so much for being supportive. God bless you all.

ABSTRACT

Mango (*Mangifera indica* L.) is a popular and economically important tropical fruit throughout the world due to its excellent visual and eating qualities and nutritional composition. But the fruit is highly perishable and utmost care is required in handling to reduce postharvest losses. Trade in mangoes has been limited because of its highly perishable nature and its susceptibility to low temperature injury, physical injury and post-harvest diseases. Approaches to extending fresh fruit shelf life have included reducing storage temperature, use of surface coatings, and modified and controlled atmospheres; yet no studies have demonstrated the use of aloe gel natural plant extract based on its antifungal properties on enhancement of shelf life and quality of mango fruits. This study was done to evaluate the effects of aloe leaf extract coating on quality and shelf life of mango fruits at two temperature levels. Two experiments were conducted at Egerton University laboratories. The objectives were: (1) to determine the effects of aloe leaf extract surface coatings on shelf life, quality and anthracnose disease incidents on mango fruit, (2) to determine the effect of varying storage temperature on shelf life, quality and anthracnose disease incidents on mango fruit and (3) to determine the interaction effects of aloe leaf extract surface coating and varying storage temperature on shelf life, quality and anthracnose disease incidents on mango fruit. The experimental design was a 5 by 2 factorial experiment embedded in complete randomized design with three replications. The fruits were randomly divided into 5 lots of twenty fruits each. The first lot constituted the positive control and was coated with chitosan. The second, third, fourth and fifth lots were coated with *Aloe vera* gel at concentrations 0%, 25%, 50% and 75% respectively and stored at room temperature and at 13ºC. The parameters which were assessed included: percentage weight loss, peel and flesh colour change, pH, titratable acidity, total soluble solids (TSS), firmness**,** Vitamin C content, and degree and anthracnose incidents. The data collected was subjected to Analysis of Variance (ANOVA) at $P \leq 0.05$, using SAS (version 9, 2005) and means for significant treatments separated using the Tukey's Honestly Significant Difference Test at $P \leq 0.05$ and t- Test at $P \leq 0.0001$.The results showed that at both temperatures 50 and 75% aloe concentrations significantly increased the shelf life evidenced by reduced percentage weight loss, reduced decrease in Titratable acidity and ascorbic acid. Fruit firmness, fruit colour and total soluble solids concentration and pH were also maintained for longer periods in these treatments. However, *Aloe vera* gel coating did not have effect on anthracnose disease. Thus *A. vera* gel at 50% can be used as a coating for improved by twelve days postharvest shelf life and maintaining quality of mango fruits hence reduced postharvest losses.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABREVIATIONS AND ACRONYMS

HCDA	Horticultural Crops Development Authority
SAS	Statistical Analysis System
CA	Controlled atmosphere
MA	Modified atmosphere

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Mango (*Mangifera indica* L.) is the most economically important fruit in the Anacardiaceae family (Tharanathan, 2006). It is one of the most important fruit crops in tropical and subtropical lowlands. Mango is native to India, Bangladesh, Myanmar and Malaysia, but can be found growing in more than 60 other countries throughout the world (Salim *et al.*, 2002). Mango and mango products such as puree, nectar, pickles, canned slices and chutneys are popular worldwide (Schieber *et al.*, 2003). In Kenya, two types of mango are grown, the local and the exotic or improved varieties and about 50 mango varieties have been documented (Kehlenbeck, *et* a*l.*, 2010). Mango is one of the high potential fruits in Kenya, suitable for different agro-ecological zones ranging from sub-humid to semi-arid (Griesbach, 2003). In 2005, Kenya produced about 250,000 metric tons of fresh mango fruit (HCDA, 2008). This amount almost doubled to about 450,000 metric tons in 2008, due to expansion of mango area as well as increasing productivity. However, only 1,800 metric tons of the mango produced were exported in 2009 (HCDA, 2010).

The world trade in mangoes has been increasing over the years, and both exports from Kenya and local consumption is growing. The world market continues to become more price-competitive in spite of postharvest challenges e.g. losses caused by diseases (HCDA, 2011). Mango is one of the most popular fruits all over the world as it has attractive color, delicious taste and excellent nutritional properties. However, mangoes are climacteric and ripen rapidly after it is harvested, that limits its storage, handling and transport potential (Mitra and Baldwin, 1997). It's an easy access to infection during the storage, and an imbalance in its production and consumption during the harvesting season leads to considerable postharvest losses (Zeng *et al*., 2006). Therefore, the current postharvest research focusing on mangoes aims at not only prolonging the shelf life of the fruit but also slowing down the ripening process while keeping quality and flavor up to the required level. Coating of the fruit just after the harvesting process is becoming popular in this respect (Malik and Singh, 2005). However, the possible health risks associated with the residue of the coating material like fungicides are reducing the scope of coatings (Charles *et al*., 1994). To overcome such issues, edible coatings as an alternative option has been tried to extend the shelf life and improve appearance (Hoa *et al*., 2002; Martinez-

Romero *et al*., 2006; Serrano *et al*., 2006; Dang *et al*., 2008). Anthracnose, caused by *Colletotrichum gloeosporioides* (Penz.) is the major postharvest disease of mango in all mango producing areas of the world (Dodd *et al*., 1997). The disease occurs as quiescent infections on immature fruit and the damage it incites is more important in the postharvest period (Dodd *et al*., 1997). However, the use of fungicides is increasingly being restricted due to public concerns over toxic residues. Moreover, fungicides are unaffordable for many mango growers in developing countries (Dodd *et al*., 1989). Postharvest control of mango anthracnose could also be accomplished by hot water treatment of fruits, alone or in combination with chemicals (Dodd *et al*., 1997). Precise control of temperature and time is critical, as fruits can be easily be damaged by overexposure to heat (Arauz, 2000).

Aloe vera is a tropical or subtropical plant characterized by lance-shaped leaves with jagged edges and sharp points. *Aloe vera* contains two major liquid sources, yellow latex (exudates) and clear gel (mucilage). Yellow latex is mainly composed of aloin, aloe-emodin and phenols. The mucilaginous jelly from the parenchymal cells of the plant is the *aloe vera* gel (Hamman, 2008). *Aloe vera* can provide many benefits to human health. The gel works better through a combination of mechanisms. Composed mostly of polysaccharides, the gel appears to act as a natural barrier to moisture and oxygen which can speed up food deterioration. The gel can also enhance food safety (Ergun and Satici, 2012). *Aloe vera* gel appears to contain various antibiotic and antifungal compounds that can potentially delay or inhibit microorganisms that are responsible for food borne illness in humans as well as food spoilage. Recently, the use of *Aloe vera* gel as an edible surface coating has been reported to prolong the shelf life and to delay the changes in the parameters related to deterioration of quality in sweet cherry and table grapes (Martinez- Romero *et al.*, 2006; Serrano *et al.*, 2006). In addition, gels derived from *A. vera* were shown to exhibit antifungal activity against four common postharvest pathogens: *Penicillium expansum, Penicillium digitatum, Botrytis cinerea* and *Alternaria alternate* (Saks and Barkai-Golan, 1995). The yellow latex (exudate) and a clear gel (mucilage) which exudes from the large leaf parenchymatic cells of *Aloe vera* has been used for centuries for its medicinal and therapeutic properties (Eshun and He, 2004).

Temperature, on the other hand, is an important component that affects quality of mango. Low temperature storage has been used in the enhancement of shelf life and quality maintenance in various fruits. The extension of storage life under cool temperature is due to the reduction in

respiration rate and lowering the production of ethylene. However, due to its tropical origin, mango is susceptible to chilling injury at lower temperatures. Storing mango at 13°C has been demonstrated to extend the post-harvest life of mangoes. However, temperature below 10°C causes chilling injury and above 15°C leads to shorter post-harvest storage life (Ezz and Awad, 2011).

1.2 Statement of the Problem

International and domestic trade in mangoes has been limited because of its highly perishable nature and its susceptibility to low temperature injury, physical injury and post-harvest diseases (Rajkumar *et al*. 2008). Under tropical conditions, green, physiologically mature mango fruits ripen within 6-7 days of harvest at 20-25°C and become overripe and spoiled within 15 days after harvest. This short period seriously restricts long distance marketing of the fruit. Sensitivity to disease and low temperature, and perishability due to ripening followed by softening of the fruit, limit its potential in terms of storage, packaging and transport. Because of these reasons, its commercialization in distant markets is seriously limited. Mangoes are a climacteric fruit with a limited shelf life, the quality of the fruit rapidly decreases once fully ripe. The fruits being a seasonal commodity, they create a glut during in and become scarce during the off season. Methods to extend fresh fruit shelf life have included holding fruits at reduced storage temperature, use of surface coatings, and modified and controlled atmospheres, yet no studies have demonstrated the use of *Aloe vera* natural plant extract based on its antifungal properties on enhancement of shelf life and quality of mango fruits.

1.3 Justification of the Study

Mango is a popular and economically important tropical fruit throughout the world, due to its excellent visual (bright colour) eating (sweet taste and luscious flavour) and nutritional composition (vitamins, minerals, fibre, and other phytochemical compounds) qualities. But the fruit is highly perishable and utmost care is required in handling to reduce postharvest losses. Surface coatings are used to delay ripening and prolong the storage life of a produce. Edible coatings are a simple, environmentally friendly and relatively inexpensive technology that can delay ripening of climacteric fruits, delay color changes in nonclimacteric fruits, reduce water loss, reduce decay and improve appearance. Fruits treated with these surface coatings have been reported to have longer shelf life and a delayed onset of fungal infection. Due to the very high

nutritive value of mango fruit, it is necessary to deploy modern methods and environmentally friendly methods to extend the shelf life for better distribution for off-season use. The use of *Aloe vera* natural plant extract seems to be appropriate and environment friendly, and an easy option for prolonging the shelf life and reducing postharvest disease problems.

1.4 Objectives

1.4.1 General Objective

To enhance shelf life and maintain quality of mango fruit by use of aloe leaf extract and temperature manipulation.

1.4.2 Specific Objectives

1. To determine the effects of aloe leaf extract surface coatings on shelf life, quality and anthracnose disease incidents on mango fruit.
2. To determine the effect of varying storage temperature on shelf life, quality and anthracnose disease incidents on mango fruit.
3. To assess the interaction effects of aloe leaf extract surface coating and varying storage temperature on shelf life, quality and anthracnose disease incidents on mango fruit.

1.5 Hypotheses

1. Aloe leaf extract surface coatings have no effect on shelf life, quality and anthracnose disease incidents on mango fruit.
2. Varying storage temperature has no effect on shelf life, quality and anthracnose disease incidents on mango fruit.
3. There are no interactions between aloe leaf extract surface coating and varying storage temperature on shelf life, quality and anthracnose disease incidents on mango fruit.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Postharvest Handling of Mango

During the postharvest period, fruits deteriorate rapidly, the main causes being weight loss, colour changes and softening, which are accompanied by occurrence of decay mainly due to fungi in the species of genera Penicillium, Botrytis, Monilia among others (Valero and Serrano, 2010). Fruit decay is the main postharvest problem, since fungal spoilage can cause great economic losses, although rot occurrence and severity depend on fruit type.

To extend the shelf life of fresh mango fruit, several loss reduction techniques have been used. Low-temperature storage is the most common method for extending the storage life of fruits and vegetables; however, its full advantage cannot be realized for mango fruit because of its sensitivity to low chilling temperatures. Low temperatures prevent the normal metabolism of mango fruit tissue, and the complex biochemical reactions associated with respiration continue in alternative pathways (Snowdon, 1990). Different cultivars vary in susceptibility to chilling injury (Ezz and Awad, 2011) but, generally, the green fruit may be stored at 10–15ºC, while ripe fruits are able to tolerate lower temperatures (Medlicott *et al.*, 1990).The optimum temperature for mango storage is between 12ºC and 13ºC (Sawant *et al* , 2009).

Controlled-atmosphere (CA) storage can also be used to extend the shelf life of mangoes (Mitra, 1997). Controlled atmospheres reduce respiration rate by lowering O_2 levels and elevating CO_2 in the storage chamber, and consequently delays senescence. However, increased ethanol production and flavor problems that accrue because of anaerobic respiration under CA have been reported (Lakshminarayana and Subramanyam, 1970). Bender *et al*. (1994) reported that a 5% O_2 in combination with higher levels of CO_2 (10% and 25%) reduced ethylene production during 3 weeks of CA storage of mango at 12ºC. For long-term storage of mango, hypobaric (low pressure) storage has also been studied. Storage of Irwin, Tommy Atkins and Kent mangoes at a pressure of 76–152 mm Hg at 13ºC with 98–100% relative humidity (RH) for up to 3 weeks resulted in a higher percentage of acceptable fruit, which took longer to complete their ripening after removal to normal pressure than those stored at 760 mm Hg. (Spalding and Reeder, 1977). Post-harvest calcium treatment by vacuum infiltration has been shown to delay ripening in mango (Wills *et al*., 1988) by 12 and 8 days when pressure (115 kPa for 2 min) or

vacuum infiltration (32 kPa) with $CaCl_2$ solution (2–8%) was applied. However, vacuum infiltration of Ca_2+ caused peel injury in mango (Yuen *et al*., 1993).

Some surface coatings have been used on mangoes and other tropical fruits like avocado, with varying degrees of success. Aqueous wax emulsions consisting of vegetable (sisal, sugar cane and carnauba) waxes and mineral petroleum with and without shellac and emulsifiers were reported to increase the storage life of mangoes (Dalal *et al*., 1971). Polysaccharide-based coatings have also shown some benefits for extending the shelf life of mangoes. When coated with 0.75–1% TAL Prolong and stored at 25ºC, mango fruits showed retarded ripening and increased storage life (Dhalla and Hanson, 1988). Baldwin (1994) also reported reduced weight loss in the coated fruit compared with uncoated controls and increased ethanol formation in fruit pulp after 13 days with 1% TAL Prolong. Nature Seal TAM, cellulose based coating, was also reported to delay ethylene production in coated mangoes stored at 21ºC (Mitra, 1997).

2.2 Effects of Natural Extracts Coating on Shelf Life and Quality of Mango Fruit

A number of studies have been conducted demonstrating that edible coatings can be used as a less costly modified atmosphere package to provide some control of ripening and enhancement of storage life in fruits. *Aloe vera* is mainly composed of polysaccharides (malic acid-acetylated carbohydrates (including 1, 4-g1ucomannans) (Esua and Rauwald, 2006) and has been recently explored as an edible surface coating owing to its antifungal activity. Dang *et al*. (2008) evaluated Semperfresh, and *Aloe vera* gel coatings on 'Kensington Pride' mangoes. They observed a few days ripening delay due to Semperfresh, and *Aloe vera* gel coatings; however these coatings also reduced the fruit aroma volatile development during ripening. Kittur *et al.* (2001) found that starch, cellulose, and chitosan-based coatings on 'Alphonso' mangoes were more effective in delaying ripening than Waxol.

Edible coatings are mainly used for reducing gas exchange and therefore weight loss during transport or storage (Donhowe and Fennema, 1994). In a study by Mart´ınez-Romero *et al.,* 2006, *A. vera* gel retarded moisture loss and reduced respiration rates in sweet cherry. They found out that, during cold storage, uncoated fruit showed increases in respiration rate, rapid weight loss and colour changes. In another study (Hoa *et al*., 2002), it was found that the coating TFC213 (carnauba-based) reduced weight loss and extended the storage time of mango fruits at ambient temperature, 12˚ C, 80% RH. Kittur *et al*. (2001) used different polysaccharide composite coatings (cellulose, starch and chitosan) on mango fruits and noticed that coated

mangoes showed the least weight loss. Slower rate of weight loss in coated mangoes can be attributed to the added barrier properties (Schreiner *et al*., 2003). According to Hoa *et al*. (2001), for all coated mangoes, there was a retardation of chemical changes including pH, TA and TSS/TA during storage compared with the uncoated controls, whereas changes in TSS were inconsistent. Baldwin *et al.* (1999) observed a delayed decrease in acidity for 'Tommy Atkins' fruit coated with HPC, but not carnauba wax. With respect to firmness, *A. vera* treatment was also effective in maintaining sweet cherry firmness (Mart´ınez-Romero *et al.,* 2006). Mangoes and bananas treated with polysaccharide-based coatings have been shown to have better firmness values than those treated with 'Waxol' (a commercial product) and untreated control fruit, with retardation of colour development (Kittur *et al*., 2001). Although the coating made by edible materials may not be risky for health, up to some extent, several other problems like change intaste, flavor, etc., have been noticed (Kittur *et al*., 2001; Hoa *et al*., 2002).

Chitosan is a high molecular weight cationic polysaccharide, normally obtained by alkaline deacetylation of chitin found in the exoskeleton of crustaceans, in fungal cell walls and in other biological materials. Chitosan has been used as an ideal semipermeable coating on several fruits to extend storage life such as strawberry (El Ghaouth *et al.,* 1991), litchi (Zhang and Quantick, 1997), peach (Li and Yu, 2001), table grape (Romanazzi *et al.,* 2002), mango (Kittur *et al.,* 2001; Srinivasa *et al.,* 2004) and citrus (Chien *et al.,* 2007). A number of other studies (e.g., Srinivasa *et al*., 2002 and 2004; Wang *et al.,* 2007) have also observed that chitosan coatings can delay the ripening of mangoes by several days. Also Zhu *et al*., 2008) found out that weight loss in the mango fruits was reduced by coating with chitosan during storage.

2.3 The Effect of the Natural Extracts Coating on Anthracnose Disease in Mango

The most serious disease problem for mango growers is anthracnose caused by *Colletotrichum gloeosporioides* (Penz.) because it can attack various parts of trees and can survive as latent infections on fruit. Synthetic fungicides are commonly used to control pre- and post-harvest anthracnose diseases. Hot benomyl (methyl [1-[(butylamino) carbonyl]-1H-benzimidazol-2-yl] carbamate) dips effectively control postharvest anthracnose diseases, but a buildup of pathogen resistance may occur (Pitkethley and Conde, 2007). Synthetic fungicides have been found unacceptable for consumers due to the presence of fungicide residues (Sanders

et al., 2000). As a result, the use of natural antifungal compounds from plants to control mango fruit anthracnose disease has been investigated (Kumpoun *et al*., 2005).

The antimicrobial properties of plant extracts from various species have been proven to affect fungal development in vitro and in vivo (Montes-Belmont *et al*., 2000). Spore formation and germination, mycelia growth and infection can sometimes be stimulated or inhibited by plant extracts (Bautista-Ban˜ os *et al.*, 2000).

The application of *A. vera* gel has been proved to maintain quality and reduce decay symptoms in table grape and sweet cherry (Valverde *et al*., 2005b; Martínez-Romero *et al*., 2006; Serrano *et al*., 2006), although the fungi responsible for decay were not determined. However, early reports have shown that *Aloe vera* extracts reduced spore survival by 15–20% for Penicillium, Botrytis and Alternaria (Saks and Barkai-Golan, 1995), and accordingly Aloe reduced by 22–38% the mycelium growth of other plant pathogenic fungi such as Rhizoctonia, Fusarium and Colleotrichum (Jasso de Rodríguez *et al.*, 2005), showing a limitation in controlling possible fungal infections. *Aloe vera* gel was used to coat table grapes and it extended shelf life by 35 days at 1ºC. The gel worked as a barrier to O_2 entry and CO_2 exit, creating a MA, and acted as moisture barrier, and thus reduced weight loss, browning, softening, and growth of yeast and molds.

Chitosan, a natural polysaccharide is an established coating material with antifungal activity and has shown direct antifungal activity against several fungi by inhibiting the mycelia growth and spore germination, and inducing morphological changes of the hyphae (Bautista-Baños *et al.* 2006). Previous studies have indicated that chitosan coating inhibited infections of postharvest pathogens on strawberry (El Ghaouth *et al.*,1992), litchi (Zhang and Quantick, 1997), table grape (Romanazzi *et al.*,2002) and citrus (Chien *et al.*,2007) during storage. The study by Zhu *et al.* (2008) also showed that the disease progress in the mango fruits inoculated with *C. gloeosporioides* was effectively inhibited by the treatment with chitosan coating.

2.4 Effects of Storage Temperature on Postharvest of Mango

Mango ripens with good quality characteristics at 25ºC with 8 days and become overripe and spoiled within 15 days (Sousa, 2002). However, refrigeration is often used during storage and transportation of mature green mango fruits in an effort to extend shelf life and improve quality with some success. Cold temperature storage affects several quality characteristics of

mango fruits during storage and during subsequent ripening at normal temperatures. Low temperature storage effects carotenoid composition by inhibiting development of total carotenoids. In a study conducted by Thomas (1975), mangos stored at 7ºC for 16 days and then allowed to ripen at room temperature produced 22-53% less carotenoids than those mangos allowed to ripen normally. Low temperature storage has also been found to decrease aroma, flavor, and overall quality upon ripening (Medlicott *et al*., 1990). Low temperature storage is also associated with an increase in physiological disorders. Mango fruit stored at temperatures between 5ºC and 10ºC for extended periods of time exhibit chilling injury (Ezz and Awad, 2011).

Chilling injury is characterized by surface and internal browning, pitting, water soaking, uneven ripening, failure to ripen, development of off-flavors and off-aroma, and increased incidence of surface mold and decay (Kader, 2002). Although chilling injury is the result of cold temperature storage, symptoms of this physiological disorder often do not appear until after the commodity has been returned to room temperature and normal ripening begins. The extent of chilling injury symptom development is influenced by temperature, length of storage, and maturity of the fruit (Lizada, 1991). Immature mango fruit have been found to exhibit a higher tolerance to cold temperature storage and chilling injury than mature fruit; however, chilled immature fruit fail to develop full ripeness characteristics such as color development and loss of firmness once transferred to normal ripening temperatures (Medlicott *et al*., 1990).Cold temperature storage may influence ripening characteristics through the ethylene controlled climacteric period. Lederman *et al*. (1997) found no direct connection between mango chilling injury and changes in ethylene production, but concluded that cold temperature stored mangos displayed an increased ability to converted added ACC, the biosynthesis precursor of ethylene, to ethylene.

Storage of fruits at temperatures below the critical temperature may cause chilling injury to fruits. Storage of mango fruit below 10ºC usually causes chilling injury, such as pitting on the surface and darkening and softening of the tissues (Hulme, 1971). Dipping of mango in hot water controlled chilling injury during low temperature storage. The enhanced chilling was associated with higher fruit TSS content (Mukherjee and Srivastava, 1979). Chilling injury was also observed to cause leakage of metabolites such as amino acids, sugars and mineral salts from the cell structure (Wills *et al*., 1981). In a study done in Egypt using two mango cultivars stored at 8,

10 and 13ºC, it was found that keeping quality in was enhanced in low temperature and decreased with increasing temperature degree. Both cultivars had longer storage life under 13˚C (Ezz and Awad, 2011).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Research Site

The postharvest study was carried out in a laboratory at Egerton University Njoro in the Department of Crops, Horticulture and Soils, Kenya. The Egerton University lies at a latitude of 0º 23' South, longitude 35º35' East, altitude of approximately 2,238 meters a.s.l in the Lower Highland 3 (LH3) agroecological zone (Jaetzold and Schmidt, 1983). The recorded annual means average maximum and minimum temperatures are 19ºC to 22ºC and 5ºC to 8ºC, respectively.

3.2 Materials

Mango: The variety Ngowe was used. Ngowe is a polyembronic variety with long slender fruits. The skin colour is orange yellow when ripe and is a mid-season fruit. The fruit has little fibre and has excellent eating quality but it is susceptible to anthracnose. All the fruits that were used in this study were acquired from a grower in Masii in Machakos County, Kenya. The fruits were harvested at the mature green stage. The mature green fruits were without any visible blemish. The fruits were transported to the laboratory in open baskets within the same day.

Aloe vera: The leaves of *A. vera* were harvested from Lare in Nakuru County. Only the fully extended mature leaves were harvested. The leaves were then stored in plastic paper and transported to the laboratory within the same day.

Chitosan: Crushed chitosan powder industrial grade was purchased from Kobian Chemicals Nairobi. Chitosan is a low acetyl form of chitin mainly composed of glucosamine, 2-amino-2-deoxy-b-D-glucose.

Figure 1: *Aloe vera* plants growing in the field in Lare area, Nakuru County

3.3 Preparation of coating solutions

Aloe gel was obtained from fresh aloe leaves, the matrix was separated from the outer cortex of leaves and the colourless hydroparenchyma was homogenized in a blender. The resulting mixture was filtered using Watman filter paper number 100 to remove the fibres. The liquid constituted fresh *aloe vera* gel. The gel matrix was pasteurized at 70ºC for 45min. For stabilizing, the gel was cooled immediately to an ambient temperature and 4.5g ascorbic acid was added; 4.5g citric acid was then added to adjust the pH to 4.

To prepare chitosan coating, 1% Chitosan (Kobian Chemical Co.) was dissolved in a 0.5% glacial acetic acid and distilled water. The pH value of the Chitosan solution was then adjusted to 5.6 using 0.1M NaOH.

3.4 Application of Treatments and Experimental Design

The coating solutions constituted *Aloe vera* gel dilutions, prepared with distilled water (aloe gel (0%) as a negative control, aloe gel (25%), aloe gel (50%), aloe gel (75%), and chitosan (1%) as a control). Aloe gel (50%) was found to be effective in maintenance of quality and enhancement shelf life in papaya fruits. The fresh fruits were dipped completely into the coatings solutions at room temperature for 25 min. The fruits were allowed to drain and then dried at room temperature to allow a thin film layer to be formed on the fruits. The fruits were then stored at room temperature (temperature varied between 15 and 22°C) and at 13ºC (optimum storage temperature for mangoes). Four hundred mature, green fruits, without any visible blemish, were brought to the lab and the pedicels were removed. The fruits were then randomly divided into eight lots of twenty fruits each. The first lot constituted the positive control and was coated with chitosan. The second, third, fourth and fifth lots were coated with *Aloe vera* gel at concentrations 0%, 25%, 50% and 75% respectively and stored at room temperature or at 13ºC (Figure 2 and Figure 3). The experiment was laid out in a 5 by 2 factorial experiment embedded in a completely randomized design with three replications. Various parameters were evaluated at 4 day intervals until the overall acceptability became unsatisfactory for each lot of samples (The fruit was considered as waste when it was infected by disease and/or its firmness value is less than 2). The parameters that were assessed included: percentage weight loss, peel and flesh colour change, pH, titratable acidity, total soluble solids (TSS), firmness**,** Vitamin C content, and degree of anthracnose incidents. Data was collected from three fruits for each parameter in each tray.

Figure 2: Mango fruits at room temperature (Room storage temperature varied between 15 and 22°C).

Figure 3: Mango fruits at 13^{o}C temperature

Table 1: Description of Treatments and Treatment combinations

Treatment	Description
A1T1	Mango coated with chitosan at room temperature (Positive control)
A1T2	Mango coated with chitosan at 13°C
A2T1	Mango coated with aloe gel (0%) at room temperature (Negative control)
A2T2	Mango coated with aloe gel (0%) at 13°C
A3T1	Mango coated with aloe gel (25%) at room temperature
A3T2	Mango coated with aloe gel (25%) at 13°C
A4T1	Mango coated with aloe gel (50%) at room temperature
A4T2	Mango coated with aloe gel (50%) at 13°C
A5T1	Mango coated with aloe gel (75%) at room temperature
A5T2	Mango coated with aloe gel (75%) at 13°C

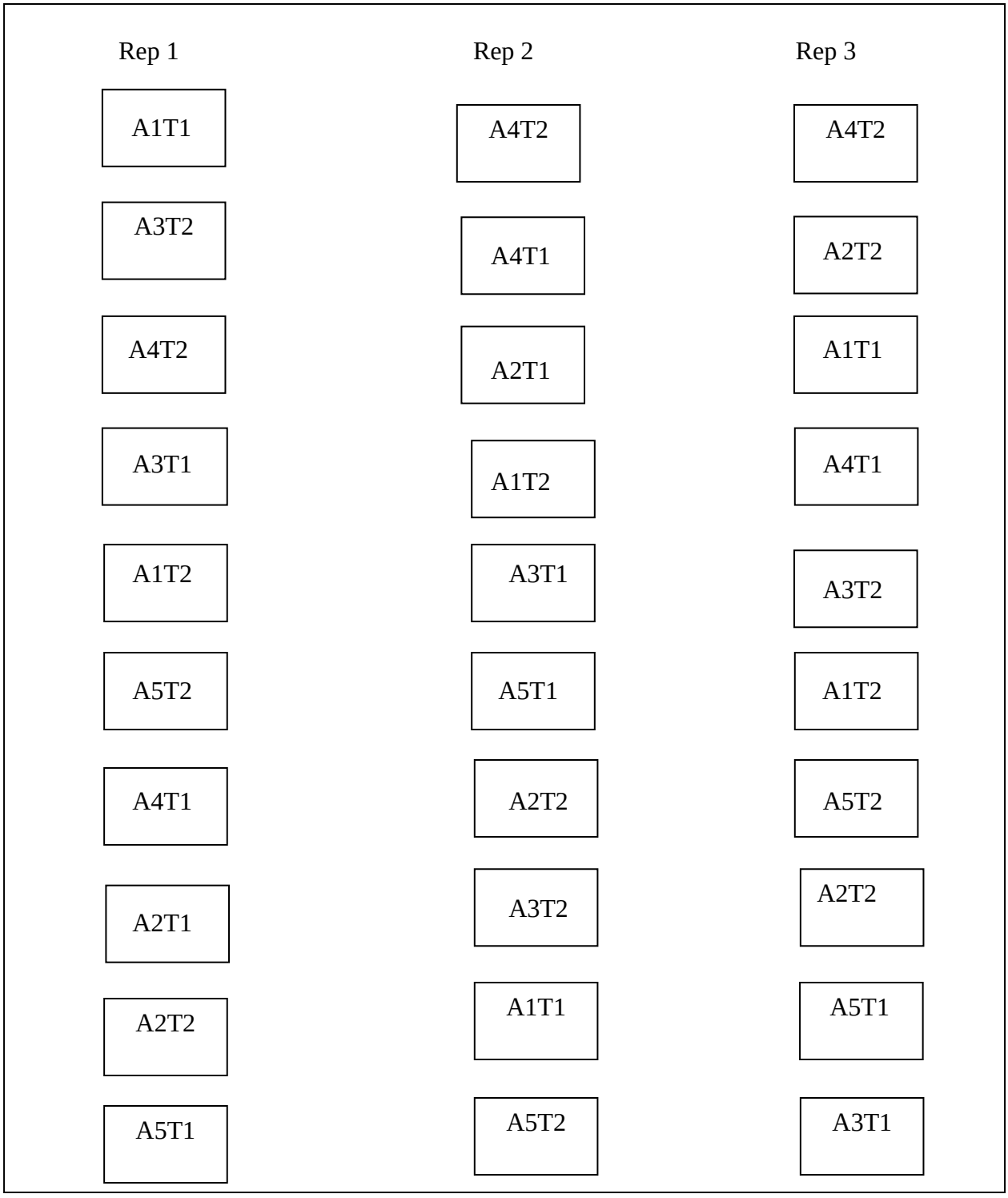

Figure 4: Experimental layout

3.5 Pathogen culture

The fungal pathogen, *C. gloeosporioides* was isolated from infected mango fruit cv. 'Ngowe' showing the typical symptoms of the disease. Infected materials were placed in humidity chambers and after 72 hours mycelia was collected to observe the typical structures of fungi following the manual for identification of fungal species published by Barnett and Hunter (1972, 241 p.). Fungal cultures were maintained in the common nutrient medium of potato dextrose agar (PDA) for 10 days at 25ºC.

Pathogenicity test

The isolated fungus *C. gloeosporioides* was investigated for its pathogenicity on healthy mature green mango fruits. Surface sterilized fruits were wounded at one of peel region with a sterilized (autoclaved) cork borer (5 mm diameter) into 1 to 2 mm depth. The wounded fruits were inoculated with a disc of mycelia and the control was not inoculated with disc of mycelia. The inoculated fruits were put in sterilized box at 25ºC. The diameter of lesions (mm) was measured for evaluation of anthracnose rot for 10 days.

3.6 Inoculation and incubation

The mango fruits were surface-sterilized in 1% sodium hypochlorite solution for 15 min, washed, dried and prepared for inoculation by inflicting one 1-mm-deep wound in the middle of each fruit with a sterile cork borer. Each wound was then inoculated with the pathogen *C. gloeosporioides* by inoculating a disc of mycelia. The inoculated fruit was incubated in a sterile box overnight at 22ºC before dipping in (0%) as a negative control, aloe gel (25%), aloe gel (50%), aloe gel (75%), and chitosan (1%) treatments. Then, the treated fruits were incubated in a moist plastic box at 22ºC for 5 days and disease developments were assessed by measuring the diameter of the anthracnose lesion on mango fruits. Each treatment was tested in three replicates.

3.7 Data collection

3.7.1 Weight loss: Three fruits in each replication for each treatment were marked before storage, and weighed using a digital balance (EK-600H, Japan). The same fruits were weighed at the beginning of the experiment and at the end of each storage period. The results were expressed as the percentage loss of initial fruit weight

$$\text{Weight Loss}(\%) = \frac{\text{average loss in fruit weight}}{\text{Average initial fruit weight}} \times 100$$

3.7.2 Degree and rate of anthracnose incidents: Anthracnose severity was assessed by measuring the diameter of anthracnose lesions on mango fruits and ranked by use of scale 1–5 where 1=0% of fruit surface rotten, 2=1–25%, 3=26–50%, 4=51–75% and 5=76–100%) .

3.7.3 Total soluble solid (TSS): Total soluble solids was determined using hand held refractometer (0-30 ºBrix) (RHW refractometer, Optoelectronic Technology Company Ltd. UK).

3.7.4 Firmness: A mango fruit from each treatment was used to determine fruit firmness using a hand held penetrometer (model 62/DR, UK) with 8 mm diameter probe. The results were reported in Kg Force.

3.7.5 pH: This was measured with a standard calibrated pH meter (Adwa Company.).This measurement was made on juice expressed from flesh of the whole fruit filtered through filter papers

3.7.6 Titrable acidity: Was determined by titrating 100 mL of juice against sodium hydroxide having concentration of 0.1 N (AOAC 2000). TA expressed as the percentage of citric acid per 100 g fresh mass

$$\text{Percentage acid} = \frac{\text{titre x acid factor x 100}}{\text{100 ml of mango juice}}$$

NB: Acid factor of mango is 0.064

3.7.7 Vitamin C content: This was determined by titrating 10 g of mixed pulp sample against the standard 2, 6 dichlorophenol dyes following the procedure outlined in AOAC (2000).

$$\text{Ascorbic acid} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract taken for estimation} \times \text{Wt or vol of the sample taken} \times 100}$$

3.7.8 Colour: Peel color was measured at the equator on opposite cheeks of the fruit. Flesh color was measured in the center of one cut cheek. Both peel and flesh colours were measured using portable whiteness colourimeter (WSD-3 TYPE**).** Measurements were recorded using standard Hunter L a b chromatic system and were expressed as lightness (L), greenness (-a), redness (+a) yellowness (+b), blueness (-b) colour space coordinates. The instrument was calibrated with a

standard white ceramic tile and black tile and set up for D65 as illuminate and a 10º observer angle.

3.8 Data Analysis

In this study all shelf life and quality variables were considered dependent while the coatings and temperature were considered independent. The data collected was subjected to Analysis of Variance (ANOVA) at $P \leq 0.05$, using PROC GLM code of SAS (version 9, 2005) and means for significant treatments separated using the Tukey's Honestly Significant Different Test at $P \leq 0.05$ and t- Test at $P \leq 0.0001$. The model for analysis was;

$$Y_{ijk} = \mu + \pi_i + \beta_j + (\pi\beta)_{ij} + \varepsilon_{ijk} \qquad \begin{matrix} i=1, 2, 3, 4, 5 \\ j=1, 2 \\ k=1, 2, 3 \end{matrix}$$

Where μ is the overall mean

Y_{ijk} is the mango response

π_i is the effect of the i^{th}rate of aloe gel

β_j is the effect of the j^{th} rate of temperature

$\pi\beta_{ij}$ is the interactive effect due to the i^{th}rate of aloe gel and the j^{th} rate of temperature

ε_{ijk} is the random error component

CHAPTER FOUR

RESULTS

4.1 Weight Loss

4.1.1. The Effects of *Aloe vera* Gel Coatings on Weight Loss

Fruits in all the treatments lost weight throughout the entire storage period (Fig. 5) irrespective of the coatings. At day four, there was significant difference ($P \leq 0.05$) between the negative control (0% *Aloe vera* gel) and the other treatments but there was no significant difference among 25, 50 and 75% *Aloe vera* gel concentrations and those coated with 1% chitosan (the positive control). Mango fruits coated with 0% *Aloe vera* gel lost 5.2% weight while other treatments 25, 50, 75% and chitosan lost 3.1, 2.6, 1.9 and 3.2% respectively.

At day eight, 75% *Aloe vera gel* was the most effective in reducing weight loss followed by 50% while the 0% aloe had the highest weight loss. Mango fruits coated with 0% *Aloe vera* gel lost 10.1% weight while other treatments 25, 50, 75% and chitosan lost 7.1, 5.9, 4.4 and 6.9% respectively. At day twelve, there was significant difference between the control and 50 and 75% Aloe vera gel treatments. Seventy five percent *Aloe vera* gel had the lowest weight loss. Mango fruits coated with 0% *Aloe vera* gel lost 13.0% weight while other treatments 25, 50, 75% and chitosan lost 10.8, 8.3, 7.4 and 11.6% respectively.

At day sixteen, there were significant effects between the control and 25, 50 and 75% *Aloe vera* gel treatments. The negative control had the highest weight loss though it was not significantly different from Chitosan. Mango fruits coated with 0% *Aloe vera* gel lost 60.6% weight while other treatments 25, 50, 75% and chitosan lost 49.3, 47.3, 41.9 and 52.5% respectively. At day twenty, 0% *Aloe vera* gel had the highest weight loss while 75% *Aloe vera* gel had the lowest weight loss among the other treatments. Mango fruits coated with 0% *Aloe vera* gel lost 70.6% weight while other treatments 25, 50, 75% and chitosan lost 50.8, 49.3, 45.3 and 55.7% respectively.

Generally weight loss was lowest in day four, eight and twelve with a sharp increase between day twelve and sixteen. After day sixteen, weight loss was highest only in the 0% *Aloe vera* treatments.

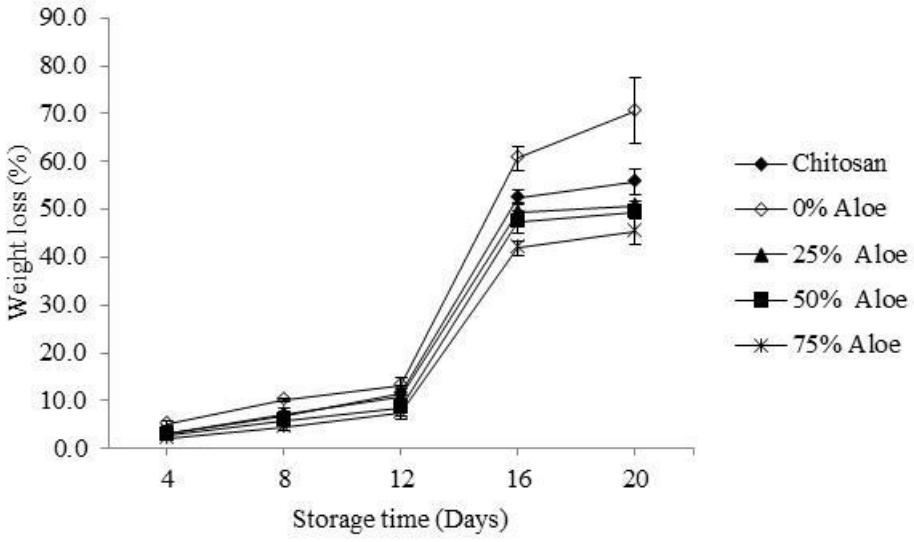

Figure 5: Effect of different *Aloe vera* gel concentrations on weight loss of mango fruits var. 'Ngowe'.

4.1.2 Effect of Storage Temperature on Weight Loss

The results indicated that weight loss of fruits was significantly lower ($P \leq 0.0001$) for fruits stored at 13°C, as compared with those at room temperature (Table 2). At day four, fruits stored at room temperature had the highest weight loss (4.1%) while fruits stored at 13°C had the lowest (2.3%) and there was significant difference between the two storage temperatures. On day eight, the fruits stored at 13°C had the lowest weight loss (5.4%) while those at room temperature had the highest weight loss (8.4%).

Similar observations were made for day twelve and day sixteen, fruits under room temperature were terminated because the overall acceptability was unsatisfactory. At day twenty the percentage weight loss was 54.3% and the fruits were terminated.

Generally, increase in storage temperature significantly increased weight loss in both trials. The lowest weight loss was storage temperature at 13°C.There were significant effects between room temperature and13°C throughout the storage period.

Table 2: Effect of storage temperature on weight loss

Storage temperature	Weight loss (%)				
	Storage time (Days)				
	4	8	12	16	20
Room temperature	4.1a*	8.4a	13.1a	52.3a	
13°C	2.3b	5.4b	7.3b	48.4b	54.3

*Means followed by the same letter between temperature treatments in a given day are not significantly different according to t- test (P≤0.0001).

*Room storage temperature varied between 15 and 22°C.

4.1.3 Interactive Effects of *Aloe vera* Gel Coatings and Storage Temperature on Weight Loss

Aloe vera gel concentrations at 50 and 75% at 13°C significantly (P≤0.05) reduced percentage weight loss (Table 3). At day four, mango fruits coated with 0% *Aloe vera* gel and stored at room temperature (A2T1) had the highest weight loss (5.5%) while those coated with 75% *Aloe vera* gel and stored at 13°C (A5T2) had the lowest weight loss values (1.5%). However there was no significant difference between A5T2 and those coated with 50% *Aloe vera* gel and stored at 13°C (A4T2). At day eight, fruits coated with 0% *Aloe vera* gel and stored at room temperature (A2T1) had the highest weight loss (10.6%) while those coated with 75% *Aloe vera* gel and stored at 13°C (A5T2) had the lowest weight loss value (3.1%) and at day twelve similar observations were made.

At day sixteen, the percentage weight loss was high in all treatments but mango fruits coated with 75% *Aloe vera* gel and stored at 13°C (A5T2) had the lowest weight loss (39.9%) followed by those coated with 75% *Aloe vera* gel at room temperature with 43.8% weight loss. Fruits under room temperature were discarded considering the overall acceptability. Generally at 13°C all fruits coated with *Aloe vera* treatments, had the lowest weight loss throughout the entire storage period. The highest weight loss suppression was achieved with the interaction of the 75% *Aloe vera* gel coating and storage temperature of 13°C.

Table 3: Interactive effects of *Aloe vera* gel concentrations and storage temperature on weight loss

Treatment	Storage time (Days) 4	8	12	16
A1T1	4.3abc*	8.9ab	14.3ab	54.3abc
A1T2	2.0de	4.9cd	8.9cd	50.8abcd
A2T1	5.5a	10.6a	16.6a	61.6a
A2T2	4.9ab	9.7a	9.3bcd	59.6ab
A3T1	4.3abc	9.1a	13.5abc	52.0abcd
A3T2	1.9de	5.2cd	8.2cd	46.7bcd
A4T1	3.6bcd	7.7abc	11.3bc	49.8abcd
A4T2	1.6e	4.0d	5.3d	44.9cd
A5T1	2.5cde	5.7bcd	9.8bcd	43.8cd
A5T2	1.3e	3.1d	4.9d	39.9d

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test ($P \leq 0.05$) where A1= Chitosan, A2= 0% *Aloe vera*, A3=25% *Aloe vera*, A4=50% *Aloe vera*, A5=75% *Aloe vera*, T1=Room temperature and T2=13°C

*Room storage temperature varied between 15 and 22°C.

4.2 Total Soluble Solids

4.2.1The Effects of *Aloe vera* Gel Coatings on Total Soluble Solids

In both trials total soluble solids increased during storage in all treatments but the rate of increase in the coated mango fruits was comparatively slower compared to the negative control (Figure 6). In trial 1, at day zero there was no significant difference ($P \leq 0.05$) between the treatments. On day four, fruits coated with 25%, 50%, 75%, *Aloe vera* gel and those coated with chitosan had a significantly lower total soluble solids (TSS) compared with those treated with 0% *Aloe vera* gel (Fig. 6). However there were no significant differences among fruits coated with 25%, 50%, 75% *Aloe vera* treatments and chitosan. Mango fruits coated with 0% *Aloe vera*

gel had TSS of 14.9 °brix while other treatments 25, 50, 75% and chitosan had 12.6, 12.6, 11.7 and 12.0°brix respectively. In day eight, similar observations were as those of day four.

At day twelve, the highest total soluble solids (TSS) was observed on fruits coated with 0% *Aloe vera* gel and the lowest readings were recorded for fruits coated with 75% .*Aloe vera*. At day sixteen of the storage period, the highest TSS was observed on fruits coated with 0% *Aloe vera* gel and the lowest readings were recorded for fruits coated with75% *Aloe vera* gel. Mango fruits coated with 0% *Aloe vera* gel had TSS of 21.2 °brix while other treatments 25, 50, 75% and chitosan had 18.0, 17.9, 17.5 and 19.1°brix respectively.

At the end of storage period (twenty days), fruits coated with 50% and 75% *Aloe vera* gel had the lowest TSS while the control had the highest TSS (20.8). Similar results were observed in the 2nd trial. Mango fruits coated with 0% *Aloe vera* gel had TSS of 20.83°brix while other treatments 25, 50, 75% and chitosan had 18.2, 17.6, 17.3 and 20.4°brix respectively.
Generally the lowest total soluble solids were recorded in day four, with a reduced increase in TSS observed for the rest of the storage period for coated fruits while there was a gradual increase in TSS for the negative control treatment in the same period.

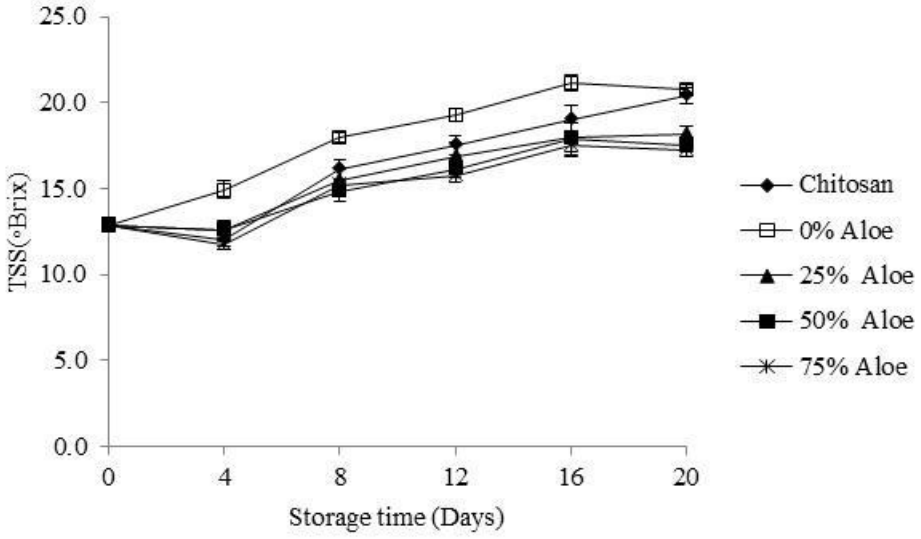

Figure 6: Total Soluble Solids of Mango fruits var. 'Ngowe' as affected by *Aloe vera* gel coatings

4.2.2 Effect of Storage Temperature on Total Soluble Solids

The results indicated that the TSS of fruits was significantly lower (P≤0.0001) in fruits stored at 13°C, as compared with those stored at room temperature (Table 4). Initially no significant difference was observed but at day four, fruits stored at room temperature had the highest (13.2°brix) while fruits stored at 13°C had the lowest TSS (12.3°brix) and was significant difference in TSS between fruits stored at the two storage temperatures in day four.

Similar observations were made for day four; twelve and sixteen, fruits under room temperature were discarded at day sixteen because their overall acceptability was unsatisfactory. At day twenty the TSS was 18.9°brix and the fruits were also discarded. There were significant effects between room temperature and 13°C throughout the storage period. Increase in storage temperature significantly increased TSS. The lowest TSS was observed for fruits stored at 13°C while those stored at room temperature had the highest TSS.

Table 4: Effect of storage temperature on total soluble solids

	Storage time (Days)					
Storage Temperature	0	4	8	12	16	20
Room Temperature	12.8a*	13.2a	16.4a	17.5a	19.8a	
13◦C	12.8a	12.3b	15.5b	16.7a	17.6b	18.9a

*Means followed by the same letter between temperature treatments in a given day are not significantly different according to t- test (P≤0.0001).

*Room storage temperature varied between 15 and 22°C.

4.2.3 Interactive Effects of Aloe vera Gel Coatings and Storage Temperature on Total Soluble Solids

Aloe gel concentrations at 50% and 75% at 13°C significantly (P≤0.05) maintained total soluble solids (Table 5). At day zero, there was no significant difference between the treatments, at day four fruits coated with chitosan as a positive control at 13°C (A1T2) had the lowest TSS (11.6°brix) followed by interaction of *Aloe vera* at 50% at 13°C (A4T2) which had 11.7°brix while the lowest TSS value (11.6°brix) was recorded in the interaction between 0% *Aloe vera* and room temperature (15.6°brix). At day eight, mango fruits coated with 0% *Aloe vera* gel and

stored at room temperature (A2T1) had the highest TSS while 50% *Aloe vera* gel aloe at 13°C had the lowest TSS value.

At day twelve, the interaction between 75% *Aloe vera* gel and 13°C had the lowest TSS value. Day sixteen, TSS was lowest (16.2°brix) for A4T2 treatment while 0% *Aloe vera* gel aloe at room temperature had the highest value (22.2°brix). Fruits under room temperature were terminated considering the overall visual quality was unacceptable. Generally at 13°C of all aloe treatments had the most reduced increase in TSS and highest TSS was observed in 0% aloe at room temperature.

Table 5: Interactive effects of *Aloe vera* gel concentrations and storage temperature on total soluble solids.

	Storage time (Days)				
Treatment	0	4	8	12	16
A1T1	12.8a*	12.4bc	16.3abc	17.6ab	19.3abc
A1T2	12.8a	11.6c	15.9abc	17.4ab	18.8abc
A2T1	12.8a	15.6a	18.2a	19.2ab	22.2 a
A2T2	12.8a	14.3ab	17.8ab	19.5 a	20.2ab
A3T1	12.8a	12.8bc	16.5abc	17.9ab	19.5abc
A3T2	12.8a	12.3b	14.5c	15.8ab	16.5 c
A4T1	12.8a	13.5abc	15.4abc	16.8ab	19.5abc
A4T2	12.8a	11.7c	14.2c	15.5b	16.2c
A5T1	12.8a	11.7c	15.4abc	16.0ab	18.5bc
A5T2	12.8a	11.8c	15.0bc	15.4ab	16.5c

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test ($P \leq 0.05$) where A1= Chitosan, A2= 0% *Aloe vera*, A3=25% *Aloe vera*, A4=50% *Aloe vera*, A5=75% *Aloe vera*, T1=Room temperature and T2=13°C

*Room storage temperature varied between 15 and 22°C.

4.3 Fruit Firmness

4.3.1. The Effects of *Aloe vera* gel Coating on fruit firmness

There was a decreasing trend in firmness in both coated and uncoated mango fruits during the course of storage (Fig.7). Initially there was no significant difference ($P \leq 0.05$) between the treatments. At day four of the storage period, 50% and 75% *Aloe vera* gel coated fruits had the highest firmness value (13.0 Kg force) while the lowest values were observed in fruits coated with 0% *Aloe vera* gel. Mango fruits coated with 0% *Aloe vera* gel had average fruit firmness of 8.8 Kg Force while other treatments 25, 50, 75% and chitosan had averages of 11.8, 13.0, 13.0 and 12.8 Kg Force respectively. At day eight, fruits treated with 0% *Aloe vera* gel had the lowest value of firmness (4.8 Kg Force) while 75% *Aloe vera* gel had the highest value of firmness(11.8 Kg Force).

At day twelve, there were significant differences among the treatments, 0% *Aloe vera* gel had the lowest fruit firmness value while 75% *Aloe vera* gel had the highest value. At day sixteen, similar observations as to day twelve were made and at the end of the storage period (twenty days), 0% *Aloe vera* gel had the lowest fruit firmness value while those coated with 75% *Aloe vera* gel had the highest value. At the end of storage period, mango fruits coated with 0% *Aloe vera* gel had firmness of 2 Kg Force while other treatments 25, 50, 75% and chitosan had average of 2.8, 3.3, 7.0 and 2.5 Kg Force respectively

Generally the results indicated that mango fruits coated with *Aloe vera* coatings had significantly higher firmness compared to those coated with 0% *Aloe vera* gel concentration in both trials. The 75% *Aloe vera* gel coatings had the highest fruit firmness as compared to others. The highest loss in fruit firmness was observed between day four and day twelve of the storage period with the negative control having the highest decrease in fruit firmness.

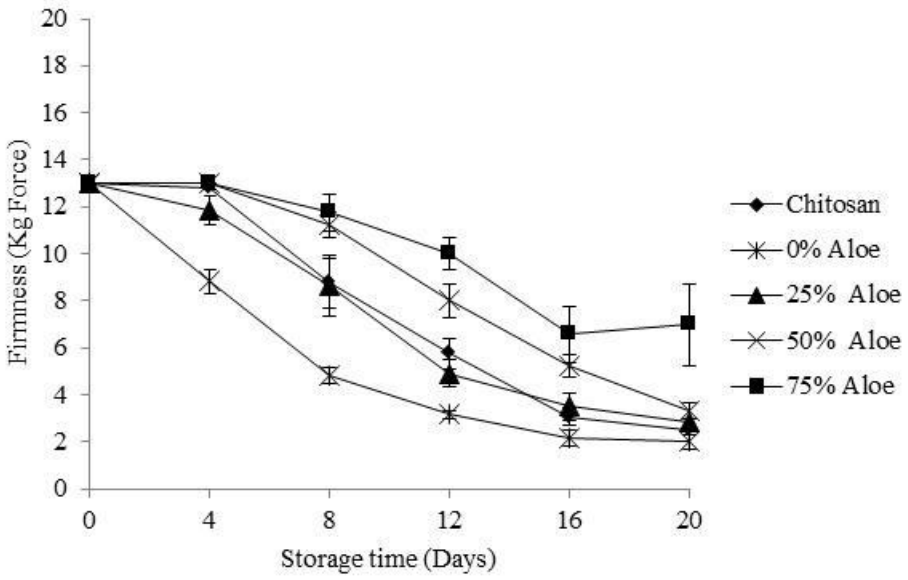

Figure 7: Fruit firmness of mango var.'Ngowe' as affected by *Aloe vera* gel coatings

4.3.2 Effect of storage temperature on fruit firmness

The results indicated that fruit firmness was significantly higher ($P \leq 0.0001$) for fruits stored at 13°C, as compared with those at room temperature (Table 6). Initially no significant difference was observed but at day four, fruits stored at room temperature had the lowest firmness value (11.6 Kg Force) while fruits stored at 13°C had the highest firmness (12.2 Kg Force) and there was significant difference between the two storage temperatures. In day eight, the same observations to day four were made.

Similar observations were made for day twelve and day sixteen, fruits under room temperature were discarded in day sixteen because their overall acceptability was unsatisfactory. At day twenty was 3.5 Kg Force and the fruits were terminated. There were significant effects between room temperature and 13°C throughout the storage period. Increase in storage temperature significantly reduced fruit firmness. The lowest fruit firmness was observed for fruits stored at room temperature and the highest fruit firmness for fruits stored at 13°C.

Table 6: Effect of storage temperature on fruit firmness

	Storage time (Days)					
Storage temperature	0	4	8	12	16	20
Room temperature	13a*	11.6b	7.9b	5.4b	3.1a	
13°C	13a	12.2a	10.2a	7.3a	5.1b	3.5a

*Means followed by the same letter between temperature treatments in a given day are not significantly different according to t- test ($P \leq 0.0001$).

*Room storage temperature varied between 15 and 22°C.

4.3.3 Interactive Effects of *Aloe vera* Gel Coatings and Storage Temperature on Fruit Firmness

Aloe vera gel coatings concentrations of 50% and 75% and storage temperature of 13°C significantly ($P \leq 0.05$) reduced loss of fruit firmness (Table 7). At day zero, there was no significant difference between the treatments, at day four *Aloe vera* coated fruits at 13°C were the firmest (13.0 Kg Force) while the least in firmness (8.5 Kg Force) was recorded for fruits coated with 0% *Aloe vera* gel and stored at room temperature (A2T1).

At day eight, 0% *Aloe vera* gel coated mango fruits and stored at room temperature (A2T1) had the lowest firmness while those coated with 50% *Aloe vera* gel and stored at 13°C had the highest fruit firmness. At day twelve fruits coated with 75% *Aloe vera* gel and stored at 13°C (A5T2) were the firmest. Day sixteen, firmest fruits were those coated with 75% *Aloe vera* gel and stored at 13°C, 0% *Aloe vera* gel at room temperature had the least firmness (1.5 Kg Force). Fruits under room temperature were discarded at day sixteen considering their overall acceptability.

Generally at 13°C all *Aloe vera* gel coated fruits had the most reduced loss of fruit firmness and highest loss in firmness was observed in the interaction between 0% *Aloe vera* gel coatings and room temperature.

Table 7: Interactive effects of *Aloe vera* gel concentrations and storage temperature on fruit firmness

	Storage time (Days)				
Treatment	0	4	8	12	16
A1T1	13.0a*	12.7ab	7.5abcd	4.5cde	2.5c
A1T2	13.0a	13.0a	10.0abc	7.0bc	3.7bc
A2T1	13.0a	8.5c	4.3d	3.0e	1.5c
A2T2	13.0a	9.2c	5.3cd	3.3e	2.8bc
A3T1	13.0a	10.7bc	6.3bcd	4.0de	2.7c
A3T2	13.0a	13.0a	11.0ab	5.8cde	4.3bc
A4T1	13.0a	13.0a	10.5abc	6.7bcd	4.3bc
A4T2	13.0a	13.0a	12.0a	9.3ab	6.2ab
A5T1	13.0a	13.0a	11.0ab	9.0ab	4.5bc
A5T2	13.0a	13.0a	12.5a	11.0a	8.7a

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test ($P \leq 0.05$) where A1= Chitosan, A2= 0% *Aloe vera*, A3=25% *Aloe vera*, A4=50% *Aloe vera*, A5=75% *Aloe vera*, T1=Room temperature and T2=13°C

*Room storage temperature varied between 15 and 22°C.

4.4 Fruit Juice pH

4.4.1 Effect of Different Concentrations of *Aloe vera* Gel on Fruit pH of Mango Fruits

The pH of the mango juice was found to be gradually increasing during the storage period (Fig. 8). Initially there was no significant difference ($P \leq 0.05$) but at day four, there was significant difference between the treatments. Fruits coated with 50%, 75% *Aloe vera* and chitosan had the lowest juice pH readings while 0% *Aloe vera* gel had the highest juice pH readings. Mango fruits coated with 0% *Aloe vera* gel had an average pH of 4.9 while other coated treatments i.e 25, 50, 75% and chitosan had averages in pH readings of 3.7, 3.4, 3.4 and 3.4 respectively. At day eight, fruits treated with 75% *Aloe vera* gel had the lowest pH value (3.6) and 0% *Aloe vera* gel had the highest pH reading (5.3).

At day twelve, fruits coated with 50 and 75% *Aloe vera* gel had the lowest pH reading (4.4) while the control (0% *Aloe vera* gel) had the highest juice pH value (5.8). For day sixteen,

fruits coated with 50% *Aloe vera* gel had the lowest pH value (4.9) and 0% *Aloe vera* gel coated fruits had the highest pH value (6.1). However in day sixteen there was no significant difference between chitosan coated fruits and 50% *Aloe vera* gel. At day twenty, it was found that 0% *Aloe vera* gel had the highest pH value while those coated with 50% *Aloe vera* gel had the lowest pH value. At the end of storage period mango fruits coated with 0% *Aloe vera* gel had an average juice pH of 6.1 while other treatments 25, 50, 75% and chitosan had averages of 5.5, 5.2, 5.3 and 5.4 respectively.

Generally, there was an increasing trend in pH from mild acidic to neutral in all the treatments but the rate of increase in coated fruits was slow compared to the negative control.

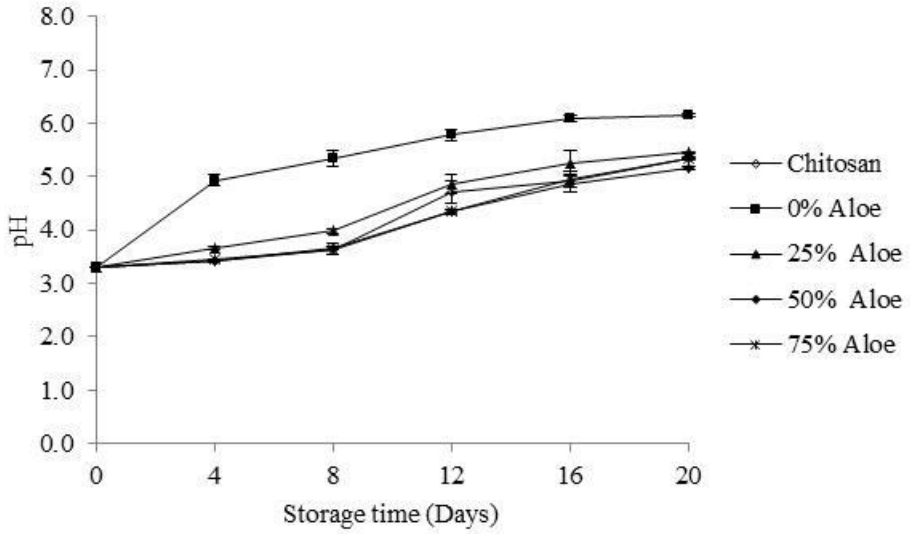

Figure 8: Juice pH of mango fruits var. 'Ngowe' as affected by *Aloe vera* gel coatings

4.4.2 Effect of Storage Temperature on Fruit Juice pH

The results indicated that fruit juice pH was significantly lower ($P \leq 0.0001$) for fruits stored at 13°C, as compared with those stored at room temperature (Table 8). Initially no significant difference was observed but at day four, fruits stored at room temperature had the highest juice pH value (3.9) while the lowest pH was recorded for fruits stored at 13°C (3.7). However there was significant difference between the two storage temperatures.

Similar observations were made for day eight; twelve and sixteen, fruits under room temperature were terminated because the overall acceptability was unsatisfactory. At day twenty was 5.5 and the fruits were terminated. There were significant effects between room temperature

and 13°C throughout the storage period. Increase in storage temperature significantly increased the juice pH. Room temperature storage resulted in the highest pH as compared to fruits stored at 13°C.

Table 8: Effect of storage temperature on fruit juice pH

	Storage time (Days)					
Storage Temperature	0	4	8	12	16	20
Room Temperature	3.3a*	3.9a	4.2a	5.6a	5.6a	
13◦C	3.3a	3.7b	3.9b	4.8b	4.8b	5.5

*Means followed by the same letter between temperature treatments in a given day are not significantly different according to t- test ($P \leq 0.0001$).

*Room storage temperature varied between 15 and 22°C.

4.4.3 Interactive Effects of *Aloe vera* Gel Coatings and Storage Temperature on Fruit Juice pH

Aloe vera gel concentrations of 50% and 75% interacted with storage temperature of 13°C resulting in a significantly reduced increase in fruit juice pH (Table 9). At day zero, there was no significant difference ($P \leq 0.05$) between the fruit coatings; at day four fruits coated with *Aloe vera* at 50%, 75% concentration and chitosan and stored at 13°C had the lowest juice pH (3.4) while the highest pH value (5.2) was recorded in the interaction between 0% *Aloe vera* coating and room temperature (A2T1). At day eight, the interaction between 0% *Aloe vera* gel and room temperature storage had the highest juice pH (5.6) while the interaction between chitosan and 13°C resulted in the lowest pH value (3.4).

At day twelve, fruits coated with 75% *Aloe vera* gel and at 13°C (A5T2) had the lowest pH value (4.2) while the highest pH (6.0) was recorded for A2T1. Day sixteen, pH was lowest (4.5) for A4T2 and A1T2 treatments while A2T1 had the highest pH value (6.2). Fruits under room temperature were discarded considering their overall acceptability. Generally at 13°C all aloe treatments had the most reduced increase in pH while the highest increase was observed in mango fruits coated with 0% *Aloe vera* gel at room temperature.

Table 9: Interactive effects of aloe gel concentrations and storage temperature on fruit juice pH.

	Storage time (Days)				
Treatment	0	4	8	12	16
A1T1	3.3a*	3.5e	3.9cd	5.2c	5.3d
A1T2	3.3a	3.4e	3.4f	4.3de	4.5h
A2T1	3.3a	5.2a	5.6a	6.0a	6.2a
A2T2	3.3a	4.7b	5.1b	5.6b	6.0b
A3T1	3.3a	3.7c	4.1c	5.3c	5.8c
A3T2	3.3a	3.6d	3.9cd	4.4de	4.7f
A4T1	3.3a	3.4e	3.7de	4.4de	5.2e
A4T2	3.3a	3.4e	3.6def	4.3de	4.5h
A5T1	3.3a	3.5e	3.8d	4.4d	5.3de
A5T2	3.3a	3.4e	3.5ef	4.2e	4.6g

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test (P≤0.05) where A1= Chitosan, A2= 0% *Aloe vera*, A3=25% *Aloe vera*, A4=50% *Aloe vera*, A5=75% *Aloe vera*, T1=Room temperature and T2=13°C

*Room storage temperature varied between 15 and 22°C.

4.5 Titratable Acidity

4.5.1 The Effects of *Aloe vera* Gel Coatings on Titratable Acidity

Mango fruits with coating presented a statistically higher titratable acidity (TA) during storage in spite of the slight decrease observed (Fig. 9). TA decreased during storage in all treatments but the rate of decrease in treated fruits was comparatively slower compared to the control. At day zero there was no significant difference (P≤0.05) between the treatments. The initial TA was 1.04% citric acid. In day four, fruits coated with 50% and 75% *Aloe vera* gel concentration had a significantly higher TA value compared with those coated with 0% *Aloe vera* gel. Mango fruits coated with 0% *Aloe vera* gel had TA of 0.81% citric acid while other treatments 25, 50, 75% and chitosan had 0.90, 1.02, 1.02 and 0.97% citric acid respectively

In day eight, fruits coated with 50% *Aloe vera* gel had a significantly lower value compared with those coated with other fruit coating treatments. Mango fruits coated with 0%

Aloe vera gel had TA of 0.59% citric acid while other treatments i.e. 25, 50, 75% and chitosan had 0.77, 0.95, 0.94 and 0.82% citric acid respectively. For day twelve, the highest TA was observed on fruits coated with 75% *Aloe vera* gel and the lowest readings were recorded for fruits coated with 0%*Aloe vera* gel. Mango fruits coated with 0% *Aloe vera* gel had an average TA of 0.40% citric acid while other treatments 25, 50, 75% and chitosan had 0.64, 0.85, 0.86 and 0.78% citric acid respectively. At day sixteen of the storage period, the highest TA was observed on fruits coated with 50% *Aloe vera* gel and the lowest readings were recorded for fruits coated with 0% *Aloe vera* gel. Mango fruits coated with 0% *Aloe vera* gel had a TA of 0.30% citric acid while other treatments 25, 50, 75% and chitosan had 0.44, 0.64, 0.63 and 0.53% citric acid respectively. At the end of storage period (twenty days), fruits coated with 50% *Aloe vera* gel had the highest TA while the control had the lowest TA value. Mango fruits coated with 0% *Aloe vera* gel had TA of 0.0.20% citric acid while other fruit coating treatments i.e. 25, 50, 75% and chitosan had 0.54, 0.62, 0.59 and 0.55% citric acid respectively.

Generally TA was maintained for those fruits coated with 50% and 75% *Aloe vera* gel in both trials. TA decreased gradually in all treatments but the rate was slower in treated fruits compared to negative control.

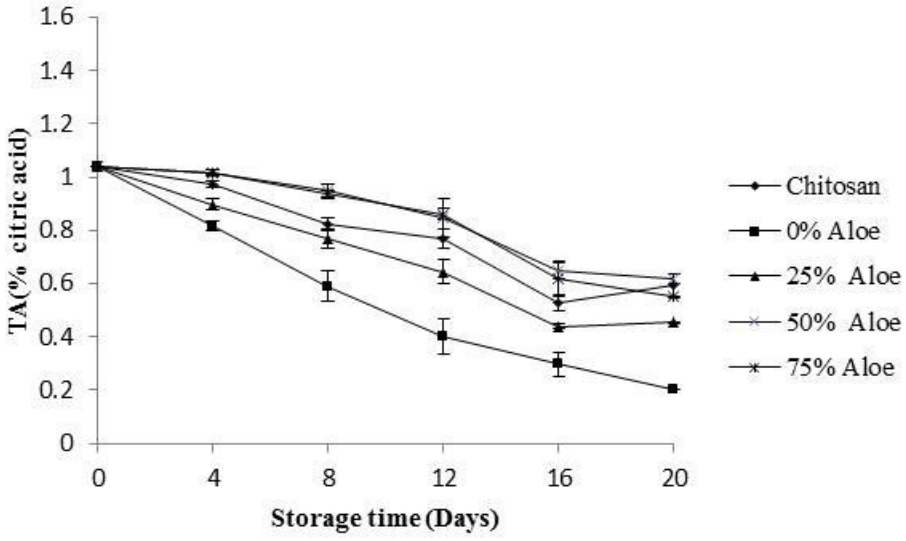

Figure 9: Titratable acidity of mango fruits var. 'Ngowe' as affected by *Aloe vera* gel coatings

4.5.2 Effect of Storage Temperature on Fruit Titratable Acidity

The results indicated that TA of fruits was significantly higher (P≤0.0001) for fruits stored at 13°C, as compared with those stored at room temperature (Table 10). Initially no significant difference was observed but at day four, fruits stored at room temperature had the lowest TA value (0.92% citric) while the highest TA(0.97% citric acid) was observed at 13°C with significant effects of the two storage temperatures. Similar observations were made for day eight; twelve and day sixteen. Fruits under room temperature were discarded at day sixteen because the overall acceptability was unsatisfactory.

At day twenty, TA values of 0.43 and the fruits were discarded. There were significant effects between room temperature and 13°C throughout the storage period. Increase in storage temperature significantly reduced TA. The lowest TA was observed for fruits stored at room temperature and the highest TA observed in fruits stored at 13°C.

Table 10: Effect of storage temperature on fruit TA (% citric acid)

	Storage time (Days)					
Storage Temperature	0	4	8	12	16	20
Room Temperature	1.04a*	0.92b	0.74b	0.75b	0.60b	
13◦C	1.04a	0.97a	0.88a	0.81a	0.58a	0.43

*Means followed by the same letter between temperature treatments in a given day within a trial are not significantly different according to t- test (P≤0.0001).

*Room storage temperature varied between 15 and 22°C.

4.5.3 Interactive Effects of *Aloe vera* Gel Coatings and Storage Temperature on Fruit Titratable Acidity

The interaction between *Aloe vera* gel concentrations at 50% and 75% and storage temperature of 13°C significantly maintained TA (Table 11). At day zero, there was no significant difference between the treatments. At day four there was significant interaction between fruits coated with *Aloe vera* at 50% and storage temperature at 13°C (A4T2) having the

highest value of TA (1.04% citric acid) while the lowest value(0.78% citric acid) was recorded for fruits coated with 0% *Aloe vera* at room temperature (A2T1). At day eight, the interaction between 0% *Aloe vera* gel and room temperature (A2T1) had the lowest value (0.46% citric acid) and 50% *Aloe vera* gel aloe at 13°C had the highest TA value (1.00% citric acid) and at day twelve, the interaction between 50% *Aloe vera* gel aloe and 13°C (A4T2) had the highest TA value (1.00% citric acid)

At day sixteen, TA was highest (0.75% citric acid) in the interaction between 75% *Aloe vera* gel aloe and 13°C storage temperature while interaction between 0% *Aloe vera* gel and room temperature had the lowest TA (0.19% citric acid). Fruits under room temperature were discarded considering the overall acceptability. Generally at 13°C all *Aloe vera* treatments had the most maintained of TA while the highest reduction in TA was observed in the 0% *Aloe vera* gel and room temperature.

Table 11: Interactive effects of *Aloe vera* gel coatings and storage temperature on fruit Titratable acidity

	Storage time (Days)				
Treatment	0	4	8	12	16
A1T1	1.00a*	0.95c	0.77f	0.68g	0.46cd
A1T2	1.00a	1.00b	0.87d	0.85c	0.58b
A2T1	1.00a	0.78e	0.46i	0.26j	0.19f
A2T2	1.00a	0.85d	0.72g	0.55h	0.40e
A3T1	1.00a	0.85d	0.68h	0.54i	0.42de
A3T2	1.00a	0.94c	0.85e	0.75e	0.46cde
A4T1	1.00a	1.01ab	0.90c	0.69f	0.58b
A4T2	1.00a	1.03ab	1.00a	1.00a	0.71a
A5T1	1.00a	0.99b	0.90c	0.82d	0.48c
A5T2	1.00a	1.04a	0.97b	0.91b	0.75a

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test (P≤0.05) where A1= Chitosan, A2= 0% *Aloe vera*, A3=25% *Aloe vera*, A4=50% *Aloe vera*, A5=75% *Aloe vera*, T1=Room temperature and T2=13°C

*Room storage temperature varied between 15 and 22°C.

4.6 Fruit Colour

4.6.1 Peel Colour

4.6.1.1 The Effects of *Aloe vera* Gel Coatings Fruit Peel Colour

The coatings were effective on peel colour change of the mangoes stored under room temperature conditions and 13ºC (colour change during ripening for this variety of mango is from green to yellow). Color changes in peel are presented as L*, a*, b* and were expressed as lightness (L*), greenness (-a*), yellowness (+b*), colour space coordinates. Fruits from each treatment for both trials registered some changes in chromatic L*, a* and b* colour values during the storage period (Figures 10, 11 and 12 respectively).

Lightness (L*) increased significantly (P≤0.05) during storage, changes in L* value for control (L* values increased from 68.1 to 75.5) which was higher than what was recorded in the coated fruits (Fig 10). L* values increased over time irrespective of the coatings from 68.1 to

75.5 for negative control, from 68.1 to 74.8 for fruits coated with 25% *Aloe vera* gel, from 68.1 to 74.0 for 50% *Aloe vera* gel coated fruits, from 68.1 to 74.1 for 75% *Aloe vera* gel coated fruits and from 68.1 to 74.0 for chitosan coated fruits while no significant difference ($P \leq 0.05$) were recorded for chitosan and 50% *Aloe vera* gel coated treatments at the end of the storage period.

Chromatic a* value from mango fruits also increased over time irrespective of the treatments. There was a gradual significant increase ($P \leq 0.05$) in peel a* value beginning on day eight (Fig 11). Before the storage, the a* value was -17.7, and after the storage the value reached to -2.9 for negative control fruits, to -8.3 for 25 % *Aloe vera* gel coated fruits, to -11.2 for 50% *Aloe vera* gel coated fruits,-11.2 for 75% *Aloe vera* gel coated fruits and to -10.3 for chitosan coated fruits. The increase in a* value was however slower for fruit coated with 50 and 75% *Aloe vera* compared to control or 25% *Aloe vera* gel treatments.

Chromatic b* value similar to L* and a* value for fruits slightly increased over time regardless of the coatings, and it was significantly higher ($P \leq 0.05$) on day eight for the negative control (Fig 12). Initial b* value was 39.6 , afterwards the value gradually increased, reaching to 46.9 for negative control fruit, to 43.5 for 25 % *Aloe vera* gel coated fruits, to 42.9 for 50% *Aloe vera* gel coated fruits, 43.1 for 75% *Aloe vera* gel coated fruits and to 43.1 for chitosan coated fruits. The increase in b* value was however slower in fruits coated with 50, 75% *Aloe vera* gel and chitosan compared to negative control.

Generally the peel color of the mango fruits coated with 50% and75% *Aloe vera* gel was significantly less developed than those coated with other treatments.

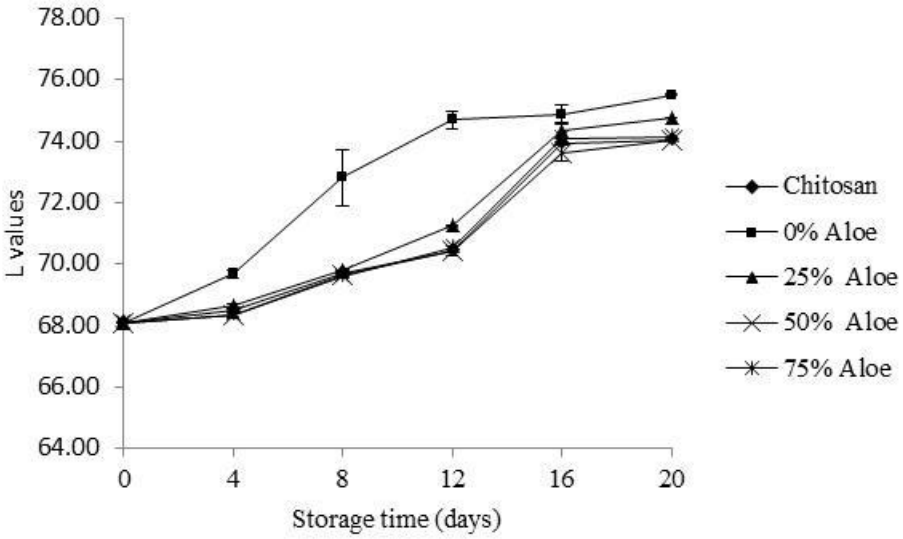

Figure 10: Effect of different *Aloe vera* gel concentrations on L* value of the peel colour of mango fruits var. 'Ngowe'.

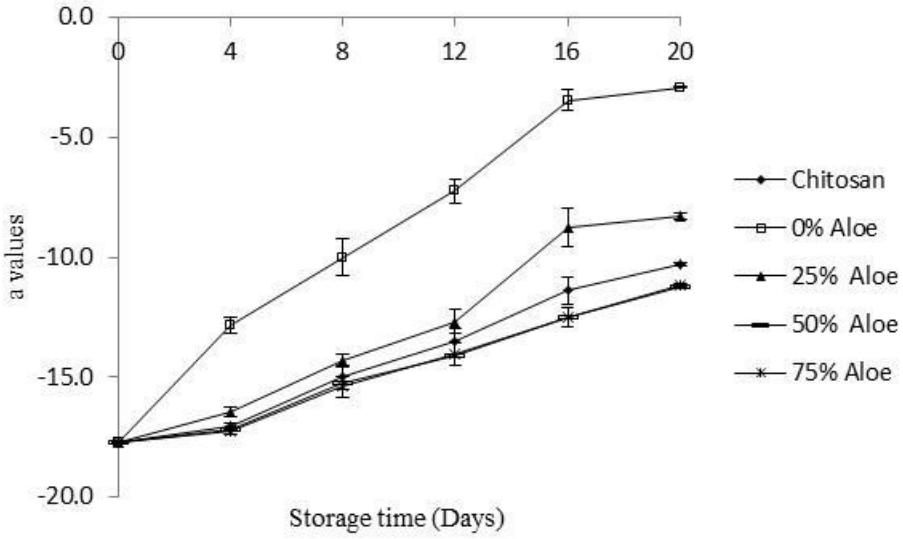

Figure 11: Effect of different *Aloe vera* gel concentrations on Chromatic a* of the peel color of mango fruits var. 'Ngowe'

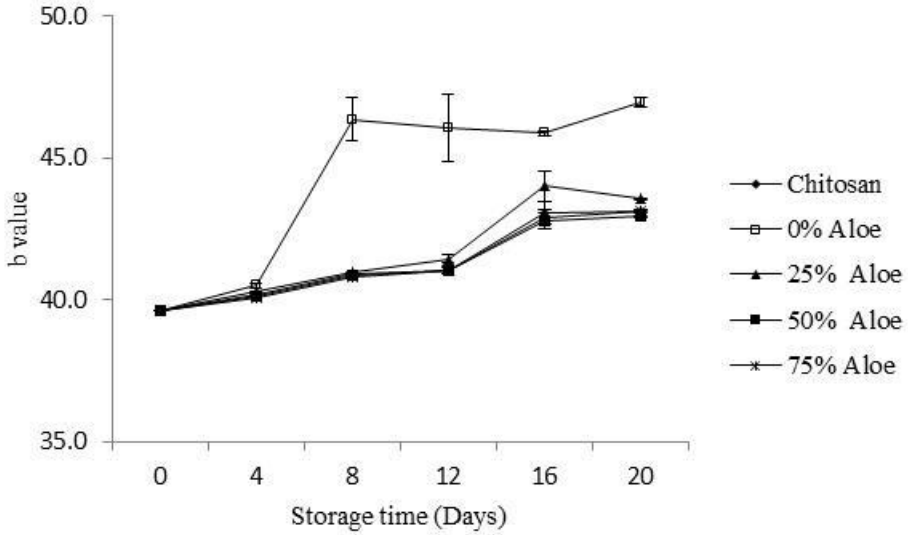

Figure 12: Effect of different *Aloe vera* gel concentrations on Chromatic b* of the peel color of mango fruits var. 'Ngowe'

4.6.1.2 Effect of Storage Temperature on Fruit Peel Color

The results indicated that the L* value of the peel colour of fruits was significantly lower ($P \leq 0.05$) for fruits stored at 13°C, as compared with those at room temperature (Table 12). Initially no significant difference was observed but by day four, fruits stored at room temperature had the highest L* value (68.8) while and fruits stored at 13°C had a value of 68.6. Similar observations were made for day eight; twelve and day sixteen, fruits stored under room temperature were discarded because the overall acceptability was unsatisfactory. At day twenty L* value was 74.5 and the fruits were discarded. There were significant effects between room temperature and 13^{o}C throughout the storage period. Increase in storage temperature significantly increased the L* value. The lowest L* value was recorded for fruits stored at 13°C and the highest L* value was recorded at room temperature.

For chromatic a* value, the results indicated that chromatic a* values of the peel colour of mango fruits was significantly lower for fruits stored at 13°C, as compared with those at room temperature (Table 13). Initially no significant difference was observed but at day four, fruits stored at room temperature had the highest chromatic a* value (-15.8) while and fruits stored at 13°C had chromatic a* value of -16.5. There was significant difference between chromatic a* value of the peel colour in the two storage temperatures.

Similar observations were made for day eight; twelve and day sixteen, fruits under room temperature were discarded because the overall acceptability was unsatisfactory. At day twenty Chromatic a* value was -8.8 and the fruits stored under 13ºC were discarded. There were significant effects between room temperature and 13°C throughout the storage period. Increase in storage temperature significantly increased a* value. The lowest a value was recorded for fruits stored at 13°C and the highest Chromatic a* value was recorded at room temperature in both trials.

For Chromatic b* value, the results indicated that b* value of the peel colour of fruits was significantly lower for fruits stored at 13°C, as compared with those at room temperature (Table 14). Initially no significant difference was observed but at day four, fruits stored at room temperature had the highest Chromatic b* value (40.3) while and fruits stored at 13°C had b* value of 40.2. At day four there was significant difference between the two storage temperatures.

Similar observations were made for day eight; twelve and day sixteen, fruits stored under room temperature experiment were discarded because the overall acceptability was unsatisfactory. At day twenty, Chromatic b* value was 43.9 and the fruits stored under 13ºC were discarded. There were significant effects between room temperature and 13°C throughout the storage period. Increase in storage temperature significantly increased Chromatic b* value. The lowest b* value was recorded for fruits stored at 13°C and the highest Chromatic b* value was recorded at room temperature.

Table 12: Effect of storage temperature on fruit peel color (L* value)

	Storage time (Days)					
Storage Temperature	0	4	8	12	16	20
Room Temperature	68.1a*	68.8a	70.8a	71.8a	74.4a	
13◦C	68.1a	68.6a	69.9b	71.1b	74.0a	74.5

*Means followed by the same letter between temperature treatments in a given day are not significantly different according to t- test (P≤0.0001).

*Room storage temperature varied between 15 and 22°C.

Table 13: Effect of storage temperature on fruit peel color (chromatic a* value)

	Storage time (Days)					
Storage Temperature	0	4	8	12	16	20
Room Temperature	-17.7a*	-15.8a	-12.9a	-11.2a	-8.6a	
13°C	-17.7a	-16.5b	-15.1b	-13.5b	-10.8b	-8.8

*Means followed by the same letter between temperature treatments in a given day are not significantly different according to t- test (P≤0.0001).

*Room storage temperature varied between 15 and 22°C.

Table 14: Effect of storage temperature on fruit peel color (chromatic b* value)

	Storage time (Days)					
Storage Temperature	0	4	8	12	16	20
Room Temperature	39.6a*	40.3a	42.4a	42.9a	44.4a	
13°C	39.6a	40.2b	41.6b	41.3b	43.0b	43.9

*Means followed by the same letter between temperature treatments in a given day are not significantly different according to t- test (P≤0.0001).

*Room storage temperature varied between 15 and 22°C.

4.6.1.3 Interactive Effects of *Aloe vera* Gel Coatings and Storage Temperature on Fruit Peel Color

Aloe vera gel coating concentrations of 50% and 75% interacted with storage temperature of 13°C and reduced increase in chromatic L*, a*, b* of peel colour significantly (P≤0.05) (Table 15). L* value at day zero was not significant. At day four fruits coated with *Aloe vera* at 50% and 75% at 13°C had the lowest L* value of 68.3 while the highest L* value (69.8) was recorded for fruits coated with 0% *Aloe vera* and stored at room temperature (A2T1). At day eight, 0% *Aloe vera* gel at room temperature (A2T1) had the highest L* value (74.9) while interaction between 50% and 75% *Aloe vera* gel aloe and 13°C had the lowest L* value (69.6).

At day twelve, the interaction between 50% *Aloe vera* gel coatings and chitosan with 13°C storage temperature had the lowest L* value (70.1) while highest L* value (75.3) was recorded for A2T1. Day sixteen, L* value was highest (75.6) for interaction A2T1 while the interaction between 50% *Aloe vera* gel coatings and 13°C storage temperature had the lowest value (73.0),however there was no significant difference between all treatments. The room

temperature experiment was terminated considering the overall acceptability of the fruits. Generally at 13°C all *Aloe vera* gel treatments had the most reduced increase of L* value and highest in L* value was observed with interaction between 0% *Aloe vera* gel and room temperature.

At day zero, there was no significant difference in chromatic a* value ($P \leq 0.05$) between the treatments (Table 16). At day four fruits coated with *Aloe vera* at 75% at 13°C had the lowest a* value of -17.5 while the highest a* value (-12.1) was recorded for fruits treated with 0% *Aloe vera* at room temperature (A2T1). At day eight, 0% *Aloe vera* gel at room temperature (A2T1) had the highest a* value (-8.3) and 75% *Aloe vera* gel aloe at 13°C had the lowest a value (-16.4).

At day twelve, the interaction between 50% *Aloe vera* gel and 13°C storage temperature had the lowest a* value (-15.2) while highest a* value (-6.1) was recorded for A2T1. Day sixteen, a* value was highest (-2.5) for A2T1 treatment; A4T2 had the lowest value (-13.4). Fruits under room temperature were discarded considering the overall acceptability. Generally the interaction between storage temperature of 13°C and all aloe treatments resulted in the most reduced increase of a* values while highest a* values were observed in the interaction between 0% *Aloe vera* gel and room temperature.

Chromatic b* value at day zero, there was no significant difference ($P \leq 0.05$) between the treatments (Table 17). At day four fruits coated with *Aloe vera* at 75% at 13°C had the lowest b* value of 40.0 while the highest b* value (40.7) was recorded for fruits treated with 0% *Aloe vera* at room temperature (A2T1). At day eight, 0% *Aloe vera* gel at room temperature (A2T1) had the highest b* value (48.1) and 75% *Aloe vera* gel at 13°C had the lowest b* value (40.7).

At day twelve, the interaction between 50% *Aloe vera* gel and 13°C storage temperature resulted in the lowest b* value (40.7) while highest b* value (48.7) was recorded for 0% *Aloe vera* gel at room temperature. At day sixteen, b* value was highest (46.0) for 0% *Aloe vera* gel at room temperature treatment; *Aloe vera* at 50% at 13°C had the lowest value (42.2). The room temperature experiment was terminated considering the overall acceptability of the fruits. Generally at 13°C all aloe treatments had the most reduced increase of b* values and highest in b* values were observed with 0% *Aloe vera* gel at room temperature.

Table 15: Interactive effects of *Aloe vera* gel coatings and storage temperature on fruit peel color (L* value)

	Storage time (Days)				
Treatment	0	4	8	12	16
A1T1	68.1a*	68.6b	69.8d	70.7e	74.2a
A1T2	68.1a	68.4b	69.7e	70.1f	73.5a
A2T1	68.1a	69.8a	74.9a	75.3a	75.6a
A2T2	68.1a	69.6a	70.7b	74.1b	74.2a
A3T1	68.1a	68.7b	69.8c	71.3c	74.9a
A3T2	68.1a	68.6b	69.7d	71.2d	73.8a
A4T1	68.1a	68.4b	69.7d	70.7e	74.2a
A4T2	68.1a	68.3b	69.6f	70.1f	73.0a
A5T1	68.1a	68.4b	69.6f	70.8e	74.6a
A5T2	68.1a	68.3b	69.6f	70.2f	73.5a

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test ($P \leq 0.05$) where A1= Chitosan, A2= 0% *Aloe vera*, A3=25% *Aloe vera*, A4=50% *Aloe vera*, A5=75% *Aloe vera*, T1=Room temperature and T2=13°C

*Room storage temperature varied between 15 and 22°C.

Table 16: Interactive effects of *Aloe vera* gel coatings and storage temperature on fruit peel color (a* value)

	Storage time (Days)				
Treatment	0	4	8	12	16
A1T1	-17.7a*	-16.8d	-13.9cd	-12.3d	-10.2d
A1T2	-17.7a	-17.3de	-16.1f	-14.7g	-12.6e
A2T1	-17.7a	-12.1a	-8.3a	-6.1a	-2.5a
A2T2	-17.7a	-13.5b	-11.7b	-8.4b	-4.4b
A3T1	-17.7a	-16.1c	-13.7c	-11.6c	-7.0c
A3T2	-17.7a	-16.8d	-14.9e	-13.8f	-10.5d
A4T1	-17.7a	-17.0de	-14.1cd	-13.0e	-11.7e
A4T2	-17.7a	-17.4e	-16.4f	-15.2h	-13.3f
A5T1	-17.7a	-17.1de	-14.4de	-13.0e	-11.6e
A5T2	-17.7a	-17.5e	-16.4f	-15.1gh	-13.4f

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test ($P \leq 0.05$) where A1= Chitosan, A2= 0% *Aloe vera*, A3=25% *Aloe vera*, A4=50% *Aloe vera*, A5=75% *Aloe vera*, T1=Room temperature and T2=13°C

*Room storage temperature varied between 15 and 22°C.

Table 17: Interactive effects of *Aloe vera* gel coatings and storage temperature on fruit peel color (b* value)

	Storage time (Days)				
Treatment	0	4	8	12	16
A1T1	39.6a*	40.3b	41.0d	41.3d	43.9d
A1T2	39.6a	40.1c	40.9f	40.7f	42.2g
A2T1	39.6a	40.7a	48.1a	48.7a	46.0a
A2T2	39.6a	40.3b	44.6b	43.4b	45.7b
A3T1	39.6a	40.3b	41.0c	41.8c	45.2c
A3T2	39.6a	40.3b	40.9d	41.1e	42.8f
A4T1	39.6a	40.1c	40.9e	41.4d	43.4e
A4T2	39.6a	40.1c	40.8g	40.7f	42.2g
A5T1	39.6a	40.1c	40.9f	41.3d	43.5e
A5T2	39.6a	40.0d	40.7h	40.7f	42.3g

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test (P≤0.05) where A1= Chitosan, A2= 0% *Aloe vera*, A3=25% *Aloe vera*, A4=50% *Aloe vera*, A5=75% *Aloe vera*, T1=Room temperature and T2=13°C

*Room storage temperature varied between 15 and 22°C.

4.6.2 Flesh Color

4.6.2.1 The Effects of *Aloe vera* Gel Coatings Fruit Flesh Color

The coatings were effective on flesh colour change of the mangoes under room temperature conditions and 13ºC (colour change during ripening for this variety 'Ngowe' is from green to yellow). Color changes in peel are presented as L*, a*, b* and were expressed as lightness (L), greenness (-a), blueness (+a), yellowness (+b), colour space coordinates. Fruits from each treatment for both trials registered some changes in chromatic L*, a* and b* colour values during the storage period (Figures 13, 14 and 15 respectively).

The L* (lightness) decreased during storage, L* values for control decreased from 88.1 to 72.5) which was lower than the coated fruits (Fig 13). L* values decreased over time irrespective of the treatments from 88.1 to 75.8 for 25% *Aloe vera* gel coated fruit, 76.0 for 50% *Aloe vera* gel coated fruits, 76.6 for 75% *Aloe vera* gel coated fruits and 76.0 for chitosan coated fruits. There was no significant difference (P≤0.05) between fruits coated with chitosan and 50% *Aloe vera* gel coated treatments at the end of the storage period.

Chromatic a* value from mango fruits increased over time irrespective of the treatments. There was a gradual increase in flesh a* value beginning on day eight (Fig 14). Before storage, a* value was -7.2, and after the storage the value increased to 7.1 for negative control fruits. It also increased to 1.7 for fruits coated with 25 % *Aloe vera* gel, -1.2 for fruits coated with 50% *Aloe vera* gel, -1.2 for 75% *Aloe vera* gel coated fruits and to -0.3 for chitosan coated fruit. The increase in a* value was however slower for fruit coated with 50 and 75% *Aloe vera* compared to negative control or 25% *Aloe vera* gel treatments. There was a significant difference ($P \leq 0.05$) among the treatments at the end of the storage period.

Chromatic b* value gradually increased over time regardless of the treatments, and it was significantly higher ($P \leq 0.05$) on day eight for fruits coated with 0% *Aloe vera* gel (Fig 15). Initial b* value was 34.4 and it gradually increased, reaching to 57.0 for fruits coated with 0% *Aloe vera* gel, to 53.6 for 25 %, to 53.0 for 50% , 53.2 for 75% *Aloe vera* gel and to 53.2 for chitosan coated fruits. The increase in b* value was however slower for fruit coated with 50, 75% *Aloe vera* and chitosan compared to 0% *Aloe vera* gel. There was a significant difference ($P \leq 0.05$) among the treatments at the end of the storage period

Generally the flesh color of the mango fruits coated with 50% and75% *Aloe vera* treatments was significantly less developed than flesh colours in the other treatments.

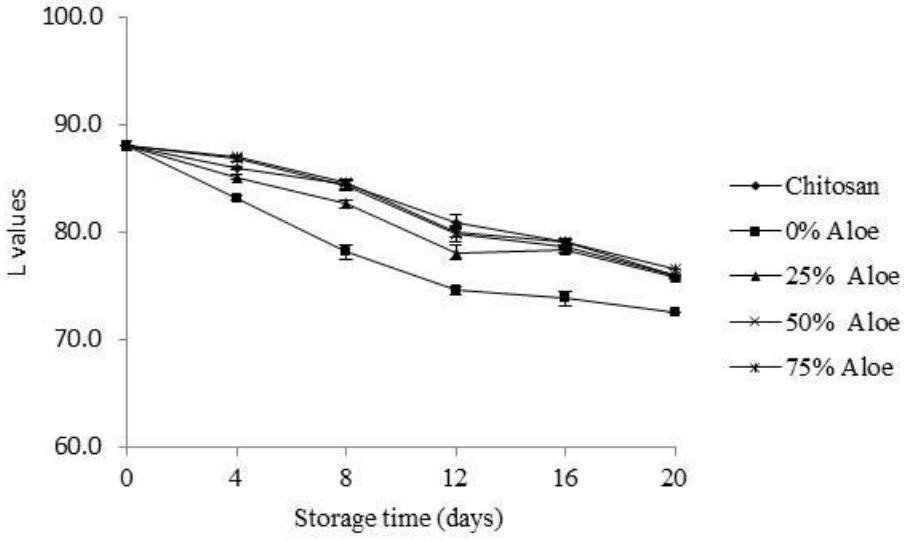

Figure 13: Effect of different *Aloe vera* gel concentrations on Chromatic L* value of the flesh color of mango fruits var. 'Ngowe'

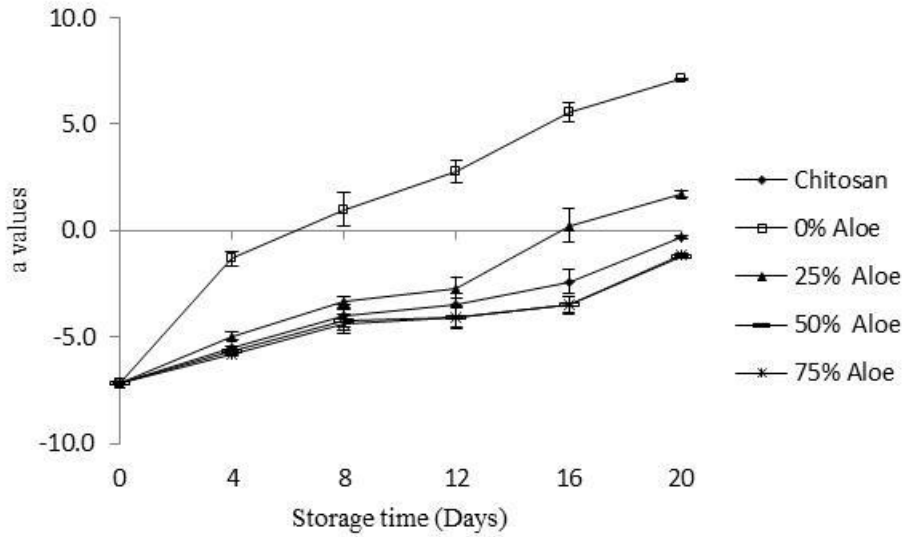

Figure 14: Effect of different *Aloe vera* gel concentrations on Chromatic a* of the flesh color of mango fruits

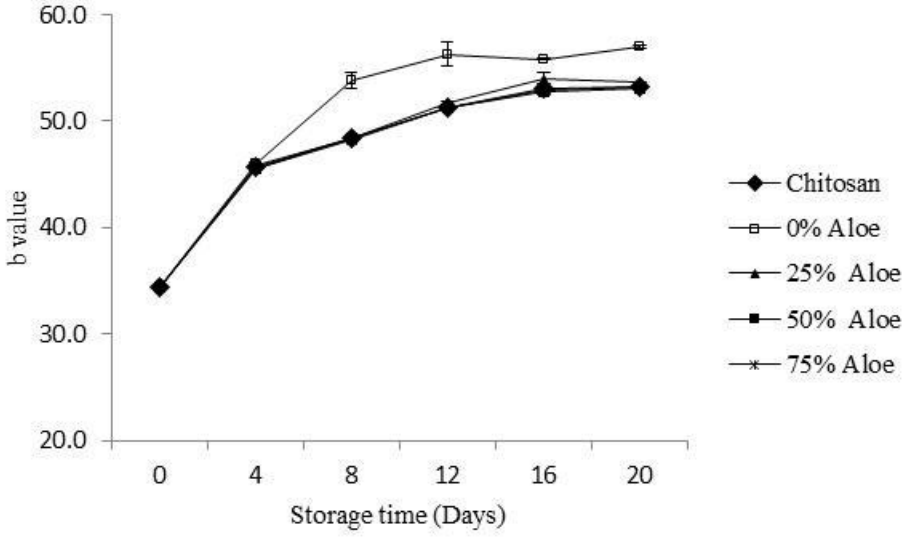

Figure 15: Effect of different *Aloe vera* gel concentrations on Chromatic b* of the flesh color of mango fruits var. 'Ngowe'

.

4.6.2.2 Effect of Storage Temperature on Fruit Flesh Color

The results indicated that L* value of the flesh colour of fruits was significantly higher for fruits stored at 13°C, as compared with those stored at room temperature (Table 18). Initially no significant difference was observed but at day four, fruits stored at room temperature had significantly ($P \leq 0.05$) the lowest L* value (85.3) while and fruits stored at 13°C had a value of 86.6 and there was significant difference between the two storage temperatures.

Similar observations were made for day eight; twelve and day sixteen. By day sixteen fruits stored under room temperature were discarded and the experiment terminated because the overall acceptability was unsatisfactory. At day twenty, had an L* value of 75.4 while the experiment was terminated. There were significant effects between room temperature and 13°C throughout the storage period. Increase in storage temperature significantly decreased L* value in both trials. The highest L* value was recorded for fruits stored at 13°C and the lowest L* value was recorded at room temperature.

For chromatic a* value, the results indicated that Chromatic a* value of the flesh colour of fruits was significantly lower for fruits stored at 13°C, as compared with those at room temperature (Table 19). Initially no significant difference was observed but at day four, there was significant difference between fruits stored at room temperature and they had the highest chromatic a* value (-4.3) while and fruits stored at 13°C had chromatic a* value of -5.0.

Similar observations were made for day eight; twelve and day sixteen. Fruits under room temperature were discarded because the overall acceptability was unsatisfactory. At day twenty, trial 1 had Chromatic a* value of 1.2 and the experiment was terminated. There were significant effects between room temperature and 13°C throughout the storage period. Increase in storage temperature significantly increased a* value in both trials. The lowest a* value was recorded for fruits stored at 13°C and the highest Chromatic a* value was recorded at room temperature.

For Chromatic b* value, the results indicated that the b* value for the flesh of fruits was significantly lower for fruits stored at 13°C, as compared with those stored at room temperature (Table 20). Initially no significant difference was observed but at day four, fruits stored at room temperature had the highest Chromatic b* value (45.8) while and fruits stored at 13°C had a value of 45.7 and there was significant difference between the two storage temperatures.

Similar observations were made for day eight; twelve and day sixteen. Fruits under room temperature were terminated because the overall acceptability was unsatisfactory by day sixteen.

At day twenty, trial 1 had Chromatic b* value of 54.0 and 54.2 for trial 2 and the fruits were terminated. There were significant effects between room temperature and 13°C throughout the storage period. Increase in storage temperature significantly increased Chromatic b* value in both trials. The lowest b* value was recorded for fruits stored at 13°C and the highest Chromatic b* value was recorded at room temperature in both trials.

Table 18: Effects storage temperature on fruit flesh color (L* value)

	Storage time (Days)					
Storage Temperature	0	4	8	12	16	20
Room Temperature	88.1a*	85.3b	81.9b	77.5b	77.1b	
13°C	88.1a	86.0a	83.8a	80.0a	78.5a	75.4

*Means followed by the same letter between temperature treatments in a given day are not significantly different according to t- test (P≤0.0001).

*Room storage temperature varied between 15 and 22°C.

Table 19: Effect of storage temperature on fruit flesh color (chromatic a* value)

	Storage time (Days)					
Storage Temperature	0	4	8	12	16	20
Room Temperature	-7.2a*	-4.3a	-1.9a	-1.2a	0.4a	
13◦C	-7.2a	-5.0b	-4.1b	-3.4b	-1.8b	1.2

*Means followed by the same letter between temperature treatments in a given day are not significantly different according to t- test (P≤0.0001).

*Room storage temperature varied between 15 and 22°C.

Table 20: Effect of storage temperature on fruit flesh color (chromatic b* value)

	Storage time (Days)					
Storage Temperature	0	4	8	12	16	20
Room Temperature	34.4a*	45.8a	49.9a	53.1a	54.4a	
13°C	34.4a	45.7b	49.1b	51.6b	53.0b	54.0

*Means followed by the same letter between temperature treatments in a given day within a trial are not significantly different according to t- test (P≤0.0001).

*Room storage temperature varied between 15 and 22°C.

4.6.2.3 Interactive Effects of *Aloe vera* Gel Coatings and Storage Temperature on Fruit Flesh Color

The interaction between *Aloe vera* gel concentrations of 50% and 75% and storage temperature of 13°C significantly reduced decrease in chromatic L*, and increase in chromatic a*, b* of flesh colour. L* value at day zero, there was no significant difference (P≤0.05) between the treatments (Table 21), at day four the interaction between fruits coated with *Aloe vera* at 50% and 75% and storage temperature of 13°C had the highest L* value of 87.3 while the lowest L* value (82.8) was recorded for fruits treated with 0% *Aloe vera* at room temperature. At day eight, the interaction between fruits coated with 0% *Aloe vera* gel and room temperature (A2T1) had the lowest L* value (76.8) and chitosan at 13°C had the highest L* value (85.4).

At day twelve, the interaction between fruits coated with chitosan and 13°C storage temperature had the highest L* value (82.4) while lowest L* value (73.8) was recorded for A2T1. Day sixteen, L* value was lowest (72.4) for A2T1 treatment while the interaction between fruits coated with chitosan and 13°C storage temperature had the highest value (79.8). Fruits under room temperature were discarded considering the overall acceptability. Generally at 13°C chitosan and all *Aloe vera* treatments had the most reduced decrease of L* value and lowest in L* value was observed on the interaction between fruits coated with 0% *Aloe vera* gel and room temperature.

Chromatic a* value at day zero, there was no significant difference (P≤0.05) between the treatments (Table 22). At day four interaction between fruits coated with *Aloe vera* at 75% and 13°C had the lowest a* value of -6.0 while the highest a* value (-0.6) was recorded on the interaction between fruits treated with 0% *Aloe vera* and room temperature (A2T1). At day eight,

0% *Aloe vera* gel and room temperature interaction had the highest a* value (2.7) and 75% *Aloe vera* gel aloe and 13°C had the lowest a* value (-5.4).

At day twelve, the interaction between 50% *Aloe vera* gel and 13°C had the lowest a* value (-5.2) while highest a* value (3.9) was recorded for A2T1. Day sixteen, a* value was highest (6.5) for A2T1 interaction; A4T2 had the lowest value (-4.4). Fruits under room temperature were discarded considering their overall acceptability. Generally the interaction between storage temperature of 13°C and all *Aloe vera* treatments had the most reduced increase of a* value and highest in a* value was observed with interaction between 0% *Aloe vera* gel and room temperature.

Chromatic b* value at day zero, there was no significant difference ($P \leq 0.05$) between the treatments (Table 23). At day four, the interaction between fruits coated with *Aloe vera* at 75% and storage temperature of 13°C had the lowest b* value of 45.5 while the highest b* value (46.2) was recorded for interaction between fruits coated with 0% *Aloe vera* and room temperature (A2T1). At day eight, the interaction between 0% *Aloe vera* gel coating and room temperature had the highest a* value (48.1) and 75% *Aloe vera* gel and 13°C had the lowest b* value (40.7).

At day twelve, the interaction between 50% *Aloe vera* gel and 13°C had the lowest b* value (48.2) while highest b* value (55.6) was recorded for interaction between 0% *Aloe vera* gel coating and room temperature . Day sixteen, b* value was highest (56.0) for the interaction between 0% *Aloe vera* gel coating and room temperature treatment; 50% *Aloe vera* gel and chitosan at13°C and had the lowest value (52.2). Fruits under room temperature were discarded considering the overall acceptability. Generally the interaction between storage temperature of 13°C and all *Aloe vera* treatments had the most reduced increase of b* value and highest in b* value was observed with the interaction between 0% *Aloe vera* gel and room temperature.

Table 21: Interactive effects of *Aloe vera* gel coatings and storage temperature on fruit flesh color (L*value)

	Storage time (Days)				
Treatment	0	4	8	12	16
A1T1	88.1a*	85.6bc	83.6b	79.6c	78.3def
A1T2	88.1a	86.4ab	85.4a	82.4a	79.8a
A2T1	88.1a	82.8d	76.8e	73.8g	72.4h
A2T2	88.1a	83.6d	79.6d	75.4f	75.3g
A3T1	88.1a	84.7c	81.7c	76.7e	77.9f
A3T2	88.1a	85.6bc	83.6b	79.6c	78.8cd
A4T1	88.1a	86.4ab	83.4b	78.4d	78.1ef
A4T2	88.1a	87.3a	85.3a	81.3b	79.1bc
A5T1	88.1a	86.9a	83.9b	78.9cd	78.6cde
A5T2	88.1a	87.3a	85.3a	81.3b	79.6ab

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test ($P \leq 0.05$) where A1= Chitosan, A2= 0% *Aloe vera*, A3=25% *Aloe vera*, A4=50% *Aloe vera*, A5=75% *Aloe vera*, T1=Room temperature and T2=13°C

*Room storage temperature varied between 15 and 22°C.

Table 22: Interactive effects of *Aloe vera* gel coatings and storage temperature on fruit flesh color (a* value)

	Storage time (Days)				
Treatment	0	4	8	12	16
A1T1	-7.2a*	-5.3d	-2.8cd	-2.3d	-1.2d
A1T2	-7.2a	-5.8de	-5.1f	-4.7g	-3.6f
A2T1	-7.2a	-0.6a	2.7a	3.9a	6.5a
A2T2	-7.2a	-2.0b	-0.8b	1.6b	4.6b
A3T1	-7.2a	-4.6c	-2.7c	-1.6c	2.0c
A3T2	-7.2a	-5.3d	-4.0e	-3.8f	-1.5d
A4T1	-7.2a	-5.5de	-3.1cd	-3.0e	-2.7e
A4T2	-7.2a	-5.9e	-5.3f	-5.2h	-4.3f
A5T1	-7.2a	-5.6de	-3.4de	-3.0e	-2.6e
A5T2	-7.2a	-6.0e	-5.4f	-5.1gh	-4.4f

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test ($P \leq 0.05$) where A1= Chitosan, A2= 0% *Aloe vera*, A3=25% *Aloe vera*, A4=50% *Aloe vera*, A5=75% *Aloe vera*, T1=Room temperature and T2=13°C

*Room storage temperature varied between 15 and 22°C.

Table 23: Interactive effects of *Aloe vera* gel coatings and storage temperature on fruit flesh color (b* value)

	Storage time (Days)				
Treatment	0	4	8	12	16
A1T1	34.4a*	45.8b	48.5d	51.6d	53.9d
A1T2	34.4a	45.6c	48.4f	51.0f	52.2g
A2T1	34.4a	46.2a	55.6a	59.0a	56.0a
A2T2	34.4a	45.8b	52.1b	53.7b	55.7b
A3T1	34.4a	45.8b	48.5c	52.0c	55.2c
A3T2	34.4a	45.8b	48.4e	51.4e	52.8f
A4T1	34.4a	45.6c	48.4e	51.6d	53.4e
A4T2	34.4a	45.6c	48.3g	51.0f	52.2g
A5T1	34.4a	45.6c	48.4f	51.6d	53.5e
A5T2	34.4a	45.5d	48.2h	51.0f	52.3g

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test (P≤0.05) where A1= Chitosan, A2= 0% *Aloe vera*, A3=25% *Aloe vera*, A4=50% *Aloe vera*, A5=75% *Aloe vera*, T1=Room temperature and T2=13°C

*Room storage temperature varied between 15 and 22°C.

4.7 Ascorbic acid

4.7.1 The effects of *aloe vera* gel coatings on ascorbic acid

Ascorbic acid content in the mango fruits decreased significantly during the ripening storage period (Fig.16). In both trials, a significant decrease ($P \leq 0.05$) in ascorbic acid contents was observed in all the treatments. Initially, the ascorbic acid was 26.6mg/100g.At day four, there was significant difference ($P \leq 0.05$) between the negative control (0% *Aloe vera* gel) and the other treatments but there was no significant difference among 50 and 75% *Aloe vera* gel concentrations and those coated with 1% chitosan (the positive control). Mango fruits coated with 0% *Aloe vera* gel had 23 mg/100g ascorbic acid while other treatments 25, 50, 75% and chitosan lost 24.4, 25.0, 24.7 and 24.9 mg/100g ascorbic acid respectively.

At day eight, 50% *Aloe vera gel* was the most effective in reducing decrease in ascorbic acid followed by chitosan while the 0% aloe had the least ascorbic acid. Mango fruits coated

with 0% *Aloe vera* gel had 21.8 mg/100g ascorbic acid while other treatments 25, 50, 75% and chitosan lost 23.2, 23.9, 23.5 and 23.6 mg/100g ascorbic acid respectively. At day twelve, there was significant difference between the control and the rest of the treatments, 75% *Aloe vera* gel had the highest ascorbic acid. Mango fruits coated with 0% *Aloe vera* gel had 20.8 mg/100g ascorbic acid while other treatments 25, 50, 75% and chitosan had 22.2, 22.8, 22.9 and 22.6 mg/100g ascorbic acid respectively.

At day sixteen, there were significant effects between the control and the other treatments 25, 50 and 75% *Aloe vera* gel and chitosan treatments. The negative control had the lowest ascorbic acid while75% *Aloe vera* gel had the highest ascorbic acid value. Mango fruits coated with 0% *Aloe vera* gel had 18.8 mg/100g ascorbic acid while other treatments 25, 50, 75% and chitosan had 20.2, 20.8, 20.9 and 20.6 mg/100g ascorbic acid respectively. At day twenty, 0% *Aloe vera* gel had the lowest ascorbic acid while 75% *Aloe vera* gel had the highest ascorbic acid among the other treatments. Mango fruits coated with 0% *Aloe vera* gel had 17.6 mg/100g ascorbic acid while other treatments 25, 50, 75% and chitosan lost 18.8, 20.0, 20.1 and 19.8 mg/100g ascorbic acid respectively.

Generally, all treatments had a decrease in ascorbic acid from the initial value. There was a gradual decrease in all days although the decrease was reduced by *Aloe vera* treatments.

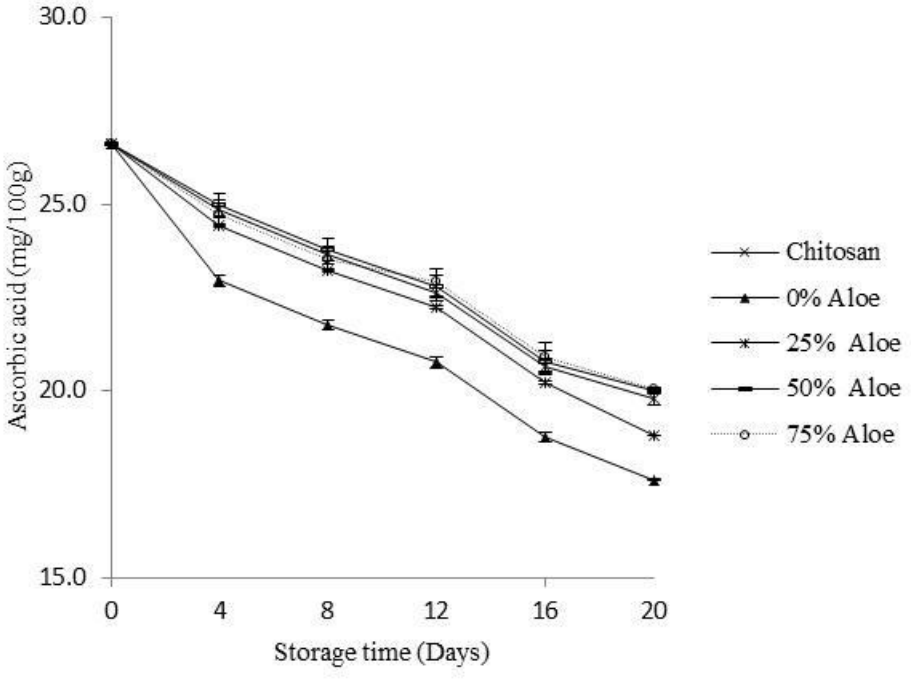

Figure 16: Ascorbic acid of mango fruits var. 'Ngowe' as affected by *Aloe vera* gel coatings

4.7.2 Effect of storage temperature on ascorbic acid

The results indicated that ascorbic acid of fruits was significantly higher (P≤0.0001) for fruits stored at 13°C, as compared with those at room temperature (Table 24). Initially no significant difference was observed but at day four, fruits stored at room temperature had the lowest ascorbic acid value and there was significant difference between the two storage temperatures. In day eight, the fruits stored at 13°C had the highest ascorbic acid (23. mg/100g ascorbic acid while fruits at room temperature had the least ascorbic acid (22.8 mg/100g ascorbic acid).

Similar observations were made for day twelve and day sixteen, fruits under room temperature were terminated because the overall acceptability was unsatisfactory. At day twenty, had a value of 19.3 mg/100g ascorbic acid and the fruits were terminated. There were significant effects between room temperature and 13°C throughout the storage period. Increase in storage temperature significantly reduced ascorbic acid. The least ascorbic acid was recorded for fruits stored at room temperature and the highest ascorbic acid was recorded at 13°C.

Table 24: Effect of storage temperature on fruit ascorbic acid

	Storage time (Days)					
Storage temperature	0	4	8	12	16	20
Room temperature	26.6a*	24.0b	22.8b	22.7b	19.8b	
13°C	26.6a	24.8a	23.6a	21.8a	20.7a	19.3

*Means followed by the same letter between temperature treatments in a given day are not significantly different according to t- test (P≤0.0001).

*Room storage temperature varied between 15 and 22°C.

4.7.3 Interactive Effects of *Aloe vera* Gel Coatings and Storage Temperature on Ascorbic Acid

The interaction between 50%, 75% *Aloe vera* gel and storage temperature of 13°C significantly reduced loss of ascorbic acid (Table 25). At day zero, there was no significant difference (P≤0.05) between the treatments, at day four fruits coated with *Aloe vera* at 50% at 13°C (A4T2) had the highest value of ascorbic acid (25.7 mg/100g ascorbic acid while the lowest value (22.7 mg/100g ascorbic acid) was recorded for fruits treated with 0% *Aloe vera* at room temperature (A2T1). At day eight, 0% *Aloe vera* gel at room temperature (A2T1) had the

lowest ascorbic acid (21.5 mg/100g ascorbic acid and 50% *Aloe vera* gel aloe at 13°C had the highest ascorbic acid value (24.5 mg/100g ascorbic acid).

At day twelve, the interaction between 75% *Aloe vera* gel and 13°C (A5T2) had the highest ascorbic acid value (23.7 mg/100g ascorbic acid) while least ascorbic acid (20.5 mg/100g ascorbic acid) was recorded for 0% *Aloe vera* gel and room temperature. Day sixteen, ascorbic acid was highest (21.7 mg/100g ascorbic acid) for A5T2 treatment, A2T1 had the lowest value (18.5 mg/100g ascorbic acid). Fruits under room temperature were discarded considering the overall acceptability. Generally the interaction between storage temperature of 13°C and all *Aloe vera* treatments had the most reduced loss of ascorbic acid and highest loss in ascorbic acid was observed in 0% *Aloe vera* gel at room temperature.

Table 25: Interactive effects of *Aloe vera* gel coatings and storage temperature on ascorbic acid

	Storage time (Days)				
Treatment	0	4	8	12	16
A1T1	26.6a*	24.5bcd	23.3bc	22.3cd	20.3cd
A1T2	26.6a	25.2abc	24.0ab	23.0bc	21.0bc
A2T1	26.6a	22.7e	21.5d	20.5e	18.5e
A2T2	26.6a	23.2e	22.0d	21.0e	19.0e
A3T1	26.6a	24.4cd	23.2bc	22.2cd	20.2cd
A3T2	26.6a	24.4cd	23.2bc	22.2cd	20.2cd
A4T1	26.6a	24.3d	23.1c	22.1d	20.1d
A4T2	26.6a	25.7a	24.5a	23.5ab	21.5ab
A5T1	26.6a	24.1d	22.9c	22.1d	20.1d
A5T2	26.6a	25.3ab	24.1a	23.7a	21.7a

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test (P≤0.05) where A1= Chitosan, A2= 0% *Aloe vera*, A3=25% *Aloe vera*, A4=50% *Aloe vera*, A5=75% *Aloe vera*, T1=Room temperature and T2=13°C

*Room storage temperature varied between 15 and 22°C

4.8 The Effects of *Aloe vera* Gel Coatings on Anthracnose Disease Incidents on Mango Fruit

None of the *Aloe vera* gel concentration tested inhibited the growth of *Colletotrichum gloeosporioides* as compared to the control, and grew almost similarly with all treatments through the 7-day incubation period. Mango fruits treated with 1% chitosan had the lowest disease severity index. The highest fungicidal effect was observed in those mangoes coated with 1% chitosan (incidence of 45%) and disease severity index of 12.5.

Table 26: Effect of *Aloe vera* gel on Anthracnose severity and anthracnose disease incidents

TREATMENT	% skin area	Severity index scores	Anthracnose incidence (%)
chitosan	12.5a*	2	45
0% Aloe	63.6a	4	93
25% Aloe	57.1a	4	80
50% Aloe	50.0a	3	73
75% Aloe	45.6a	3	60

*Means followed by the same letter between treatments in a given day are not significantly different according to Tukey's HSD test ($P \leq 0.05$)

4.9 The effects of *aloe vera* gel coatings on Shelf life of mango fruits

Mango fruits with *Aloe vera* and chitosan coatings presented a statistically higher shelf life compared to those of 0% *Aloe vera* coating during storage (Fig. 17). The results indicate that under room temperature the coated fruits can be stored for sixteen days while the control had a shelf life of around 8 days while *Aloe vera* gel and chitosan coatings prolonged storage life of mango up to 20 days at 13^{o}C.

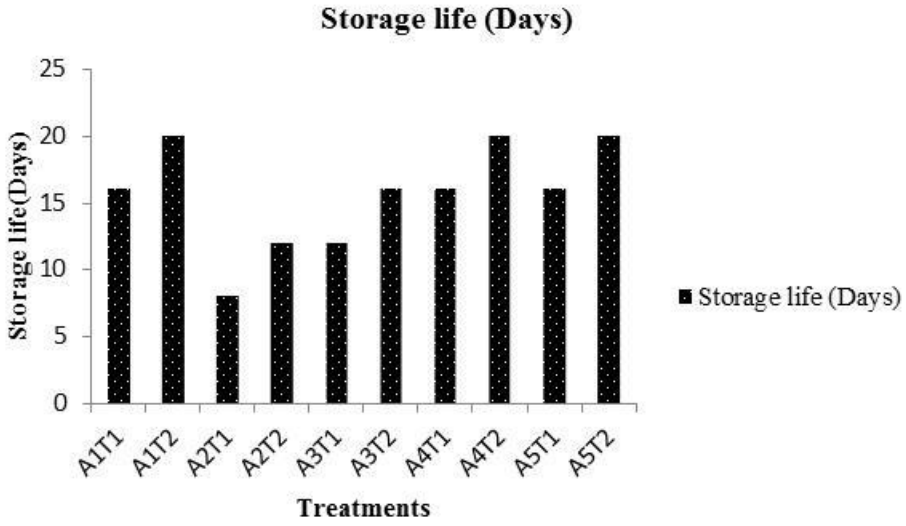

Figure 17: Effects of *Aloe vera* coatings on shelf life of mango fruits

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effects of *Aloe Vera* Coatings on Shelf Life, Quality and Anthracnose Disease Incidents

Results on study on shelf life indicated that mango fruits coated with *Aloe vera* gel and chitosan coatings had longer shelf life compared to uncoated mangoes. It was found that under room temperature the coated fruits can be stored for sixteen days while the control had a shelf life of around 8 days at ambient conditions while *Aloe vera* gel and chitosan coatings prolonged storage life of mango up to 20 days at 13^{o}C. The shelf life is extended by reducing the respiration rate and moisture loss from the fruits. Application of physical barrier such as wax coating regulates permeability of water vapour and other gases and retards ripening thus extending shelf life (Rajkumar *et al*. 2008). These results were similar with the studies of Wongmetha and Ke (2012) who reported that Chitosan coating and 1-MCP combine with chitosan treatment prolonged storage life of mango up to 29 days after storage at 10^{o}C that was significantly longer than, 1-MCP and control (28 and 27 days after storage, respectively).

Weight loss is an important index of postharvest total storage life in the fresh produce. Fruit weight loss occurs as a result of dehydration and loss of water from fruit surface. *Aloe vera* gel and chitosan coatings reduced weight loss of mango fruits as compared to control. Weight loss of fruit occurs as a result of the gradient of water vapour pressure between the fruit and the surrounding air, which is usually reduced by both epidermal cell layer and cuticle. However, edible coating (*Aloe vera* gel and chitosan) acted as an extra layer which also coated the stomata leads to a decrease in transpiration and in turn, to a reduction in weight loss, this being the primary beneficial effect of edible coatings (Neeta *et al.* 2013).

Aloe vera gel and chitosan must have created a semi-permeable barrier to gases and water vapor and therefore reduced water loss and hence reduced weight loss. Similar to the present results, *Aloe vera* gel reduced weight loss in 'Arctic Snow' nectarines (treated with 2.50%, stored at 20°C (Ahmed *et al*.(2009), 'StarKing' cherries (treated with 33%, stored at 1°C; Martinez-Romero *et al*., 2006) and 'Autumn Royal' table grapes (treated with 33%, stored at 2°C; Castillo *et al*., 2010). The obtained results are also in agreement with the findings of (Singh *et al.* 2011) for strawberries coated *Aloe vera* coatings and those of Martinez et al. 2006 who reported that reduction in weight loss for strawberries coated with *Aloe vera.*

The results on total soluble solids (TSS) revealed that fruits coated with of *Aloe vera* gel and chitosan reduced the increase in TSS. *Aloe vera* gel and chitosan coatings must have modified the fruits internal atmosphere resulting in high CO_2 concentration. Carbon dioxide retards conversion of starch to sugars as well as moisture loss thus reducing the rate of ripening and maintaining TSS (Ahmed et al. 2009).which retards conversion of starch to sugars and less moisture loss thus reducing ripening and maintaining the TSS. It was also observed that TSS increased with storage time. This behavior of TSS was likely due to losses in water through respiration and evaporation and hydrolysis of starch during storage and hence increases in TSS (Eman *et al*. 2013). Ahmed *et al*. (2009) observed the formation of soluble pectinic acid from insoluble protopectin during senscence of fruit; and they attributed such increase in TSS to the conversion of starch into sugar. Similar results were obtained using *Aloe vera* gel treatment (2.5%) which suppressed the increase in TSS for 'Artic Snow' nectarines during ripening at 20°C (Ahmed *et al*., 2009).

Fruit Firmness of mango fruits treated with the *Aloe vera* gel and chitosan coatings was higher. It was therefore apparent that the increased firmness was due to the effect of the coating which delayed the softening while minimum values in negative control fruits could be due loosening of cell wall, reduction of pectic enzymes which reduced the firmness of mango fruits (Jitareerat *et al.,* 2007). *A. vera* gel and chitosan must have modified the internal gas composition (coating excludes O_2) of mangoes causing reduction of cell wall degrading-enzymes responsible for mango softening (Aguiar *et al.,* 2011).

It has been postulated that softening and texture changes during mango fruit ripening determine fruit storability and shelf life, as well as reduced incidences on decay and less susceptibility to mechanical damage. These results on firmness demonstrated beneficial effects of the *Aloe vera* coating on enhancement of the mango shelf life. The present study demonstrates observations similar to those of Arowora *et al.*(2013) who worked on oranges coated with *Aloe vera* gel. It was, also, observed that fruit firmness significantly decreased with increasing storage period. Loss in fruit firmness with the progress of storage period is due mainly to decomposition, enzymatic degradation of insoluble protopectins to simpler soluble pectins, solubilization of cell and cell wall contents as a result of the increase in pectin esterase activity and subsequent development of juiciness and the loss in peel and pulp firmness.

The pH of *Aloe vera* coated mangoes and those fruits coated with chitosan had lower values this was due to the semi-permeability created by *Aloe vera* and chitosan coatings on the surface of the fruit, which modified the internal atmosphere i.e. endogenous O_2 and CO_2 concentrations in the fruit, thus retarding ripening. Baldwin *et al*. (1999) reported similar results using Nature Seal (NS) and Tropical Fruit Coating 213 (TFC) coatings on mango ripening during storage.

There was a lower decrease in the TA for *Aloe vera* and chitosan coated mangoes. *Aloe vera* gel and chitosan coating must have modified internal atmosphere thus reducing ripening and maintenance of the TA (Nabigol and Asghari, 2013). Reduction in TA for uncoated fruits is due to conversion of acids into sugars and their further utilization in the metabolic processes of the fruit. Doreyappa and Huddar (2001) reported the similar pattern in different varieties of mango fruits stored at 18-34°C. They observed a series of physico-chemical changes during ripening and the major changes were decrease in acidity. The acidity of the fruit is an important character to determine its quality and acceptability. Very high or very low values of the acidity are not recommended for good fruit.

Color is related to the presence of various pigments. Changes in colour are mainly due to chlorophyll transformation into other pigments and to the synthesis of new pigments e.g. carotenoids and anthocyanins. Chlorophyll retention was higher in the fruits coated with *Aloe vera* gel and chitosan coatings and least of it was seen in the uncoated fruit. *Aloe vera* gel treatment and chitosan delayed the green colour loss on the fruit skin, synthesis of new pigments e.g. carotenoids require O_2. Coatings applied to fruit act as a barrier, altering permeability to gases. This results in increased internal CO_2 contents, slowing down the external and internal colour change of the fruit in return delaying chlorophyll degradation and carotenoid synthesis (Ergun and Satici, 2012). Similar results of colour retention in coated fruit had been reported in carambola fruits (Neeta *et al*. 2013).

Ascorbic acid is one of the most abundant antioxidants present in fruits. Results suggest that *Aloe vera* gel and chitosan coating caused lower losses of antioxidant capacity by the end of storage, when coated fruits were compared to the negative control. Application of *Aloe vera* gel and chitosan modified internal atmosphere, more concentration of CO_2 resulting to lower concentration of O_2 hence the oxidation process was retarded which caused reduction in

conversion of ascorbic acid to dehydro ascorbic acid. Lal *et al.* (2007) reported similar results on mango using various chemicals under different storage period.

The result on anthracnose disease demonstrated that *Aloe vera* does not inhibit *C. gloeosporioides* growth. The findings of this study are in disagreement with previous reports on the antifungal activity of plant extracts such as *Echinops* sp., *Ruta chalepensis*, *Thymus serrulatus* and *Artemisia* genus (Ademe *et al*, 2014). Other studies on *A. vera* gel on table grape and sweet cherry (Martínez-Romero *et al*., 2006; Serrano *et al*., 2006) maintained quality and reduced decay symptoms although the fungi responsible for decay were not determined. However, early reports have shown that Aloe reduced spore survival by 15–20% for Penicillium, Botrytis and Alternaria (Saks and Barkai-Golan, 1995), and *Aloe vera* reduced 22–38% the mycelium growth of other plant pathogenic fungi such as Rhizoctonia, Fusarium and Colleotrichum (Jasso de Rodríguez *et al*., 2005), showing a limitation in controlling possible fungal infections.

5.2 Effects of Storage Temperature on Shelf Life and Quality of Mango Fruits

Results on study on shelf life indicated that mango fruits stored at room temperature had shorter shelf life than those stored at low temperature. It was found that under room temperature the coated fruits can be stored for sixteen days while the control had a shelf life of around 8 days at ambient conditions while *Aloe vera* gel and chitosan coatings prolonged storage life of mango up to 20 days at 13ºC. Reducing storage temperature improves the shelf life of perishable commodities mainly due to its effect on biochemical and physiological activity leading to retarded senescence of fruit in storage (Pinto *et al*., 2004). Similar results were reported by Ezz and Awad (2011) who reported the effect of different treatment; potassium permanganate, hot water treatment under 5ºC for 30 min. and shrink film addition to control on storage life of mango cultivars Hindi Be- Besennara (early ripe) and Alphonse (mid-season) under three low temperature 8, 10 and 13ºC and R.H. (80-85%) for 30 days.

The results indicated that weight loss of fruits was lower for fruits stored at 13°C, as compared with those at room temperature. This could be due to the fact that low temperature retards ripening through reduced respiration rate and other undesirable metabolic changes. High temperature is known to increase enzymatic catalysis and leads to a chemical and biochemical breakdown in fruits and vegetables (Ezz and Awad, 2011).

The present results indicated that increasing storage temperatures significantly decreased the firmness of mango fruits. It was, also, found that fruit firmness significantly decreased with increasing storage period. Loss in fruit firmness with the progress of storage period is due mainly to decomposition, enzymatic degradation of insoluble protopectins to more simple soluble pectins, solubilization of cell and cell wall contents as a result of the increasing in pectin esterase activity and subsequent development of juiciness and the loss in peel and pulp hardness (Ezz and Awad, 2011).

The present results showed that in fruit titratable acidity was higher in low temperature and decreased with increasing temperature. The relatively higher storage temperature led to higher rate of reduction in the TA during ripening and storage of mangoes. This could be associated with rapid ripening and senescence process of mangoes when stored at higher temperature. The changes in TA is based on changes in citric acid, the concentration of this acid is known to diminish during ripening (Medlicott *et al*., 1986). Citric acid is a respiratory substrate and its consumption in respiration increased with the progress of storage period, as it could be used as an organic substrate in the respiration process (Ezz and Awad, 2011).

Concerning the effect of storage temperature on fruit ascorbic acid content, the results showed that its values significantly decreased with increasing storage temperature. This could be due to the fact that low temperature retards ripening through reduced respiration rate and other undesirable metabolic changes. High temperature is known to increase enzymatic catalysis and leads to a chemical and biochemical breakdown in fruits and vegetables (Ezz and Awad, 2011).

5.3 Interactive Effects of *Aloe vera* Gel Coatings and Storage Temperature

Aloe vera gel coatings and chitosan coating and low storage temperature greatly reduced weight loss in mango fruits. *Aloe vera* gel-coating significantly reduced weight loss during fruit ripening and during low temperature storage compared to uncoated fruit. Fruit weight loss occurs as a result of dehydration and loss of water from fruit surface. Earlier reports on mango showed higher weight loss with increased fruit ripening and storage periods (Abbasi *et al*. 2011). *Aloe vera* gel coating reduced weight loss in coated fruit because of hygroscopic properties that enable the formation of a barrier to water diffusion between fruit and environment (Martinez-Romero *et al*., 2006). Similar reductions in weight loss have been reported in *Aloe vera* coated sweet cherry and table grapes (Valverde *et al*., 2005; Martinez-Romero *et al*., 2006).

The lower total soluble solids in *Aloe vera* gel coated and chitosan coated fruits stored at low temperature might be due to delayed fruit ripening. Similarly a delayed and a smaller increase in TSS has been reported in *Aloe vera* gel coated sweet cherry and table grapes (Valverde *et al*., 2005; Martinez-Romero *et al*., 2006), and in starch-coated strawberry fruit (Mali and Grossman, 2003)

Aloe vera gel and chitosan coatings and low temperature resulted in a significant retention of fruit firmness during ripening compared to the uncoated fruit. This was possibly due to reduced ethylene production consequently delaying the fruit ripening process in mango fruits with *Aloe vera* gel coating. Generally, fruit softening involves structural as well as compositional changes in the various components of the cell wall carbohydrates partly as a result of action of fruit softening enzymes (Abbasi *et al*. 2011). Fruit softening has been reported to be a result of cell wall digestion by pectinesterase, polygalacturonase and other enzymes, and this process is increased by the increase in storage temperature (Ahmed *et al*., 2009). Similar results have been reported in *Aloe vera* gel coated sweet cherry and table grapes (Valverde *et al*., 2005; Martinez-Romero *et al*., 2006).

It was found that *Aloe vera* gel and chitosan coated mangoes under low temperature had lower value of pH at the end of storage period; this was due to the semi-permeability created by *Aloe vera* coatings on the surface of the fruit, which might have modified the internal atmosphere i.e. endogenous O2 and CO2 concentrations in the fruit, thus retarding ripening (Arowora *et al* (2013).

Reduced increase in Titratable Aacidity in *Aloe vera* gel and chitosan coated fruits under low temperature due loss due to the low oxygen permeability and lowered respiration rate and consequent prevention of acid oxidation. Reduced TA in negative control fruit is due to a higher respiration rate that resulted in degradation of organic acid. This confirms the earlier reports that organic acids act as substrates for the enzymatic reactions of respiration that result in reduction in the fruit acidity (Yaman & Bayoindirli, 2002). Similar results have been reported in *Aloe vera* gel coated nectarines kept in ambient and cold storage.

Aloe vera gel and chitosan coatings and low temperature resulted in a reduction in loss of ascorbic acid during storage compared to the uncoated fruit. This is due to retarded oxidation process and hence the rate of conversion of ascorbic acid into dehydro-ascorbic acid was slowed down during storage. The results are comparable with Abbasi *et al*. (2011) who examined a

slower decrease in ascorbic acid in mangoes coated with different coatings and packaging at low temperature.

There was little change in peel and flesh colour in fruits coated with *Aloe vera* gel coating and low temperature during storage compared to the uncoated fruit. The colour in plants is contributed by different pigments, which are classified into four categories based on their chemistry; chlorophylls, carotenoids, flavonoids and betalains. The increase in a* nd b* values is due to chlorophyll degradation indicating transition of color from green to yellow. The yellow colour is associated with the yellow pigment carotenoids (Abbasi *et al*. 2011). These carotenoids are stable compounds which are synthesized during developmental stages but musked by presence of chlorophyll. These results are in agreement with those of Abbasi *et al*. (2011).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the results and the observations of this study, the following conclusions can be drawn:

1) *Aloe vera* gel applied as agri based coating in fruits is beneficial for maintaining quality and extending shelf life of mango fruits but does not control the anthracnose disease
2) Storage temperature of 13^{o}C maintains fruit quality extends shelf life and reduces disease incidences.
3) *Aloe vera* gel coatings and storage temperature of 13^{o}C maintains fruit quality extends shelf life and does not control disease incidences.

6.2 Recommendations

- Mango fruits should be coated with 50% *Aloe vera* gel for longer (twenty days) postharvest shelf life
- Mango fruits should be stored at 13^{o}C for longer shelf life and quality maintenance
- Mango fruits should be coated with *Aloe vera* gel coatings and stored at storage temperature of 13^{o}C to maintain fruit quality and extend shelf life and reduce disease incidences.

6.3 Further research

- Research should be conducted using *Aloe vera* gel coatings on other fruits such as bananas and avocado to observe its effect on quality maintenance, safety and commercial application on large scale.
- Essential oils which are effective on anthracnose control should be combined with *Aloe vera* gel coatings to investigate its effects on disease during postharvest.

REFERENCES

Abbasi, K.S., Anjum , N., Sammi, S., Masud, T and Ali, S. 2011 Effect of Coatings and Packaging Material on the Keeping Quality of Mangoes (*Mangifera indica* L.) Stored at Low Temperature. *Pakistan Journal of Nutrition* 10 (2): 129-138

Ademe, A, Ayalew, A, Woldetsadik, K. 2014. *In Vitro* and *In Vivo* Activity of Selected Plant Extracts against Papaya (*Carica papaya* L.) Anthracnose (*Colletotrichum gloeosporioides*). Journal of Horticulture 1: 104.

Ahmed MJ, Singh Z, Khan AS (2009). Postharvest *Aloe vera* jel-coating modulatesfruit ripening and quality of 'Arctic Snow' nectarine kept in ambient and cold storage. Int. J. Food. Sci. Tech. 44: 1024-1033.

AOAC, Williams, S. (Ed.). 1984. Official methods of analysis. Association of Official Analytical Chemists.

Arauz, L.F. 2000. Mango anthracnose: economic impact and current options for integrated management. *Plant Diseases*, 84: 600–609.

Baldwin, E.A. 1994. Edible coatings for fresh fruits and vegetables: Past, present and future. In *Edible Coatings and Films to Improve Food Quality* (J. Krochta, E.A. Baldwin and M.O. Nisperos, eds.) pp. 1–65, Technomic Publishing CO., INC, Lancaster, PA.

Baldwin, E.A., Burns, J.K., Kazokas,W., Brecht, J.K., Hagenmaier, R.D., Bender, R.J.and Pesis, E. 1999. Effect of two coatings with different permeability characteristics on mango (*Mangifera indica*, L.) ripening during storage. *Postharvest Biology Technology*, 17: 215–226.

Bautista-Ban˜ os, S., Barrera-Necha, L.L., Bravo-Luna, L. andBermudezTorres, K. 2002. Antifungal activity of leaf and stem extracts from various plant species on the incidence of *Colletotrichum gloeosporioides* of papaya and mango fruit after storage. *Phytopathology*, 20: 8–12.

Bender, R.J., Brecht, J.K. and Campbell, C.A. 1994. Response of Kent and Tommy Atkins mangoes to reduced O2 and elevated CO2. *Proceedings Flaurida State Horticulture Society*.107: 274–277.

Chauhan, O.P, Raju, P. S., Singh, A. and Bawa, A. S. 2010.Shellac and aloe-gel-based surface coatings for maintaining keeping quality of apple slices. *Food Chemistry*, 126: 961–966.

Dalal, V.B., Eipeson, W.E. and Singh, N.S. 1971. Wax emulsion for fresh fruits and vegetables to extend their storage life. *Indian Food Packer* 25: 9–15.

Dang, K.T.H., Singh, Z. and Swinny, E.E. 2008. Edible coatings influence fruit ripening, quality, and aroma biosynthesis in mango fruit. *Agriculture and Food Chemistry*, 56:1361–1370.

Dhalla, R. and Hanson, S.W. 1988. Effect of permeable coatings on the storage life of fruits. II. Pro-Long treatment of mangoes (*Mangifera indica* L. cv. Julie). *Food Science Technology*, *23*: 107–112.

Dodd, J.C., Prusky, D. and Jeffries, P. 1997. *Fruit diseases.* In: Litz, R.E. The Mango: Botany, Production and Uses. CAB International, UK, pp. 257–280.

Donhowe, I.G. and Fennema, O. 1994. Edible films and coatings: Characteristics, formation, definitions, and testing methods. In *Edible Coatings and Films to Improve Food Quality* (J. Krochta, E.A. Baldwin and M.O. Nisperos, eds.) pp. 1–65, Technomic Publishing CO., INC, Lancaster, PA.

El Ghaouth, J., Ponnampalam, R. and Boulet, M. 1991. Chitosan coating effect on storability and quality of fresh strawberries. *Food Science*, 56: 1618–1620.

Ergun, M. and Satici F. 2012. Use of *Aloe vera* Gel as Biopreservative for " Granny Smith " and " Red Chief " Apples. *Animal and Plant Sciences*, 22(2): 363-368.

Eshun, K. and He, Q. 2004. *Aloe vera*: a valuable ingredient for the food pharmaceutical and cosmetic industries—a review. Crit. Rev. *Food Science Nutrition*. 44: 91–96.

Esua, M.F. and Rauwald, J.W. 2006. Novel bioactive maloylglucans from *aloe vera* gel: isolation, structure elucidation and in vitro bioassays, *Carbohydrate Res.* 27: 355-364.

Ezz, M.T. and Awad R.M. 2011.Effect of some post-harvest treatments under different low temperature on two mango cultivars. *Basic and Applied Sciences*. 5: 1164-1174.

Farooqui, Q.A., Sattar, A., Daud, K. and Hussain, M. 1985. Studies on the postharvest chilling sensitivity of mango fruit. *Proceedings Flaurida State Horticultural Society98*: 220–221.

Food and Agriculture Organization of the United Nations, 2007. FAO Statistical Database. FAO/United Nations, Rome. http://faostat.fao.org/.

Ghaouth, A.E., Arul, J. and Ponnampalam, R. 1991. Use of chitosan coating to reduce water loss and maintain quality of cucumber and bell pepper fruits. *Food Processing Preservation, 15*: 359–368.

Hamman, J.H. 2008. Composition and Applications of *Aloe vera* Leaf Gel. *Molecules, 13:*1599-1616

HCDA, 2008. Horticultural Data 2005-2007. Validation Report.HCDA, Nairobi, Kenya.

HCDA, 2010. Export Statistics. Website:http://www.hcda.or.ke/Resource_centre.htm.

Hoa, T.T., Ducamp, M.N., Lebrun, M. and Baldwin, E. 2002.Effect of different coating treatments on the quality of mango fruit. *Food Quality*, 25: 471–486.

Hulme, A.C. 1971. The mango. In: Biochemistry of fruits and their products. Academic press, London and New York. Pp. 233-253.

Jaetzold, R. and Schmidt, H. 1983. Farm Management Handbook of Kenya. Natural Conditions and Farm Management Information.Ministry of Agriculture, Kenya.400 pp.

Jasso de Rodríguez, D., Hernández-Castillo, D., Rodríguez-García, R. andAngulo- Sánchez, J.L. 2005.Antifungal activity in vitro of *Aloe vera* pulp and liquid fraction against plant pathogenic fungi. *Indian Crops Production*, 21: 81–87.

Kader, A.A. 2002. *Postharvest Technology of Horticultural Crops*. University of California Agriculture and Natural Recourses Publication 3311: Oakland, California.

Kalra, S.K. and Tandon, D.K. 1983. Ripening behavior of Dashehari mango in relation to harvest period. *Science Horticulture, 19*: 263–269.

Kehlenbeck, K., Rohde, E., Njuguna, J.K., Omari, F., Wasilwa, L. and Jamnadass, R. 2010. Mango Cultivar Diversity and its potential for improving mango productivity in Kenya. Kenyan Agricultural Research Institute KARI, Dept. Horticulture, Nairobi, Kenya.

Kittur, F.S., Saroja, N., Habibunnisa, E.A. and Tharanathan, R.N. 2001. Polysaccharide-based composite coating formulations for shelf-life extension of fresh banana and mango. *European Food Respiration Technolology*, *213*: 306–311.

Kumpoun, W., Chansri, P., Somsrivichai, J. and Supyen, D., 2005. Antifungal compounds in Thai mango fruit latex. *Acta Hort.* 682: 2057–2061.

Lakshminarayana, S. and Subramanyam, H. 1970. Carbon dioxide injury and fermentative decarboxylation in mango fruit at low temperature. *Food Science and Technolology, 7*: 148–152.

Litz, R.E. 1997. *The Mango: Botany, Production and Uses*, pp. 1–587, Cab International, Cambridge, UK.

Lizada, M. C. 1991. Postharvest physiology of the mango-a review. *Acta Hort.* 291:437-453.Lederman, I. E.; Zauberman.

Marpudi, S.L., Abirami, L. S.S., Pushkala, R. and Srividya, N. 2011. Enhancement of storage life and quality maintenance of papaya fruits using Aloe vera based antimicrobial coating. *Indian Journal of Biotechnology*, 10: 83–89.

Martinez-Romero, D., Alburquerque, N., Valverde, J. M., Guillen, F., Castillo, S. and Valero, D. 2006. Postharvest sweet cherry quality and safety maintenance by Aloe vera treatment: a new edible coating. *Postharvest Biology and Technology*, 39: 93–100.

Medlicott, A.P., Sigrist, M. and Sy, O. 1990. Ripening of mangoes following low temperature storage. *Journal of American Society Horticultural Science, 115*: 430-434.

Mitra, S. 1997. Mango. In *Postharvest Physiology and Storage of Tropical and Subtropical Fruits* (S.K. Mitra and E.A. Baldwin, eds.) pp. 85–101,CAB International, Wallingford, UK.

Mitra, S. P. 2005. Postharvest physiology and storage of tropical and subtropical fruits. Cabi Publishing, India.175-182

Mitra, S.K. and Baldwin, E.A. 1997. Mango. In: Mitra, S.K. (Ed.), Postharvest Physiology and Storage of Tropical and Subtropical Fruit. CAB International, New York, NY, pp. 85–122.

Moore, E.D. and MacAnalley, B.H. 1995. A drink containing mucilaginous polysaccharides and its preparation. *US Patent*. 5: 443-830

Mukherjee, P.K. and R.B. 1979. Increasing the storage life of mango ((*Mangifera indica* L.) by lowering the critical temperature. *Porgu Hort*, 10:63-69.

Nabigol, A. and Asghari, A. 2013. Antifungal activity of *Aloe vera* gel on quality of minimally processed pomegranate arils. International Journal of Agronomy and Plant Production, 4: 833-838.

Neeta B. G., Manu L. C. and Rao, T. V. R. 2013. Effect of edible coatings on quality and shelf life of carambola (Averrhoa carambola L.) fruit during storage. Journal of Food Science Technology.

Pitkethley, R. and Conde, B. 2007. Mango anthracnose. Available at http://www.nt.gov.au/d/Content/File/p/Plant Pest/604

Rajkumar, P Kailappan, R. and Ambrose CP Studies on the shelf life of fully ripe mango fruits using wax emulsions. *Madras Agric*., 95 (1-6): 162-169.

Saks,Y. and Barkai-Golan, R. 1995. *Aloe vera* gel activity against plant pathogenic fungi. *Postharvest Biology Technology*, 6: 159–165.

Sanders, G.M., Korsten, L. and Wenner, F.C. 2000. Survey of fungicide sensitivity in *Colletotrichum gloeosporioides* from different avocado and mango production areas in South Africa .*European Journal of Plant Pathology*, 106: 745-752.

Sawant, A.A., Sonawane, S.P. and Thakor, N.J. 2009. Postharvest Handling, Storage and Marketing of Mango. *New Agriculturist*, 20:135-139.

Schieber, A., Berardini, N. and Carl, E.R. 2003. Identification offlavonol and xanthon glycosides from mango peels by high-performance liquid chromatography-electrospray ionization mass spectrometry. *Agricultural Chemistry.* 51: 5006–5011.

Schreiner, M., Heuyskns-keil, S., Krumbein, A., Pronowidayat, H. and Ludders, P. 2003.Effect of film packaging and surface coating on primary and secondary plant compounds in fruit and vegetable products. *Food Engineering, 56*: 237–240.

Serrano, M., Castillo, S., Valverde, J., Martianez-Romero, D., Guillean, F. and Valero, D. 2006. Use of *Aloe vera* gel coating preserves the functional properties of table grapes.*Agricultural and Food Chemistry*, 54: 3882–3886.

Snowdon, A. L. 1990. *A Color Atlas of Postharvest Diseases and Disorders of Fruits and Vegetables. Volume 1: Fruits*, pp. 128, 130 and 138, Wolfe Scientific Ltd., Barcelona, Spain.

Sousa J.P., Praça E.F., Alves D.E, Bezerra-Neto F. and Dantas F.F. 2002. Influence of refrigeratedstorage and plastic film-modified atmosphere in quality of 'Tommy Atkins' mangoes. 24: 665–668.

Spalding, D.H. and Reeder, W.F. 1977. Low pressure (hypobaric storage) of mangoes. *Journal of America Society Horticultural Science*, 102: 367–369.

Togrul, H. and Arslan, N. 2004.Extending shelf life of peach and pear by using CMC from sugar beet pulp cellulose as hydrophilic polymer in emulsions. Food Hydrocolloids, 18: 215-226.

Tharanathan, R.N., Yashoda, H.M and Prabha, T.N. 2006. Mango (*Mangifera indica* L.), "The King of Fruits"—An Overview. *Food Reviews International*, 22(*2*): 95-123

Thomas, P. 1975. Effect of postharvest temperature on quality, carotenoids, and ascorbic acid content of Alphonso mangoes on ripening. *Food Science,* 40:704-706.

Valero, D. and Serrano, M. 2010. Postharvest Biology and Technology for Preserving Fruit Quality. CRC-Taylor and Francis, Boca Raton, FL, USA.

Valverde, J. M., Valero, D., Martinez-Romero, D., Guillen, F., Castillo, S. and Serrano, M. 2005. Novel coating based on *Aloe vera* gel to maintain table grape quality and safety. *Agriculture and Food Chemistry,* 53: 7807–7813

Vazquez-Salinas, C. and Lakshiminarayana, S. 1985.Compostional changes in mango fruit during ripening at different storage temperatures. *Food Science,* 50: 1646-1648.

Weksler, A., Rot, I. and Fuchs, Y. 1997.Ethylene-forming capacity during cold storage and chilling injury development in 'Keitt' mango fruit. *Postharvest Biology and Technolology,* 10:107-112.

Wills, R.B.H., Lee, T.H., Graham, D., McGlosson, W.B. and Hall, E.G. 1981. Post-harvest: An introduction to the physiology and Handling of Fruits and Vegetables. AVI. Westport, CT.

Yuen, C.M.C., Ton, S.C., Joyce, D. and Chettri, P. 1993. Effect of postharvest calcium and polymeric films on ripening and peel injury in Kensington Pride mango. *ASEAN Food Journal*, 8: 110–113.

Zeng, K.F., Cao, J.K. and Jiang, W.B. 2006. Enhancing disease resistance in harvested mango (*Mangifera indica* L. cv. "Matisu") fruit by salicylic acid. *Science Food Agricultulture. 86: 694–698.*

Zhu, X., Wang, Q., Cao, J. and Jiang, W. 2008. Effects of chitosan coating on postharvest quality of mango (*Mangifera indica* L. CV. Tainong) fruits. *Food Processing and Preservation,* 32: 770–784.

APPENDICES

Appendix I: Publications

1. Ochiki, S., Wolukau, J. N., & Gesimba, M. R. (2014). Effect of various concentrations of Aloe vera coating on postharvest quality and shelf life of mango (Mangifera indica L.) fruits Var. 'Ngowe'. African Journal of Biotechnology , 13(36), 3724-3729
2. Ochiki, S., Gesimba, M. R. & Wolukau, J. N., (2014). Effect of *Aloe vera* gel coating on postharvest quality and shelf life of mango (*Mangifera indica* l.) fruits. Journal of Horticulture and Forestry, 7(1),1-7.
3. Ochiki, S., Wolukau, J. N., & Gesimba, M. R. (2014). Effect of various concentrations of *Aloe vera* coating on postharvest quality and shelf life of mango (Mangifera indica L.) fruits Var. 'Ngowe'. 8th Egerton University International Conference, 26th to 28th March, 2014, Faculty of Education Complex, Egerton University, Njoro, Kenya