EFFECTS OF GUM ARABIC SURFACE TREATMENT ON NUTRITIONAL QUALITY OF WHOLE MANGO (*Mangifera indica*) IN MAKUENI COUNTY AND EVALUATION OF CANNED MANGO CHUNKS

LELGUT LANOI DAISY CHEROP

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

EGERTON UNIVERSITY

JUNE 2020

DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented for the award of a degree in any other university.

Signature ……. Date …….

Lelgut Lanoi Daisy Cherop

KM16/14423/15

Recommendation

This thesis has been submitted with our recommendation as the official university supervisors.

Signature ……... Date ……

Prof. Joseph W. Matofari, **PhD**.

Department of Dairy and Food Science and Technology.

Egerton University.

Signature ……... Date ……

Prof. Richard S. Mulwa, **PhD**.

Department of Crops, Horticulture and Soil.

Egerton University.

Signature ……. Date ……

Dr. John M. Nduko, **PhD**.

Department of Dairy and Food Science and Technology.

Egerton University.

DEDICATION

With sincere appreciation, I dedicate this thesis to my father, Mr. David K. Lelgut, my mother, Mrs. Jane Naipanoi Ketere and to my brothers Kigen Kasaine, Wilfred Saidimu and Lemayian Lelgut. Thanks for your prayers, motivation, inspiration and financial support throughout my education.

ACKNOWLEDGEMENT

I thank the Almighty God for the gift of life and good health, grace, favour and guidance without which this work would not have been possible. I am greatly thankful to the International Centre for Development and Decent Work (ICDD) and also the Strengthening Capacities for Agricultural Education, Research and Adoption in Kenya (SCARA) Projects for partly funding my research work through their programme. My profound appreciation goes to my supervisors, Prof. Joseph Matofari, Prof. Richard Mulwa and Dr. John Nduko for their continued support and guidance in all aspects through the duration of this research work. Their support and guidance has led to the success of this research work. Thanks to Madam Bennedette Misiko and Madam Rachael Njunge (laboratory staff at the department of Dairy and Food Science and Technology) and Mr Paul Kamau (technician at chemistry department), for their assistance during laboratory analysis at Egerton University. Thanks also to Mr Evanson Njuguna (Production Manager at Njoro Canning Factory), Mr David Baraza, Madam Joyce Njuguna and the entire Njoro canning fraternity for allowing me to use their facility for my research work. I am very grateful. Thanks also to Mr John Ndungu (Head of Department at Cereal Chemistry Lab-KALRO Njoro), Madam Peris Wandia, Madam Beatrice Wanjiku and the entire KALRO-Njoro fraternity for allowing me to use their facility for my research works. I am indeed indebted. All the advice and guidance in all the above laboratories were of great help to me and I'll be forever grateful. Thanks to my fellow colleagues including Nobert Wafula, Johnson Mwove, Milcah Wambua, Linnette Mwangi, my classmates and the rest of the graduate students from the Department of Dairy and Food Science and Technology, for their support during analysis and encouragement throughout my studies. It has been good working with you guys. Finally, special thanks to my parents and brothers for their constant support in form of prayers, encouragement and their physical presence throughout my studies. I have made it this far because of them.

ABSTRACT

Mango production in Kenya has been on the rise. In 2013 about 581,290 MT were produced of which 40% were lost due to lack of proper postharvest management practices. The greatest loss was through pest and microbial spoilage and chemical deterioration of nutrients. The study aimed at developing methods to preserve the nutritional quality and reduce post-harvest losses in the mango value chain. Using a structured questionnaire, randomly administered to 40 mango farmers, post handling practices were assessed along the entire value chain. Whole mature mango fruits were sampled at farm, transport and market levels for nutrient deterioration assessment. A method that involved coating of whole mangoes with 0%, 10%, 15% and 20% gum arabic was developed for nutrient preservation. Another method involving canning of mango chunks packed in different sugar syrup concentrations (0, 30, 40, 50 and 60^{o}Bx) for mango preservation and shelf life was developed to reduce post-harvest loss. The survey data collected was analysed using statistical package (SPSS. Version 20.0). Laboratory analysis for nutrient content was conducted at Egerton University, Kenya Agricultural and Livestock Research Organization (KALRO) laboratories and Njoro Canning Factory. Changes in weight, ascorbic acid, β-carotene, total soluble solids (TSS), titratable acidity (TA) and pH of the fruits were evaluated using standard methods. Data was arranged in a complete randomized design in a factorial arrangement and analyzed using SAS (Version 9.3). Means were separated using Tukey's HSD (P<0.05). From the survey, the main mango varieties grown were Apple (74.5%) followed by a combination of Apple and Ngowe (12.7%). Storage at farm level was by heaping of mangoes in ventilated stores. Draining mango latex after harvesting was practiced to reduce deterioration. Laboratory analysis revealed that gum arabic coating could extend the shelf life of mangoes up to 15 days by reducing percentage weight loss by 20% while maintaining the fruits' nutritional composition. A coating concentration of 10% gum was the most efficient. Canning process extended the shelf life of canned mango chunks up to three months. Higher concentration of sugar syrup (60^{o}Bx) was efficient in maintaining the nutritional composition of the canned chunks. There was significant (P<0.05) increase in TSS during storage, significant decrease (P<0.05) in weight, titratable acidity, vitamin C, β-carotene and pH in coated mangoes while canned mango chunks, showed no significant (P>0.05) difference on the pH during storage, TSS increased significantly (P<0.05), titratable acidity, β-carotene and vitamin C decreased significantly (P<0.05) during storage. The study concluded that mangoes could be extended by coating with edible gum arabic. Similarly, mango chunks could be canned in sugar syrup for extended storage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

AAO	Ascorbic Acid Oxidase
ABD	Agricultural Business Development
AOAC	Association of Official Analytical Chemists
FAO	Food and Agriculture Organization of the United Nations
HCDA	Horticultural Crops Development Authority
HTST	High Temperature and Short Time
KALRO	Kenya Agricultural and Livestock Research Organization (Formerly Kenya Agricultural Research Institute; KARI)
LSD	Least Significant Difference
LTLT	Low Temperature and Long Time
MOA	Ministry of Agriculture
MT	Metric Tonnes
PPO	Polyphenol Oxidase
RH	Relative humidity
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background information

Mango (*Mangifera indica*) is the third most important fruit produced in Kenya, after bananas and pineapples, due to its characteristic flavour, taste, pleasant aroma and nutritional value. Its production has experienced significant growth in recent years; an annual growth rate of 26% since 2005. In 2011 and 2013, the volume produced increased from 452,944 MTs to 581, 290 MTs (HCDA, 2013). Table 1.1 below shows the trend in Kenya's mango production as from the years 2001-2008. The principal mango production zones in Kenya include Eastern and Coastal regions (responsible for 85% of national mango production) followed by Central region and other emerging areas such as Nyanza, Rift valley, North and Western region (HCDA, 2010). The two main mango varieties produced include apple (50% of produce from Eastern region) and Ngowe (49% of produce from Coast Region).

Table 1.1 Kenya's mango production trend

	2001	2002	2003	2004	2005	2006	2007	2008
Hectares(Ha)	16,542	17,673	17,268	18,094	17,738	17,264	23,730	28,790
Volume(MT)	179,648	176,504	183,486	183,440	168,663	163,726	396,461	448,572
Value(Million KSh)	1,345.7	1,078.8	1,208.4	1,360.4	1,046.4	1,157.1	5,867.5	6,398.4

Source: Agricultural Business Development, (ABD, 2011)

Mango production is mainly for fresh fruit consumption whereby,98% of the total mangoes produced are consumed locally while the remaining 2% goes to the export market (Faida, 2006). Some growers sell their produce to local beverage industries and fruit industries for export. Some harvest ripe and semi-ripe fruits and deliver them to the market in urban centres.

The relatively short ripening period and reduced post-harvest life are however, the limiting factors influencing the economic value and utilization of mangoes in these mango growing zones. Mangoes are climacteric fruits; therefore they cannot be preserved for long periods after harvesting at room temperature as they ripen within 2 to 10 days after harvest at ambient temperatures and two to three weeks in cold storage (13^{o}C) depending on variety, storage and

transportation conditions (Narayana *et al.,* 1996; Carrillo-Lopez *et al.,* 2000).This is hence the reason as to why they are generally harvested at mature green stage, then left to ripen up during the marketing, storage and consumption process.

During ripening, a series of metabolic activities occur which are controlled through genetically programmed events. It also involves actions of various enzymes/chemicals like ethylene, glycanases, glycosidases, beta-D-galactose and protein kinases. This result to chemical changes, increased respiration and ethylene production, change in structural polysaccharides leading to fruit softening, degradation of chlorophyll and carotenoids biosynthesis, starch hydrolysis to sugars hence ripening of fruits with softening of texture to acceptable quality (Lalel *et al.,* 2003). The process of ripening is sensitive to temperature, humidity, exposure to sunlight and harvesting days among others (Ali *et al.,* 1995), and hence, small changes in pre-harvest environment, harvesting techniques and storage and transportation conditions may affect the shelf life and the quality of the fruit.

In Kenya, due to dry conditions in some of the mango growing areas like Makueni, there may occur excessive fruit drop resulting to low yield. Infestation of pests and diseases reduce the shelf life and the quality of mango fruits (Ishaq *et al.,* 2004; Bally, 2006; Lechaudel and Joas, 2007). Loss of mango fruits due to stem end rot and anthracnose limits the storage potential of the mango fruit (Narayana *et al.,* 1996). Most of the orchards in Kenya are handled by untrained personnel who neither know the proper techniques of harvesting nor the impact of such over the quality and shelf life of the fruit. This leads to huge losses in terms of physical damage, bruising, sap burn injury and later spoilage of the mango fruit. A major impact of ill harvest technique during harvest time is the detachment of the pedicel. The ducts of the fruit that contains the sap are normally at high pressure and the sap can come out and get deposited at the surface of the fruit as soon as the pedicel abscission zone is broken at harvest (Joel, 1980; Loveys *et al.,* 1992; Campbell, 1992; Lim and Kuppelweiser, 1993; Bosquez *et al.,* 2000). The sap deteriorates the fruit's quality through the following processes: It destroys the fruit's appearance by blackening the skin; the flow of the latex causes the mangoes to lose water, thus reducing the fruit's mass; due to the sticky nature of the sap, the soil particles as well as micro-organisms become attached/attracted to the fruit resulting to a decrease in shelf life; it browns, hardens and stains the fruit surface and it also provokes skin necrosis.

Various techniques have been used to overcome the sap burn menace. Some of which include, mechanical de-sapping, chemical treatment application of Sodium carboximethyl

cellulose, sodium lauryl sulphate and calcium hydroxide and dabbing with waxes, powder and vegetable oil (Baker, 1991; Landrigan *et al.,* 1991; Meurant, 1991)

Fruit exposure to light impacts over its quality. For example, it influences the carotenoids resulting to the synthesis of yellow pigmentation on the skin and production of sugar. On the other hand, if the fruit is not sufficiently exposed to sunlight, the green skin colour is retained inside the canopy, affecting the fruit's quality (Lechaudel and Joas, 2007; Saengnil *et al.,* 2011).

One of the most important parameters for fruit quality is shelf life; and it is very sensitive to temperature and other post-harvest conditions (Simmons *et al.,* 1998). In Kenya, preservation as an issue, affects the mango industry. Low temperature storage, drying and use of inorganic chemicals such as potassium metabisulphite, are some of the methods that have been made use of in the country (Gathambiri *et al.,* 2006). Such methods have resulted to chilling injuries on the mango fruits and loss of volatile nutrients especially during drying. The inorganic chemicals cause adverse health conditions to consumers due to their residual effects. In fact, such methods are expensive to run and the small holder farmer may find challenges in adopting the same. High perishability of intact and minimally processed fruits make it necessary to develop methods aimed at preserving them for a longer duration for storage. Documenting harvesting and post-harvest handling practices is thus essential in order to design appropriate mango preservation methods.

Application of edible coatings has been identified. Edible coatings are formed when a layer of an edible material is applied on the surface of an intact or minimally processed fruit, forming a protective barrier (Guilbert, 1986). This preserves the quality of such fruits by forming a film that acts as a partial barrier to gases (oxygen and carbon dioxide), water vapour and aroma compounds, creating a modified atmosphere around the fruit, decreasing the respiration rate, and water loss and preserving texture and flavor (Baldwin, 1994). Coatings are also used as carriers of additives such as antimicrobial and antioxidants (Olivas and Barbosa, 2005). Edible coatings can be consumed together with the fruits.

Use of edible coatings like Gum arabic that has been embraced in the preservation of tomatoes and cucumbers in Malaysia and Saudi Arabia respectively, has not been attempted in mango preservation. Gum arabicis a dried, gummy exudate obtained from the stems and branches of Acacia species and it is the least viscous and most soluble hydrocolloids (Ali *et al.,* 2010). Its extensive use in the industrial sector is because of its emulsification, film

forming and encapsulation properties (Motlagh *et al.,* 2006). It consists of a complex mixture of macro-molecules of different size and composition; characterized by a high proportion of carbohydrates (~97%), predominantly composed of D-galactose and L-arabinose units, and, a low proportion of proteins (<3%) (Islam *et al.,*1997). Some physico-chemical properties such as moisture, total ash content volatile matter and internal energy are used as international Gum arabic quality parameter; and this may vary depending on the origin and age of trees, exudation time, the storage type and climate. The solubility of gum arabic carbohydrate hydrophilic and hydrophobic proteins is facilitated by moisture content. The total ash content determines the critical levels of foreign matter, insoluble matter in acid, calcium, potassium and magnesium (Mocak *et al.,* 1998). Gum arabic has been found to delay the ripening process, by slowing down the rate of respiration and ethylene production during storage. It forms a film that acts as a partial barrier to gases (oxygen and carbon-dioxide), water vapour and aroma compounds, creating a modified atmosphere around the fruit, decreasing the respiration rate and water loss and preserving texture and flavor.

Canning technology is also another method that has been applied in the preservation of fruits and vegetables. The goal of the canning process is to destroy microorganisms and prevent recontamination by the same. The technology makes use of heat as an agent used to destroy microorganisms. Removal of oxygen is used in conjunction with other methods to prevent the growth of aerobic microorganisms. A typical commercial canning process may employ the following general process: washing, sorting/grading, preparation, container filling, exhausting, container sealing, heat sterilization, cooling, labelling/casing and storage, ready for dispatch. In most cases, sugar syrup and brine solutions have been used during the canning process of fruits and vegetables. Mango processing factories in Kenya can improvise a canning line for such a noble task to contribute to value addition and minimize post-harvest losses hence benefit for the mango farmers and value chain actors.

1.2 Statement of the problem

Forty percent (40%) of mangoes in Kenya go to waste due to lack of appropriate post-harvest treatments and preservation technologies, leading to economic losses. Mangoes are climacteric fruits; they ripen fast after harvesting leading to spoilage within 2 to 10 days after harvest. Damage to mangoes during the harvesting season happens as a result of lack of knowledge of handling by the farmers. Currently, there is limited application of preservation and processing technologies of mangoes in Kenya. In most cases, fresh mangoes are subjected to hot water treatments followed by fungicide application to reduce surface

microbial loads to enable them keep longer. The use of fungicides is not encouraged with the current residual chemical and food safety concerns. However, safer surface treatments such as the surface coating with gum Arabic have not been investigated. Mangoes are also processed into juices and pulps, with some being sliced and dried into chips. Whereas juices and pulp can find industrial use, dried mangoes are not as preferred to as fresh mangoes in the market. Drying of mangoes leads to loss of important volatile nutrients. Consumers prefer mangoes in their fresh state. Fresh mango canning has not been explored as a preservation method in Kenya even though other tropical fruits such as pineapples are canned and made commercially available to consumers. There is therefore need to investigate such methods of fresh mango preservation to overcome the seasonality challenge experienced with this popular fruit in Kenya and create value for farmers.

1.3 Objectives of the study

1.3.1 General objective

To contribute to improved food and nutrition security of Kenya through development of methods to preserve nutritional quality and reduce post-harvest losses in the mango value chain.

1.3.2 Specific objectives

i. To document local mango preservation methods in Makueni County of Kenya.
ii. To determine the effect of different concentrations of gum arabic surface treatment on preservation of whole mango fruits' nutritional quality during storage.
iii. To determine the effect of canning technology on nutritional composition of mango chunks during storage.

1.4 Research question

i. What are the local mango preservation methods in Makueni County of Kenya, and how are they carried out?

1.5 Hypotheses

ii. Gum arabic surface treatment has no effect on the preservation of whole mango fruits' nutritional quality during storage.
iii. Canning technology has no effect on the nutritional composition of mango chunks during storage.

1.6 Justification

Documenting the local mango preservation methods in Makueni county of Kenya marks a good starting point to highlight the basic activities involved in the production, harvesting, utilization, preservation and processing of mangoes in the Eastern region. The losses encountered in the value chain will be captured and this will make it easy for such issues to be addressed hence contributing to the reduction of losses by suggesting the use of locally available materials such as gum arabic (an edible coating) found in those localities. Edible coatings have been proved to prolong the shelf-life of fruits through their antibacterial, antifungal and antioxidative properties. Gum arabic in particular, will help in prolonging the shelf life of the mangoes through its emulsification, encapsulation and film forming properties. The use of gum arabic will cut the cost that will have been incurred by the small holder farmers if they had opted to use low temperature storage through refrigeration, hot water treatment or even the use of fungicides. Such methods are expensive to run on small scale, require trained personnel and are dependent on electricity, which is expensive and unavailable in some mango producing zones. Gum Arabic is a cheaper and readily available material that will be used for preservation purposes. Canning technology employs the use of heat treatment in the preservation process and guarantees processors the extension of shelf life of canned products for a period of several months or even years. The canning line which can be improvised in the mango processing factory in Makueni County will make it possible for the processors to preserve fresh mango chunks for long periods hence making the product available out of season. This study therefore has addressed an urgent need to document the local production and post-harvest handling procedures in the mango growing counties in Kenya and encourage the reduction of post-harvest losses of the mango fruits by use of gum arabic for surface treatments of whole fruits and canning technology for the preservation of mango chunks. This will improve the income of farmers in the target regions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Mango production in Kenya

In Kenya, mango fruit has been the third most important fruit produced after bananas and pineapples for the last ten years in terms of area and total production (Okoth *et al.,* 2013). The hectares under mango production, production output (ton) and the revenue earned, have continued increasing over years. Hectarage increased from 36,304Ha to 59,260Ha while production from 528,815 metric tonnes to 636,585 metric tons (HCDA, 2013).

Mango has been cultivated in the Kenya's Coast Province for centuries. It was first introduced into the country by ivory and slave traders who brought seed during the 14th century. Since then it has spread to most parts of the country including Eastern, Central, North Eastern, Western and South Nyanza Provinces.

In Kenya, two varieties of mangoes are grown commercially, the local varieties and the exotic or improved varieties. The local varieties include Ngowe, Dodo, Boribo and Batawi. The exotic varieties include the Apple, Kent, Keit, Tommy atkins, Van Dyke, Haden, Sensation, Sabre, Sabine, Pafin, Maya, Kensingtone and Gesine (Ndungu *et al.*, 2008). The exotic varieties are usually grafted on local mangoes. They are of superior qualities; have higher juice yields and are often grown targeting the export market. Mango fruits from the various cultivars differ greatly in shape, size appearance and internal characteristics. The quality of the fruit is majorly based on the sweetness, low fibre and minimal turpentine taste. The flesh of the improved cultivars is peach-like and juicy, of a melting texture and more or less free from fibre (MOA, 2001).

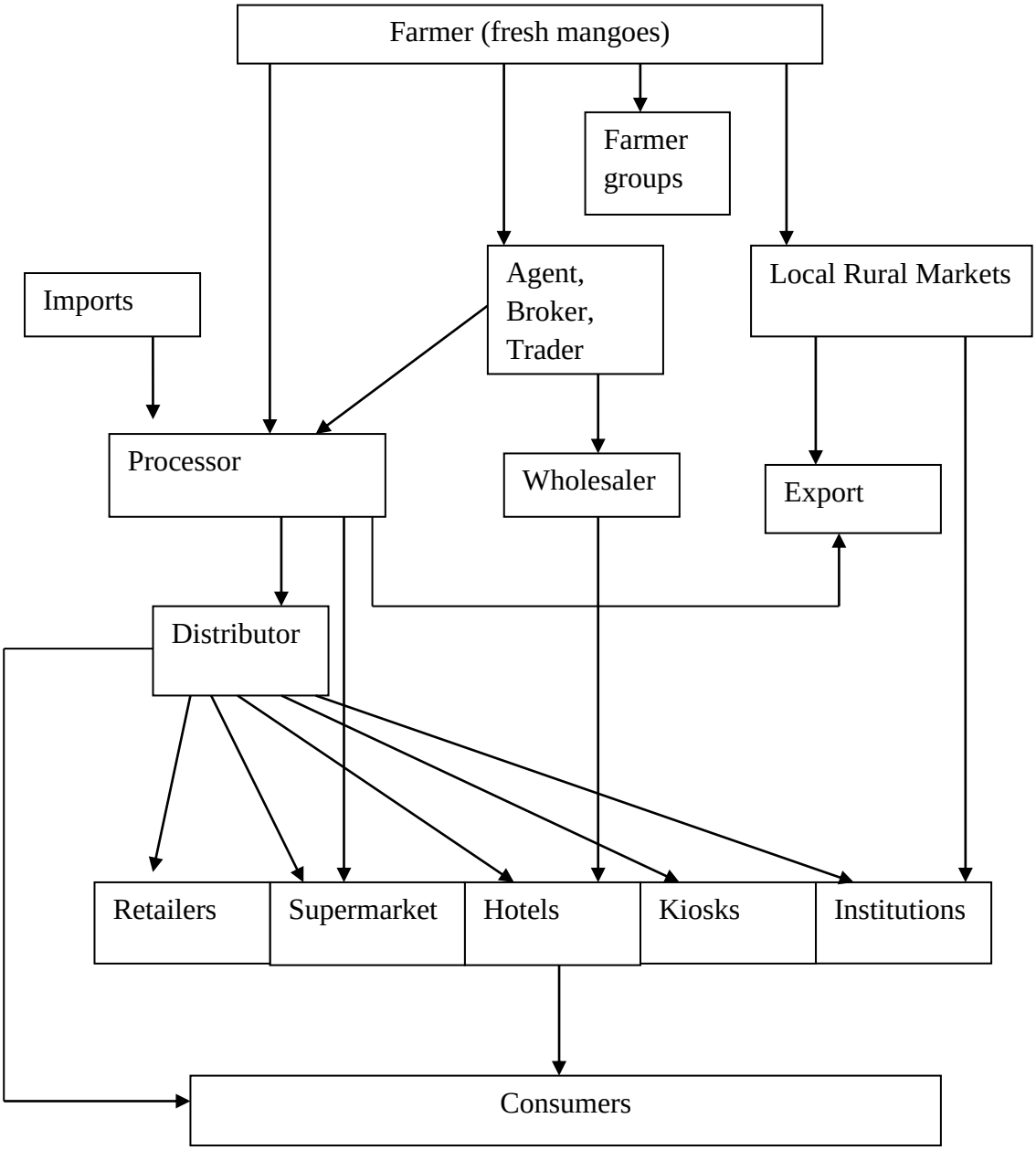
Mangoes in Kenya are consumed locally and some are exported or processed into various products such as pickles, chutneys and even pulps. Mango processing is considered to be among the initiatives that contribute to the extension of the shelf life of the fruit hence reducing the post-harvest losses. In Kenya, several companies are involved in mango processing and they include: Kevian Kenya Ltd in Nairobi and Thika, Sunny Processors Ltd in Maragua and Delmonte in Thika. Mangoes are a source of income to farmers, they contribute to the foreign exchange and they are good raw materials for food industries.

2.2 Fruit ripening phenomenon

In fruits, ripeness is used to define the appropriate state for harvesting and for eating. It marks the completion of a fruit's development and the commencement of senescence. Fruits complete their development and maturation only when they are attached to the plant. Ripening and senescence on the other hand, may proceed on or off the plant. After harvesting, the physiological changes in fruits occur immediately. Fruit ripening is a highly coordinated, genetically programmed and an irreversible phenomenon involving a series of physiological, biochemical and organoleptic changes that leads to the development of a soft edible ripe fruit with desirable quality attributes. Carbohydrates play a key role in the ripening process through depolymerization leading to decreased molecular size with concomitant increase in the levels of ethylene; the ripening inducing gas. Starch, pectins, cellulose and hemicelluloses are the major classes of cell wall polysaccharides that undergo modifications during ripening contributing to the texture and quality of the fruits, hence tissue softening. Other biochemical changes involved during fruit ripening include increased respiration, chlorophyll degradation, biosynthesis of carotenoids, anthocyanins, essential oils, flavour and aroma compounds, increased activity of cell-wall degrading enzymes and transient increase in ethylene production (Rose *et al.,* 2003).

2.3 Post-harvest losses

About 40% of the total amounts of mangoes produced in Kenya go to waste during the peak season. This is due to poor post-harvest handling, inadequate infrastructure, infestation by pests and diseases, poor quality, wrong variety, poor handling techniques, mechanical damage as well as excess fruits in the market (Muchira *et al*., 2006; Shiferaw *et al.,* 2006). Production is carried out mainly by small holder farmers who depend largely on brokers, export agents or local traders for market information. These kinds of outlets are unstable and offer them low and unpredictable prices. Figure 2.1 illustrates the mango value chain in Kenya. In this case, the farmers lack ways of ensuring year-round income for instance by employing appropriate up-to-date village-level preservation and processing technologies and minimizing post-harvest losses. Most of the mangoes produced are consumed within the same production area or sold cheaply in local urban markets causing high wastage due to surplus in the market and perishability of the mango fruits.



Source: PSDA, 2010

Figure 2.1 Mango value chain in Kenya

2.4 Post-harvest factors

Fruits undergo various physiological changes during post-harvest storage. Some of the changes include: tissue softening, increase in sugar level, decrease in organic acid levels, degradation of chlorophyll accompanied by synthesis of anthocyanins and carotenoids upon maturation, production and losses of volatile flavour compounds, decrease in phenolic and amino acids contents and breakdown of cell materials due to respiration (Sharma & Singh, 2000).The extent of variability in maturation and physical injuries, are some of the factors that determine harvesting practices. Physical injuries for example, lead to accelerated loss of water and vitamin C and increases susceptibility to decay by pathogens or fungi for example *Colletotrichum gloesporioides* Penz., during storage (Sharma *et al.*, 2000; Kader, 2002; Lamikanra, 2002;). Relative humidity (RH) and temperature directly affect postharvest respiration and transpiration of fruits. Increase in temperature will result to increase in respiration, resulting to increased production of ethylene and carbon dioxide and hence changing the flavour, taste colour, texture, appearance and nutrients of the produce (Kader, 2002). It is of great importance to avoid exposure of fruits for example mangoes, to unwanted ethylene. This can be done by separating ethylene-producing commodities from ethylene sensitive commodities by using ethylene scrubbers or by inducing fresh air into storage rooms. Microorganisms play a big role in spoilage. Implementing appropriate post-harvest sanitation procedures during preparation, processing and maintenance of products in sanitized condition is essential for controlling microbial growth hence providing high quality and safe products.

2.5 Mango harvesting and post-harvest handling practices in Kenya

Depending on cultivars and environmental conditions, it takes 90 to 160 days after flowering for the mangoes in Kenya to reach maturity (Griesbach, 2003). Fruits on one tree do not ripen at the same time, and in this case, those mangoes harvested too early have inferior quality after storage while those picked when they are too ripe, cannot be stored for long.

Mangoes are generally picked when they begin to change colour from green-white to yellow or orange (Griesbach, 2003). In standard practice, ladders or long picking poles with a cutter blade attached with canvas bag, held open by a ring are used. The picked mangoes should be carefully placed into clean wooden or plastic containers and transferred to a store or packing shed to minimize sunburn, loss of moisture and accumulation of dust. After any sorting, grading, washing and fungicidal treatment, the fruits are ready for packing, preferably into

shallow single-layered trays of 4-5 kg each (Griesbach, 2003). This normally happens in large scale mango plantations.

In small scale farming, harvesting is done by directly picking of the fruits from the tree tops. The fruits are then dropped down into a heap until all the mature fruits have been picked. The mangoes are then re-heaped under a shade that is made some distance from the farm, waiting for brokers to come and select the mangoes for distribution and sale. Some farmers however, are involved in activities that aim at preserving mangoes in small scale. This is normally done by solar drying where the farmers chop the fruits into thin sizes and keep them in the drier to dry throughout the day. Most of such driers are donated by international organisations and they use solar waves to dry the fruits which can then be stored for longer. This helps in managing fruit wastage during peak seasons.

2.6 Post-harvest value addition

This refers to a process which includes primary, secondary and tertiary processing operations of farm produce with the aim of increasing the shelf life and its value, hence maintaining/improving the quality and enhance form, space and time utility of the produce to reduce problems experienced in fresh produce markets such as lack of information and market integration, reliance on spot markets, transport constrains and wastage(Abe *et al*., 1997).

Mangoes have a shelf life of 2 to 4 weeks at 10^{o}C to 15^{o}C, limiting their availability in fresh markets (Yahia, 1998). Pests and insects, chilling temperatures and fungal rot can threaten the shelf stability, physical and the chemical qualities of mangoes, as these conditions may induce abiotic and biotic stress to the fruit (Cisneros-Zevallos, 2003). Processing of mangoes will therefore extend their shelf life and enable producers to diversify their products. This will in turn help producers have alternative and additional means of marketing their produce and increase their income. Some of the products that result from mango processing will include juices, pickles, pulps and chutneys for example.

2.7 Preservation of Mangoes

Fruit preservation is the process of treating and handling fruits in order to stop or slow down fruit spoilage, loss of quality, nutrition value, edibility and allow for longer storage. Mango preservation is a very crucial process since the fruits are perishable. Various methods have previously been employed to effect the preservation process. Some of these methods are highlighted below:

2.7.1 Blanching

This is a hot-water treatment method. This operation is done to inactivate enzymes, eliminate air inside the fruit tissues, remove off-flavours and aromas, fix fruit colour and soften the tissues and reduce surface microorganisms (Holzwarth *et al.,* 2013; Korbel *et al.,* 2013). Two methods are currently used to effect blanching: dipping in boiling water or direct steam injection. The thermal treatment is applied such that internal fruit temperature reaches 75°C. This usually requires 10 minutes in boiling water, or 6 minutes with steam. The mango fruit is blanched unpeeled. The effectiveness of the blanching treatment is usually determined by measuring the residual activity of the peroxidase enzyme. This is usually conducted on the mango kernels where there is polyphenol oxidase activities taking place. Peroxidase is an enzyme that catalyses the oxidation of phenol, hence classified as phenolase. This oxidation is responsible for browning reaction of most fruits such as mangoes (Jimènez-Atiènzar *et al.,* 2007). The residual amounts of peroxidase enzyme will hence determine the effectiveness of the blanching process in mangoes, as a preservation strategy (Vasquez-Caicedo *et al.,* 2007).

2.7.2 Sulphiting

This is a process which involves dipping the mango fruits in a solution of metabisulphite (200ppm). It is aimed at preventing undesirable colour changes of the mangoes. A solution of sodium sulphite, sodium metabisulphite or potassium metabisulphite (1g/L solution) is often prepared and the fruits are dipped into it for 5-10 minutes. It also helps in preventing additional microbial and enzyme activity and retains a residual concentration of 100 ppm in the final product.It is mostly applied during the processing of mango pulps in order to maintain the natural colour of mango fruits. Sulphur dioxide protects the natural colour of fruits like bananas and pineapples (Fellows, 2009)

2.7.3 Freezing

This is a process aimed at subjecting mangoes to cold storage conditions using freezers. When mangoes are purposed to be stored for a year, freezing of the fresh and ripened mangoes is the best method. Mangoes of the same ripening stage are obtained; their skins peeled off then depitted. They are then cut into small pieces. The cut slices are then placed in zip lock freezer bags, which are then zipped and wrapped in aluminum foil. After this, they can be stored in the freezer for a period of up to one year (Gathambiri *et al.,* 2006).

2.7.4 Drying

This is one of the oldest methods of food preservation, which reduces water activity sufficiently to delay or prevent bacterial growth. Drying of fruits allows their better preservation by reduction of water content. This inhibits microbial growth and enzymatic modification. Loss of moisture content due to drying, leads to increased concentration of nutrients in the remaining fruit mass. Control of bacterial contaminants in dried foods requires high-quality raw materials having low contamination, adequate sanitation in the processing plant, pasteurization before drying and good storage conditions. In Kenya, mangoes are often dried using solar driers. The fruits are often chopped into thin sizes and kept in the drier early in the morning to dry throughout the day. One of the advantages of drying fruits is the reduction in size and weight, which facilitates transportation, reduces storage space and avoids the need of using expensive cooling systems among other preservation procedures (Sagar and Sugesh, 2010). The factors determining the end of the drying process are the high concentration of sugar, low moisture content and the energetic optimization of the process. The choice of the final moisture content should consider not only the stability of the fruit, but also the final physical and chemical properties that characterize its quality (Guinè *et al.,* 2002).

2.7.5 Modified atmosphere (controlled atmosphere)

Controlled atmosphere (CA) storage usually involves regulating the concentration of oxygen (O_2) and carbon dioxide (CO_2) using nitrogen, storage temperature, as well as relative humidity in the storage environment. The concentrations of carbon dioxide are elevated and those of oxygen and ethylene reduced. This helps in reducing respiration, ethylene production and sensitivity to ethylene; retard softening and compositional changes; alleviate certain physiological disorders and reduce decay. The replacement of the air of packaging headspace with an atmospheric gas whose proportion is different from that of air, is the basic idea of using modified atmosphere in packaging. Controlled atmosphere in combination with an optimum storage temperature has been reported to prolong the storage life and maintain fruit quality including aroma volatiles in mango fruit depending on the cultivar. Temperature control is therefore very important for modified atmosphere system to work effectively (Ščetar *et al.,* 2010).

2.7.6 Canning

This is a method of preserving food in which the food contents are processed and sealed in an airtight container. Canning provides a shelf life typically ranging from one to five years, although under specific circumstances it can be much longer. In this process, heat sufficient to destroy all vegetative microorganisms is applied to mango slices packed into sealed or "airtight" containers. The slices are then heated under steam pressure at temperatures of 116-121°C. In most cases, the amount of time needed for processing is different for various fruits, depending on the food's acidity, density and ability to transfer heat. Some workers have however suggested the replacement of sugar syrup with corn syrup in canning of fruits. Apple juice has been used for canning stone-free peaches. Addition of 15% mango pulp and 20-30% of the apple juice concentrate of 35^{o}Brix in covering syrup has successfully been used in the canning of mango and apple rings respectively. Citric acid has been used in the canning of fruits including mangoes (Hoa *et al.,* 2010). In most cases, heat alone will not destroy *Clostridium botulinum* spores that cause the deadly botulism poisoning, hence the need of adding some recommended acids like the citric acid. In mango canning, the acid is also used to bring the pH level of the canned fruits to below 4.6; a point that the *Clostridium botulinum* spores are destroyed (Hoa *et al.,* 2010).

2.7.7 Surface coating (Waxing)

This is considered as one of the several treatments developed to reduce post-harvest losses and to prolong the shelf- life of fruits. It reduces water evaporation from the fruits hence reducing weight loss by up to 50% depending on the coating type and concentration. This ultimately extends the shelf life of fruits. Examples of some of the edible coatings that have been used include gum arabic and chitosan (Khaliq *et al.,* 2016). The need for high quality products and the demand for minimal food processing and storage technologies has emphasized the concept of using edible coatings to extend the shelf life of fresh and minimally processed produce and protect them from harmful environmental effects. The application of the coating can be realized by dipping or spraying methods followed by film formation process like removing the solvent (normally water), coagulation of proteins, solidification of gel structures or chemical reactions. Film formation relevant factors are the chemical composition of the coating material (hydrophilic or hydrophobic), the concentration and viscosity, which influence the homogenous distribution, flexibility and the barrier properties (gas exchange) of the layer as well as the release of the functional component by diffusion. Selection of edible coatings depends on the requirements on barrier properties

(water vapour, oxygen, and carbon dioxide), mechanical strength, gloss and durability. Examples of functional components could be antimicrobials (e.g. organic acids, fatty acid esters, polypeptides, essential oils), antioxidants (e.g. oxalic acid, ascorbic acid, cysteine), texture improvers (e.g. calcium salts), and aroma or nutraceutical compounds such as vitamins (García *et al.,* 1996; Fransen *et al.,* 2003; Rojas-Graü *et al.,* 2009).

2.8 Gum arabic and the food industry

Gum arabic is an edible, dried, gummy exudate obtained from the stems and branches of Acacia species (Azeez, 2005; Ali *et al*., 2009; Hadi *et al*., 2010). It is certainly the most ancient and the most well-known of all the gum types. It is a solid of a pale to orange brown colour which when ruptured, secretes a vitreous substance. It dissolves very well in hot or cold water forming a solution of up to 55% acacia gum. It has a small amount of protein which is important to its properties in foods (Imeson, 2010). Gum arabic is known to have the following properties that have enabled its widespread application in the food industry: emulsification, encapsulation and film forming properties (Motlagh *et al.,* 2006)

2.8.1 Application of Gum arabic in the food industry

Gum arabic has been applied as an edible coating for fruits and vegetables e.g. tomatoes and cucumbers. It prevents dehydration, inhibits ethylene production and triggers the accumulation of total phenolic compounds and other compounds with antioxidant properties. This has greatly contributed to the preservation of the same hence extending the shelf lives of the fruits and the vegetables. Apple fruits coated with Gum arabic resulted in a significant delay in the change in weight loss, titratable acidity, firmness, total soluble solids, decay and colour during cold storage when compared to the uncoated control (El-Anany *et al.,* 2009). Its use has been incorporated in the wine gums as it produces a clarity that is higher than can be obtained by other hydrocolloids. It prevents sucrose from crystallizing. It provides a controlled flavor release and slows down melting in the mouth making the wine gum long lasting (Vivas, 2001).

Gum arabic has also been used as an emulsifier in the manufacture of soft drinks. Its stability in acidic conditions and its high solubility makes it well suited for use in citrus and cola flavor oil emulsions. It prevents flocculation and calescence of oil droplets and can also form a stable cloud in the drink, imitating the effect of added fruit pulps and juices. It is used as a source of soluble fiber in low calorie and dietetic beverages. It is usually added to produce

the same opacity, appearance, mouth feel and palatability as natural fruit juices especially in powdered beverage mixtures (Imeson, 2010).

In low calorie candies, it is used to compensate for the loss of texture, mouth feel and body, resulting from the replacement of sugars by artificial sweeteners. It is used as a coating agent in chewing gums and also as a pigment stabilizer. It acts as a whipping and stabilizing agent in marshmallows, nougats and meringues. In toffees and caramel, it is used as an emulsifier to maintain a uniform distribution of the fat across the product. It is used to provide a fibrous, fruit-like texture (Elmanan *et al., 2008*).

Gum arabic is therefore unique among the natural hydrocolloids due to its high solubility in water, yielding a solution of up to 50% concentration. This hence makes it responsible for the excellent stabilizing and emulsifying properties of the product.

Majority of past studies have assessed the impact of edible coatings like gum arabic in extending the shelf life and preserving nutritional composition of tomatoes and cucumbers (Ali *et al*., 2010). However, none of these studies have analysed the effect of gum arabic in preserving the nutritional qualities and extending the shelf life of whole mangoes. Also, canning technology has been applied to other tropical fruits like pineapples, to extend their shelf life. But it has not been explored as a preservation method for mangoes in Kenya. The mangoes have however been subjected to drying leading to loss of volatile nutrients (Guinè *et al.,* 2002). The fresh state of mangoes is more preferred to consumers than the dried form. There is therefore need to analyze the effectiveness of such methods of fresh mango preservation.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

Mango samples for use in this study, were collected from Makueni County of Kenya, shown in Figure 3.1. Makueni is located between 1^{o} 48' 0" S, 37^{o} 37' 0" E and is 1155 m above sea level. It extends to an approximated area of 8,034.7 Km^2 with a population of about 900,000 people. Out of this, 51% are female and 49% are male. The county has six subcounties: Mbooni, Kaiti, Kilome, Makueni, Kibwezi East and Kibwezi West. The Makueni sub-county hosts the county's administrative unit (Gor *et al.*, 2012).

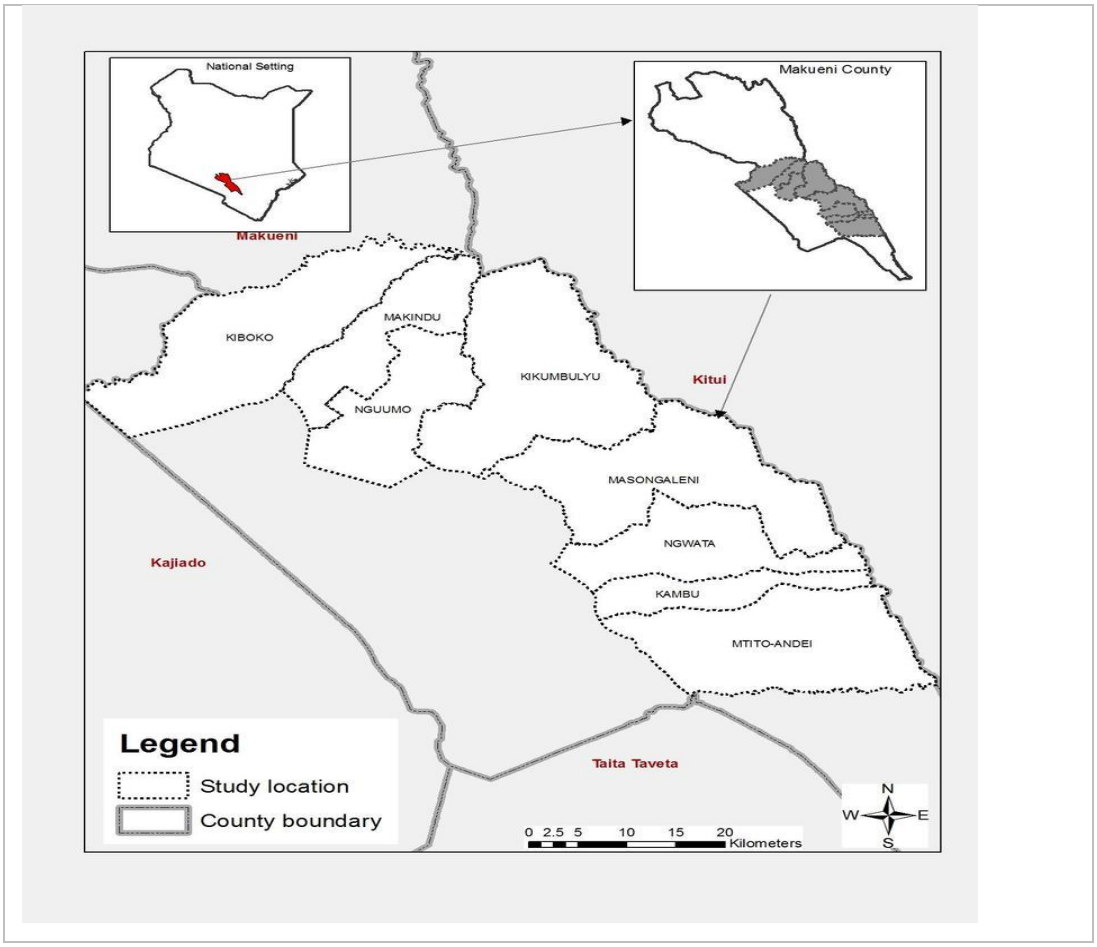


Figure 3.1 Makueni County (Amwata, 2009)

The county lies in the arid and semi-arid zones of the country and it receives two rainy seasons. Long rains are experienced in March and April while short rains are experienced between November and December. A number of agricultural activities including horticulture and livestock farming are carried out in this area (Amwata, 2009). The major agricultural products are mangoes, maize, cow peas, watermelons, pigeon peas, milk and meat. Eastern

Kenya accounts for over 54% of total mango production in Kenya (Gor *et al.*, 2012), with Makueni County leading in mango production with an annual value of Kshs. 1.3 billion. It produces mangoes from approximately 1, 172,636 trees (ABD, 2011)

3.2 Survey data collection procedure

The data for the study was collected using semi-structured questionnaires (Appendix I) which were used to collect the information from the respondents about the variables in question. Face to face interviews with different households, in Makueni County was done, where both qualitative and quantitative data was collected to answer the different questions. Purposive sampling was used to select Makueni County based on the requirements of the project. Forty respondents were randomly selected for this study using the Central Limit Theorem, which states that: as the number of occurrences (n) increases, the expected results move closer to the actual results and hence, any sample size that is greater than 30, is justified to infer population characteristics from the sample selected.

3.3 Laboratory experiment I: Effect of different gum arabic surface treatment on the physico-chemical properties of whole mango fruits during ripening

3.3.1 Collection of Mangoes

Apple mango variety fruits (200), of uniform size and at the mature green stage were obtained from a local farm in Makueni County. The fruits were handpicked directly from the trees and de-sapped placing on top of leaves that were spread on the ground, with the pedicel abscission zone, facing down. They were allowed to drain the sap for one hour after which they were kept in cool boxes and transported to the laboratory at Egerton University. They were temporarily stored in a cold room (4^{o}C) before evaluation.

3.3.2 Formulation of gum arabic solutions and application of the coating treatments

Finely ground gum arabic powder from *Acacia Senegal* var. *kerensis* collected from Isiolo County, Kenya, was made into solutions at concentrations of 0, 10, 15 and 20% (w/v) in distilled water with low heat (40^{o}C) for around 15 minutes. The solutions were then left to cool to approximately 20^{o}C.

A total of one hundred and twenty (120) mango fruits were used in the experiment. Thirty fruits were randomly allocated to the four different treatments and each treatment was replicated three times (10 fruits/replicate) and the layout is as presented in Table 3.1 below. Each replicate group of the fruits was dipped in the respective concentrations of gum arabic

solution for around one hour, ensuring that the coating solution uniformly covered the surface of the fruit (Plate 1.1 B, C and D). The control fruits (30) in Plate 1.1 A were dipped in distilled water only. The fruits were then air-dried on trays, packaged in cardboard boxes and stored in a clean room under the normal room conditions in terms of temperature (23±2^{o}C) and relative humidity (45-60%). Photos showing the coated mango samples are as below:

Plate 1.1Photos of mangoes coated with 0% (A), 10% (B), 15% (C) and 20% (D) gum arabic solutions.

Table 3.1 Layout of laboratory experiment one

Gum arabic treatments % (w/v)	Replicates/ No. of fruit samples per replicate		
	A	**B**	**C**
0	10	10	10
10	10	10	10
15	10	10	10
20	10	10	10

3.3.3 Determination of weight change

Three fruits from each replicate were marked and individually weighed using a well calibrated weighing balance before storage commenced. Those fruits were subsequently weighed at five-day intervals, for the entire experiment, until the mangoes got spoilt. Weight measurements were taken and their averages determined in order to compute the overall weight changes. Percentage weight change/loss was calculated using equation 1 below:

$$\%Wl = \left[\frac{(Wi - Wf)}{Wi}\right] \text{ x } 100\% \quad \text{..... Equation 1.}$$

Where Wl was the weight loss (%), Wi (g) and Wf (g) were the initial and final weights respectively.

3.3.4 Preparation of mango crude extract

Three pieces of mangoes from each replicate subjected to the various gum arabic treatments were randomly picked, peeled and blended into homogeneous paste using an electric blender. The blended solutions were then taken for analysis of physico-chemical parameters including ß-carotene, ascorbic acid, total soluble solids, titratable acidity and pH changes, as affected by the various treatments. Initial determinations were done on day zero (0) and thereafter at five-day intervals until the mangoes got spoilt.

3.3.5 Physico-chemical analysis

Protocols for analyses were as described below:

Determination of ß-carotene

Two millilitres of the various sample solutions were measured using a 10ml measuring cylinder and transferred into a mortar. Colour extraction was done by adding small portions of acetone and crushing the solution with a pestle until the residue was colourless. The extracts were combined into a 50ml volumetric flask by draining through a funnel staffed

with cotton wool. The extract (25 ml) was taken into a round bottom flask and evaporated to dryness in a water bath at 60^{o}C. To the evaporated sample, 1ml of petroleum ether was added to dissolve the ß-carotene. This was then eluted in a column chromatography (Rangana, 1979).

Column preparation

Twenty (20) grams of silica gel was weighed and activated by dissolving it in 1ml of absolute ethanol. A slurry was made with petroleum ether to have a column of 10-15cm. At the top of the column, 1g of anhydrous sodium sulphate was packed. Up to 50 ml of the sample was allowed to drain through the column. The elute was received in a 25ml volumetric flask until the beta-carotene in the column was not visible. It was then shaken well, covered with an aluminium foil and stored in a dark place. Absorbance was then read at 450nm using UV-Vis spectrophotometer. Readings were taken two more times on all the samples. The β-carotene content was then calculated using equation 2 below (Rangana, 1979):

$$Concentration = \frac{0.4}{0.12}\left(Absorbance * \frac{Finalvolume}{Weightofsample}\right) * DilutionFactor$$ .....Equation 2.

Determination of ascorbic acid

Preparation of reagents

Preparation of 0.07M sodium thiosulphate ($Na_2S_2O_3$) involved dissolving 17.4g of $Na_2S_2O_3.5H_2O$ in 500ml of freshly prepared distilled water containing 0.1g Na_2CO_3. The solution was then stored in a tightly capped amber bottle. Potassium iodate (KIO_3) was thereafter prepared by accurately weighing 2g and dissolving in a 1000ml volumetric flask. Starch indicator was prepared by making a paste of 1g of soluble starch and 1g of H_2I_2 in 100ml of boiling water which was then boiled until it was clear (Dioha *et al.,* 2011).

Analysis of the sample

Sample solution (50 ml) was pipettted in a 250ml volumetric flask. Solid potassium iodide (2 g) was added. Ten (10) millilitres of both 0.5M H_2SO_4 and potassium iodate solutions were added into the flask simultaneously. The solution was immediately titrated with 0.07M thiosulphate until it lost almost its entire colour. Two (2) millilitres of starch indicator was added and the titration process completed (Dioha *et al.*, 2011). The procedure was replicated twice on each sample. The titre values were obtained and their means computed.

Determination of total soluble solids (^{o}Brix)

This was determined by use of a digital bench refractometer. Homogeneous sample solutions prepared by blending the flesh of three mango samples subjected to the various concentrations of gum arabic were obtained and used for analysis. A drop of the specific solution was placed on the prism-plate of the refractometer (Mazumdar and Majumder, 2003). The reading obtained after adjusting the refractometer to the mark was directly recorded as total soluble solids (^{o}Brix)(Majid *et al.,* 2011).This was done on three replicated samples solutions and the refractometer was calibrated afresh using distilled water prior to the use for the next sample.

Determination of titratable acidity

Ten (10) millilitres of the various mango sample solutions were transferred into a 250 ml conical flask. An equal amount of distilled water was added into the flask. Phenolphthalein indicator (3-4 drops) was then added and the solution stirred. The contents were rapidly titrated with 0.1N NaOH solution and end point determined when there was a definite colour change (Majid *et al.,* 2011). The final burette reading was then noted and the titratable acidity computed using equation 3 below (Rangana, 1979):

$$\%\ acid = \frac{mlsNaOHusedxMilliequivalentfactor\ (0.064)\ x\ 100}{gramsofsample} \quad \text{..... Equation 3.}$$

Determination of pH

The pH of the sample solutions was measured using an electric pH meter as explained by Rangana, (1979). Twenty (20) millilitres of freshly prepared sample was placed in a beaker. The electrode end of the pH meter was used to agitate the solution until a stable reading was obtained. This was done on the three replicated samples respectively. Between readings the electrode was rinsed with distilled water to eliminate cross-contamination.

3.4 Laboratory experiment II: Evaluation of canning technology for mango chunks

3.4.1 Preparation and canning of mango chunks in different concentrations of cane sugar syrup

Uniformly mature hard ripe mangoes of the Kent variety were obtained from a local market in Nakuru town and transported to Njoro canning factory for experimentation. The fruits were washed with chlorine treated water, peeled by hand using sharp stainless steel knives, sliced uniformly and cut into chunks of approximately 1.5 cm^3(Plate 1.2). The chunks were then

blanched in aluminum cooking pots for 2 min at 90^{o}C (Plate 1.3 A), weighed and equal weights of 250g (of the chunks) placed in clean glass jars previously washed with hot water (Plate 1.3B). Hot sugar syrup of varying concentrations, namely 0^{o}Bx, 30^{o}Bx, 40^{o}Bx, 50^{o}Bxand 60^{o}Bxwere prepared using the blanching water and added into the jars respectively, ensuring a preset fill weight of 250g (of the syrup) was attained and sealed immediately. The samples were then labelled to differentiate them based on the varying sugar levels of the filling solutions (Plate 1.4). They were differentiated as Sample S_0 for the one with 0^{o}Bxsugar solution (control), S_1 with 30^{o}Bxsugar, S_2 with 40^{o}Bxsugar, S_3 with 50^{o}Bxsugar and S_4 with 60^{o}Bxsugar solution. The control (0^{o}Bx) was prepared by adding blanch water (without any sugar) into glass jars containing mango chunks. Samples composed of each of the five treatments were placed in eight glass jars. All the jars were then subjected to pasteurization using a retort (Plate 1.5), which was set at a constant temperature-time range of110^{o}C for 10 min. The jars were immediately cooled by allowing the hot water from the retort's jacket to drain off, while a valve was turned open to allow chilled water to cool them. After cooling, two glass jars from each of the treatments were set aside for incubation, such that one glass from each of the selected batch was incubated at 35^{o}C and the other at 55^{o}C for the accelerated shelf life studies. The other remaining jars were packed in clean plastic crates (Plate 1.6) and stored in a clean room for three months where samples were taken for analyses on a monthly basis.

Table 3. 2 Layout out of laboratory experiment two.

Sugar syrup (^{o}Bx)	Months/ No. of glass jars per batch to be analysed within the three months		
	Month 1	**Month 2**	**Month 3**
0 (S_0)	2	2	2
30(S_1)	2	2	2
40(S_2)	2	2	2
50(S_3)	2	2	2
60(S_4)	2	2	2

S_0 Control; no sugar syrup added; S_1, S_2, S_3 and S_4 mango chunks with 30, 40, 50 and 60 ^{o}Bx syrup added, respectively.

Mango canning process at Njoro Canning Factory is as depicted in the plates below:

A **B**

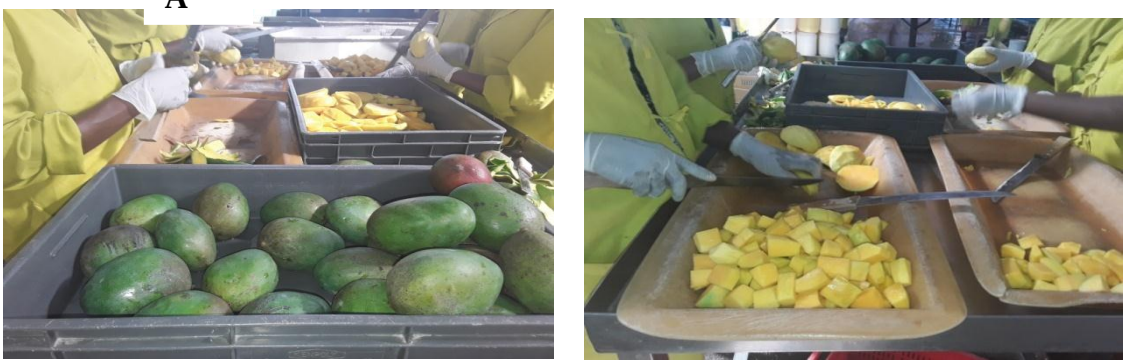


Plate 1. 2 Preparation and chopping (A) of washed mangoes into chunks (B) for processing.

A **B**

Plate 1. 3 Blanching (A) and hot packing (B) of weighed blanched chunks

Plate 1. 4 Sealing and labeling glass jars

Plate 1. 5 Sterilization of the chunks in a retort

Plate 1. 6 Sterilized mango chunks ready for storage

Chemical analysis

Two glass jars from each of the sample treatments were picked and the fill solution (sugar solutions) obtained from them and set aside for the analysis of pH, titratable acidity, total soluble solids and ascorbic acid content. The mango chunks were used during the analysis of β-carotene content. Initial determinations were done on day zero (initial readings) and thereafter at one-month interval for three months.

The protocol for the analyses are as described in the first laboratory experiment above (section 3.3.5) with the difference being that the sample used for the analysis of pH, titratable acidity, total soluble solids and ascorbic acid content was the sugar solution (fill solution), while the mango chunks themselves, were used in the analysis of β-carotene.

3.5 Statistical analysis

Data collected from the field using questionnaires, was sorted and coded after which it was analyzed using SPSS software version 20.0 of year 2009. The analyzed data was presented in percentages as distribution tables, graphs and figures while the qualitative aspects were discussed in the study.

The experimentation employed a two factor factorial experiment in a completely randomized design. The two factors in the first laboratory experiment were the percent (%) level of gum arabic used for coating purposes (0%, 10%, 15% and 20%) and the storage period in terms of days. In the second laboratory experiments, the two factors were the levels of the sugar syrup (0^{o}Bx, 30^{o}Bx, 40^{o}Bx, 50^{o}Bx and 60^{o}Bx) used as a fill solution in the canning process and the storage period in terms of weeks. The interaction of the above factors was also determined.

Statistical model: $\mathbf{Y_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + e_{ijk}}$.....Equation 4

where in the first laboratory experiment: Y_{ijk} is the response from i^{th} level of gum arabic, and j^{th} level of storage period, μ is the overall mean responses, α_i is the effect of i^{th} level of gum arabic, β_j is the effect due to the j^{th} level of storage period and $\alpha\beta_{ij}$ is the interaction between the i^{th} level of gum arabic and j^{th} level of storage, while e_{ijk} is the random error component. In the second laboratory experiment: Y_{ijk} is the response from i^{th} level of sugar syrup, and j^{th} level of storage period, μ is the overall mean responses, α_i is the effect of i^{th} level of sugar syrup, β_j is the effect due to the j^{th} level of storage period and $\alpha\beta_{ij}$ is the interaction between the i^{th} level of sugar syrup and j^{th} level of storage period, while e_{ijk} is the random error component.

The data obtained from the experiments above were put to statistical analysis using statistical package SAS (Version 9.3). The two factor experiments above had three replications on all the experiments apart from that involving analysis of ascorbic acid which had two replicates. The data were analyzed for analysis of variance (ANOVA) using Tukey's HSD ($P<0.05$) for significance difference test. The results were expressed as mean ± standard deviation.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Socio-economic characteristics of the mango farmers, storage and preservation of the mangoes in Makueni County

Most (72.7%)of the respondents interviewed were mango farmers (Table 4.1), majority of whom were women (Figure 4.1), who were aged between 36 and 60 years (56.4%) (Figure4.2). Most of them (43.6%) had attained secondary school as their highest education level (Table 4.2). This clearly indicated that majority of the female farmers were encouraged to indulge in mango farming. Very few youths engaged in agricultural activities. The constitution of Kenya defines a youth as a person between 15 years and 34 years of age (GoK, 2010); hence the findings above clearly showed that those involved in farming were those that had passed the youthful stage. The Institute of Economic affairs (IEA, 2010), clearly reports that up to eighty percent of Kenyans are below 34 years of age and there are various reasons as to why agriculture is not attractive to the youths. In this current study, it could be due to lack of requisite resources especially land, to carry out mango farming.

Most of the decision making with regards to the management of the farm, were made by the males who were the head of the family. In contrast, as reported by KNBS (2009), less than half of the households in Makueni County were headed by females. The males were also actively involved with on-farm activities like ploughing of the farm using ox-ploughs in collaboration with other male friends who would come to assist out of will. However, in some instances, some farmers opted to use hired labour on their farm. The women played a very critical role especially in situations where they were the head of the family as a result of being divorced or single parenthood. In such instances, they were involved in all the decision making process. Only in some few instances where the women involved in tasks like ox-ploughing. The oxen may be owned by the farmers and sometimes they were hired for such purposes.

Table 4.1 Respondents' occupation (n=40)

Respondents' occupation	Percentage (%)
Farming (Mango farmers)	72.7
Self employed off- farm/trader (of mangoes)	16.4
Farming/trader (of mangoes)	10.9
Total	100

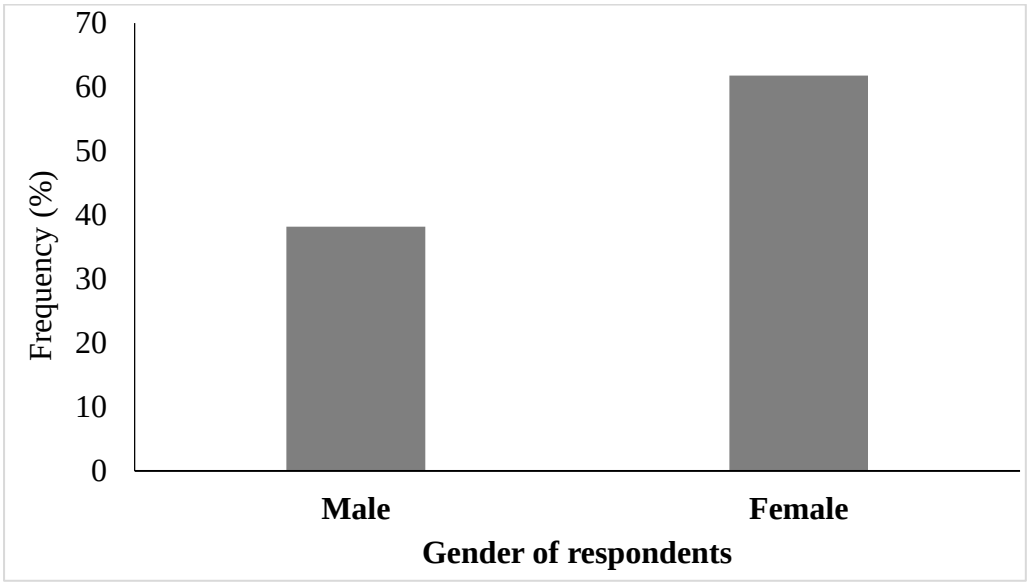


Figure 4. 1 Gender of respondents (n=40)

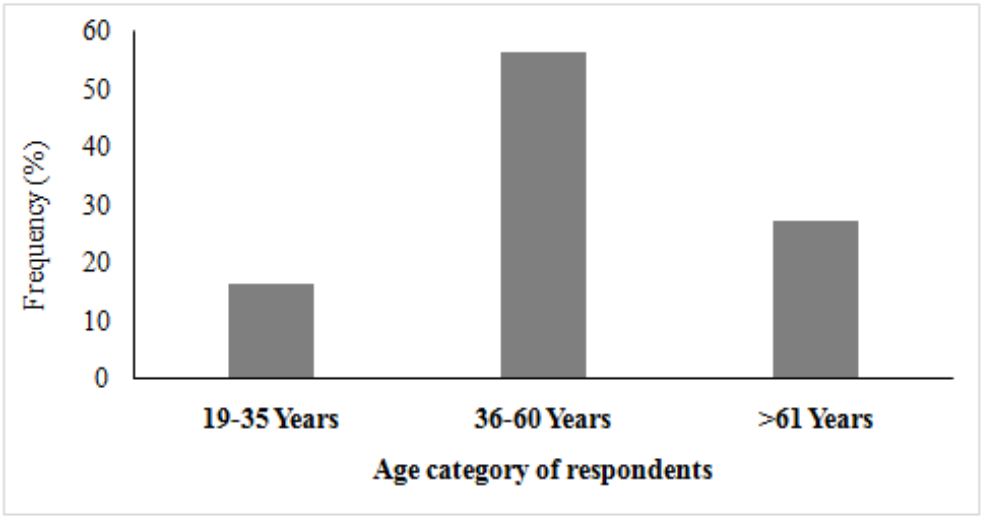


Figure 4. 2 Age category of respondents (n=40)

Table 4.2 Education Level of respondents (n=40)

Education level	Percent (%)
No formal education	3.6
Primary level	40.0
Secondary level	43.6
Post-secondary level	5.5
University level	7.3

Mango farming and post-harvest handling practices

Mango farming is one of the key agricultural practices carried out in Makueni County. In this County some farmers have small mango plantations while a few have large plantations of mango trees. Apple variety of mangoes was the dominating variety planted, giving the highest percentage of 74.5% (Table 4.3). Some farmers planted a combination of Apple and Ngowe varieties giving a total percentage of 12.7%. Apple variety planted together with Kent occupied a percentage of 1.8% while the same percentage was experienced by those who planted apple together with dodo (indigenous) and apple together with Tommy Atkins. A combination of apple, Ngowe, Kent and Tommy Atkins occupied a percentage of 7.3% of the farms of interviewed farmers as in Table 4.3 below.

Table 4.3 Mango varieties grown in Makueni County

Mango varieties	Percentage (%)
Apple	74.5
Apple and Ngowe	12.7
Apple and Kent	1.8
Apple and Dodo	1.8
Apple and Tommy Atkins	1.8
Apple, Ngowe, Kent and Tommy Atkins	7.3

Post-harvest handling of mangoes is one of the critical measures to consider within the mango value chain. This is because, mangoes are very delicate as they are perishable, hence cannot be stored for long once harvested. Most farmers in Makueni County used well ventilated stores (50.9%), as shown in Table 4.4below; to temporarily store their mangoes before selling them to brokers or before transporting them to the market for sale. However, 40% of the farmers did not exercise storage since the mangoes were harvested on demand. In

this case, the buyer came with his/her workers who would do the harvesting after which payment would be made directly through cash or through mobile money transfer services. Market stores (9.1%) (Table 4.4) were only used by the traders who hired stores and heaped the remaining mangoes there overnight, awaiting sale the following day. Such stores were fitted with air vents that allowed air circulation hence regulating the temperatures to some extent. In most cases, those farmers having well ventilated stores always made use of them just incase they harvested mangoes in plenty and they were all not taken by the buyers. They also however harvested the mangoes on demand.

Table 4.4 Mode of storage of mangoes in Makueni County

Mode of storage	Percent (100%)
No storage	40
Well ventilated stores	50.9
Market stores	9.1
Total	100

During storage, 50.9% (Table 4.4) of the farmers used no material for storage purposes. This was because; majority of them only harvested the mangoes and sold them on demand, hence there was no need for storage. A combination of crates and gunny bags and bulk package on trucks were applied by 1.8% (Table 4.5) of the farmers which was the least representation. Gunny bags were used by 25.5% while cartons and crates were used by 12.7% and 7.3% of the farmers respectively. These materials were used especially during the transportation of the mangoes from the market places to the stores, and the mangoes were left in them during the short storage period. The need for using such materials during storage was firstly, to act as barriers in preventing attack of the fruits by storage pests. Secondly, and this applied to most of the traders within the same County and who conducted their activities within the market places; they had a common store for temporarily storing their mangoes before selling. So these storage materials became handy in clearly differentiating people's packages.

There was a tally in the percentage (40%) of those who stored the mangoes for two days and those who did not store them at all; and this was the highest percentage (Table 4.5). Only 1.8% of the population stored them in three days and they represented the minority. Table 4.5 gives an illustration of the storage period of the mangoes.

Table 4.5 Storage period of mangoes

Days	Percent (%)
None	40.0
1 Day	1.8
2 Days	40.0
3 Days	9.1
5 Days	5.5
7 Days	3.6

Majority of the farmers (50.9%) did not use any preservation technique for the mangoes. This was because they only harvested the mangoes upon demand. Only 5.5% of the population preserved their mangoes during the ripening and storage period (Table 4.6). From the interviewees, only 1.8% (Table 4.7) of them used charcoal coolers as a mode of preservation. The charcoal coolers brought about a cooling effect to the mango fruits and this regulated their ripening process by slowing it down, hence extending the shelf life of the mangoes. Charcoal coolers were readily available and affordable to some of the farmers compared to the electric refrigerators which were very expensive. The same percentage (1.8%) of the population processed the mangoes into juice as a way of preserving them. The sugar added to the juices helped in preserving the mangoes further by preventing or slowing down the growth of bacteria, moulds and yeast. Only 21.8% spread them on the floor so that the cool temperatures of the floor would extend their shelf lives. Only 9.1% kept the fruits in well ventilated rooms as a way of preserving them. The well ventilated rooms enhanced air circulation within the stores and this in the long run regulated the temperatures within the stores.

Table 4.6 Stage of preservation

Stage of preservation	Percent (%)
No Preservation	50.9
At harvesting	18.2
Before ripening stage	9.1
At ripening stage	5.5
During storage	5.5
At selling	10.9

Table 4.7 Preservation method

Preservation method	Percent (%)
Not applicable	50.9
Draining the latex	14.5
Spreading on the floor	21.8
keeping in well ventilated rooms	9.1
Use of charcoal coolers	1.8
Processing into juice	1.8

With the preservation methods applied, only 10.9% of the mangoes could keep for either five or seven days. A small percentage of the mangoes (1.8%) could keep for only one day while 5.5% could stay for up to 4 days as seen in Table 4.8below.

Table 4.8 Duration of storage

Duration of storage	Percentage (%)
1 day	1.8
2 days	7.3
3 days	9.1
4 days	5.5
5 days	10.9
7 days	10.9
14 to 15 days	3.6

In the event of the preservation process, there were some losses which were encountered. 30.9% of the interviewees agreed that they encountered some losses while 14.5% of the same experienced no losses. Since some did not apply any preservation technique, a percentage of 54.5% therefore had no experience on that.

High temperatures contributed to the losses and this was as reported by 10.9% (Table 4.9) of the interviewees. Other challenges encountered during storage were as reported by 1.8% of the same who reported that labour and electricity (in the case of blending the fruits into juice), rodents in the stores and wasting away of charcoal used in charcoal coolers, contributed a lot to the lack of efficiency during storage as in Table 4.9 below.

Table 4.9 Challenges encountered during the preservation period

Challenges	Percent (%)
Not applicable	50.9
None	27.3
Rodents	1.8
High temperatures	10.9
High temperatures and rodents	1.8
Labour and electricity	1.8
Tiring	1.8
Rodents and rent	1.8
Wasting away of charcoal	1.8

4.2 Laboratory experiment one: Effect of gum arabic levels on the physico-chemical properties of coated mangoes

4.2.1 Effect of gum arabic surface coating and storage period on weight loss of mangoes

Gum arabic coating treatments and storage period significantly ($P<0.05$) affected weight loss of the mango fruits (Figure 4.3). Weight loss increased significantly ($P<0.05$) with the progression of storage period and reached its maximum on the 10^{th} day for the control and the 15^{th} day for the treatments, after which the mangoes went bad, respectively. All the coating treatments exhibited less fruit loss than the control fruits. However; there were no significant ($P \geq 0.05$) effects on the weight loss of the coated mangoes with increasing levels of gum arabic concentration (Figure 4.3).

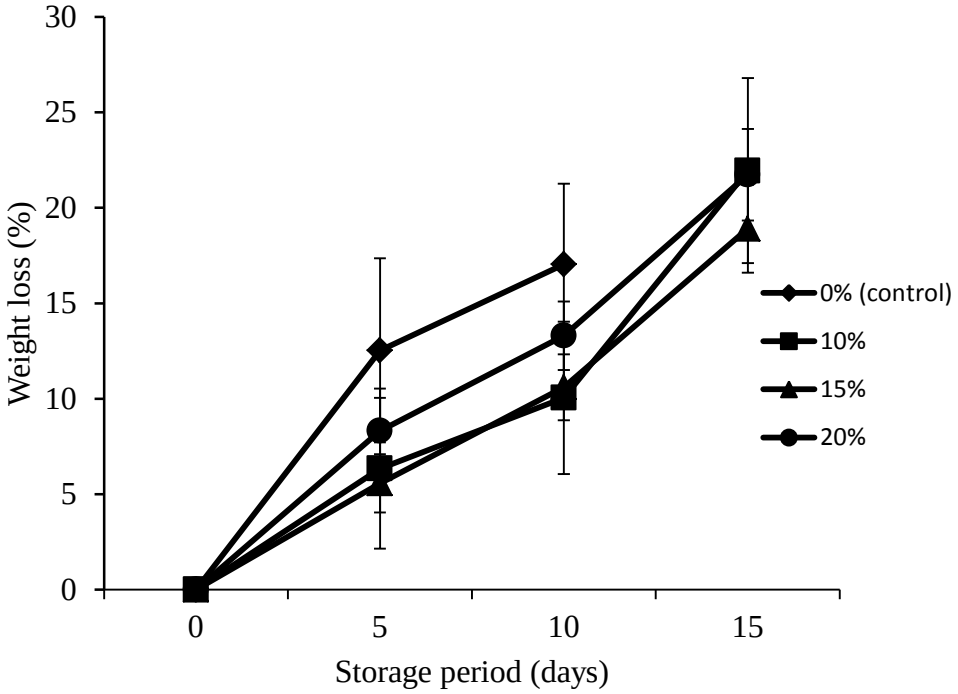


Figure 4. 3 Effect of different coating treatments on the weight loss of mango during storage at room temperature.

4.2.2 Total Soluble Solids (TSS), Titratable Acidity (TA) and pH

Total soluble solids (TSS) of mangoes was significantly ($p<0.05$) affected by gum arabic coating treatments, storage period, and their interactions. The control mangoes showed significant ($p<0.05$) increase in TSS that peaked on day 5 at 18.00%. However, gum arabic coating treatments significantly ($p<0.05$) delayed increase in TSS of mangoes during the storage period. Among the gum arabic treatments, 10% gum arabic surface coating treatment showed insignificant ($P \geq 0.05$) change in TSS, while 15% and 20% treatments showed a drop in TSS in the first 10 days but increased thereafter till the 15th day when all the mangoes decayed (Figure 4.4). Similarly, TA of mangoes was significantly ($P<0.05$) affected by gum arabic coating and the storage period. There was a decrease in TA with increased storage period for the control but for the treatments, TA increased for the first 5 days, after which it started decreasing with storage time except for 10% gum arabic treatment, until the mangoes decayed. In all treatments, TA was higher in the treatments compared to the control during storage (Figure 4.5). With little TSS increments and low TA decreases in all the gum arabic treatments, there was an indication that ripening was slower with the gum arabic treatment.

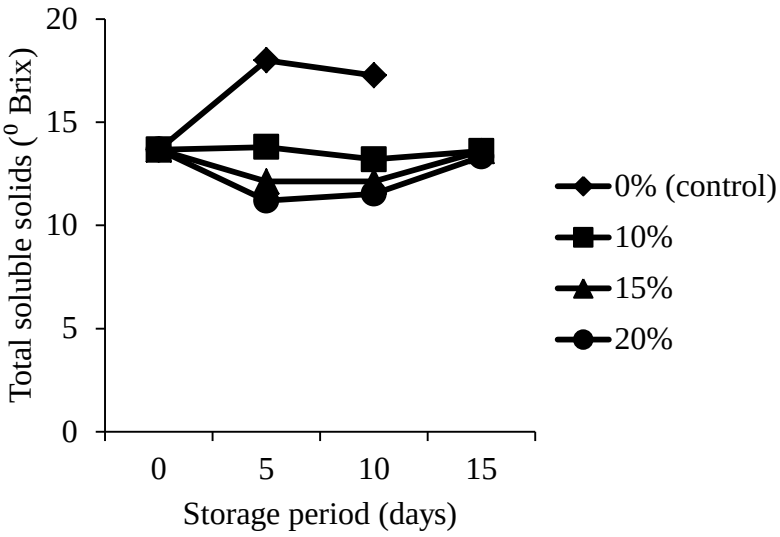


Figure 4. 4 Effect of different coating treatments on the TSS of mangoes during storage at room temperature.

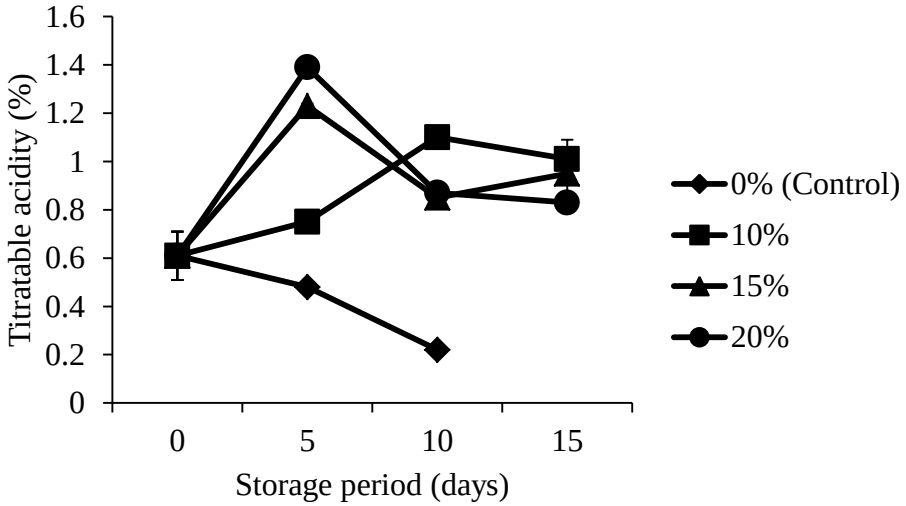


Figure 4. 5 Effect of different gum arabic coating treatments on titratable acidity of mangoes during storage at room temperature.

4.2.3 β-Carotene and Ascorbic Acid Contents and pH

The ß-carotene concentration in the mangoes was significantly ($p<0.05$) affected by gum Arabic coating treatments and the storage period (Figure 4.6). The control mangoes and the treatments with 10% and 15% gum arabic treatments showed little change in the first 5 days. However, thereafter, the ß-carotene concentration in the control samples increased significantly ($p<0.05$) and by day 10, the concentration was more than two-fold than that in the treatments. After day 10, control mangoes went bad but the ß-carotene concentration in

10% and 15% gum Arabic treatments slightly dropped but the concentration at 20% gum arabic treatment, the ß-carotene concentration increased significantly ($p<0.05$) and at day 15, it was marching the levels of the control mangoes at day 10.

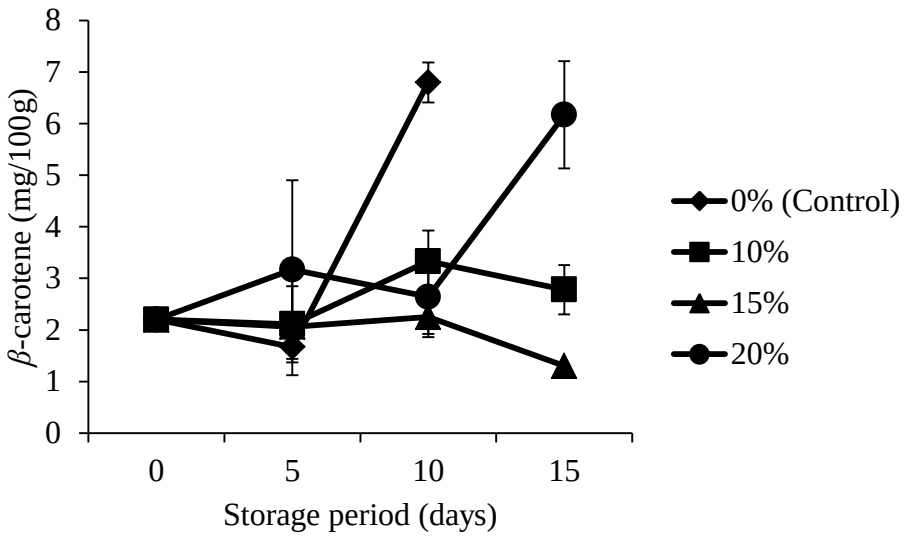


Figure 4. 6Effect of different gum Arabic coating treatments on beta β-carotene content of mangoes during storage at room temperature.

The vitamin C concentration in the mangoes was significantly ($p<0.05$) affected by gum arabic coating treatments and the storage period (Figure 4.7). The control mangoes and the treatments with 10% gum arabic treatments exhibited little change in the first 5 days compared to 15% and 20% gum arabic treatments. However, the 10% gum arabic treatment had vitamin C concentration increasing to 0.94 and approached those in 15% and 20% treatments (0.86–1.02) after which their concentration decreased steadily towards day 15 when the mangoes started rotting. However, in most cases, the vitamin C concentrations were significantly ($p<0.05$) higher in the treatments than in the control in most parts of the storage period.

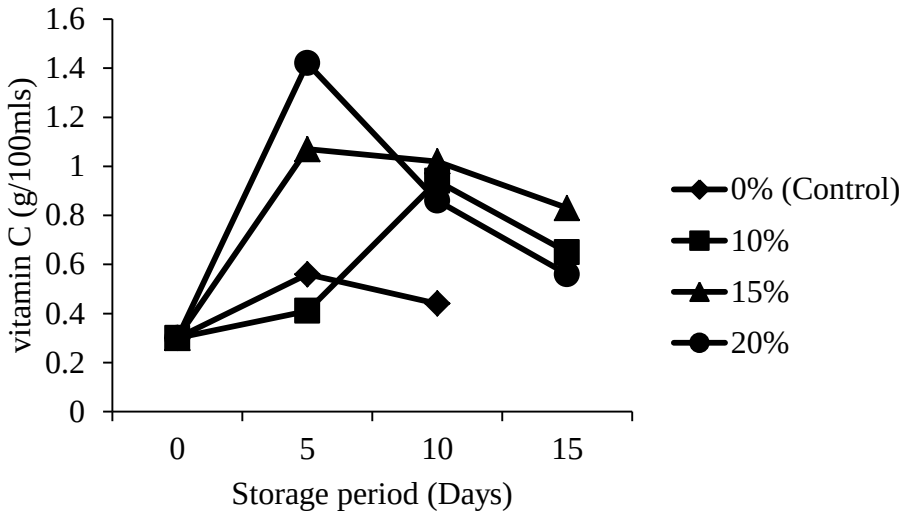


Figure 4. 7 Effect of different gum arabic coating treatments on vitamin C content of mangoes during storage at room temperature.

The effect of gum arabic treatments on pH was significant (P<0.05) (Figure 4.8). The control samples had pH increasing with respect to the storage period and the pH readings of the control were significantly higher than the treatment pH. The treatments had insignificant (P>0.05) changes in the pH up to the 15th day.

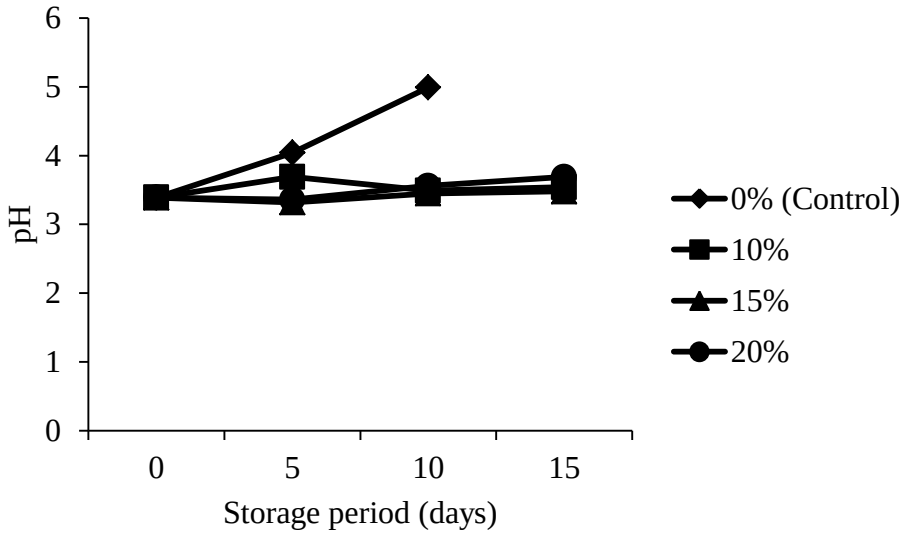


Figure 4. 8 Effect of different gum arabic coating treatments on pH of mangoes during storage at room temperature.

4.3 Laboratory experiment two: Effect of canning technology on the chemical properties of mango chunks during storage

Mango chunks packaged in glass jars were stored at ambient temperatures (30-35^{o}C) after which chemical analyses weredone on the samples at an interval of one month for three months. The following results (Table 4.10) were obtained:

Table 4.10 Chemical Characteristics of pasteurized mango chunks in a three month period

Time	Sugar solution (^{0}Bx)	pH	Total Soluble Solids(^{0} Bx)	Titratable Acidity (%)	B Carotene(mg/100g)
0 Day	0 (S_0)	3.52±0.00^{a}	14.37±0.03^{e}	0.64±0.00^{a}	1.83±0.05^{a}
4 Weeks	0 (S_0)	3.47±0.00^{a}	5.97±0.03^{f}	0.51±0.00^{b}	1.72±0.06^{a}
	30 (S_1)	3.46±0.01^{a}	22.23±0.07^{d}	0.45±0.00^{c}	1.86±0.03^{a}
	40 (S_2)	3.48±0.00^{a}	26.53±0.07^{bc}	0.45±0.00^{c}	1.25±0.05^{b}
	50 (S_3)	3.46±0.00^{a}	30.20±0.12^{b}	0.49±0.02^{c}	0.75±0.10^{c}
	60 (S_4)	3.35±0.00^{a}	38.97±0.07^{a}	0.64±0.00^{a}	0.69±0.07^{c}
8 Weeks	0 (S_0)	3.40±0.00^{a}	5.23±0.09^{f}	0.70±0.04^{a}	1.31±0.07^{b}
	30 (S_1)	3.45±0.00^{a}	20.47±0.12^{d}	0.64±0.00^{a}	1.69±0.03^{a}
	40 (S_2)	3.42±0.00^{a}	26.10±0.12^{c}	0.64±0.00^{a}	1.17±0.00^{b}
	50 (S_3)	3.45±0.00^{a}	30.03±0.22^{b}	0.62±0.02^{ab}	0.83±0.05^{c}
	60 (S_4)	3.43±0.00^{a}	41.87±0.44^{a}	0.66±0.02^{a}	0.64±0.03^{c}
12 Weeks	0 (S_0)	3.39±0.00^{a}	5.67±0.15^{f}	0.58±0.04^{b}	1.00±0.05^{bc}
	30 (S_1)	3.43±0.00^{a}	25.50±0.10^{c}	0.51±0.00^{b}	1.47±0.11^{b}
	40 (S_2)	3.37±0.00^{a}	26.43±0.07^{c}	0.55±0.02^{b}	0.94±0.03^{c}
	50 (S_3)	3.35±0.00^{a}	30.23±0.34^{b}	0.64±0.00^{a}	0.61±0.06^{c}
	60 (S_4)	3.34±0.00^{a}	41.50±0.00^{a}	0.70±0.00^{a}	0.36±0.06^{d}

Values presented as mean± Standard deviation. a – f means within a column with the same superscript letters are not significantly different (P>0.05). S_0, S_1, S_2, S_3 andS_4 represent the different concentrations of the sugar syrup.

4.3.1 Effect of syrup concentration and storage period on pH

The initial amount of pH in all the samples was 3.52. There was however, no significant (P>0.05) difference on the pH readings among the treated samples throughout the storage period (Table 4.10). The readings though reduced during storage, with the highest reading being the initial amount recorded (3.52), while the lowest being 3.34. The lowest reading was obtained from the sample (S4) which was stored for 12 weeks and whose sugar solution was the highest (60^{o}Bx). Interactively, storage period and sugar levels in the syrup did not affect the pH of the samples.

4.3.2 Effect of syrup concentration and storage period on the total soluble solids

At the start of the experiment, the initial reading of TSS recorded was 14.37^{o}Bx (Table 4.10). With increased storage time, there was significant (P<0.05) increase in the total soluble solids (TSS) content in the canned mango chunks. However, with the control sample, the TSS dropped from the initial 14.37 ± 0.03^{o}Bx to below 6.0^{o}Bx from week 4 and remained within a similar range throughout the entire storage period. For the treatments with varying concentrations of the syrup, the TSS increased significantly (P<0.05) with increase in syrup concentration, but the storage period did not significantly (P<0.05) affect the TSS values within a given treatment except treatment S_1 that had a significant increase in TSS between week 4 and week 8 compared to week 12.

4.3.3 Effect of syrup concentration and storage period on titratable acidity of canned mango chunks

The initial reading of the titratable acidity of the sample was 0.64%. During storage, there were some significant (P<0.05) changes in the titratable acidity content. Sample S_1 and S_2 showed some uniform decrease in the titratable acidity content to 0.45% towards the fourth week of storage and later on an increase to 0.64% of the same towards the eighth week of storage (Table 4.10). There was however a significant (P<0.05) decrease to 0.51% and 0.55%, respectively, of the content towards the twelfth week of storage. Continuous increase was experienced in sample $S_4$where the highest acidity reading was 0.70% which was obtained during the twelfth week of storage. Sample S_3consisting of mango chunks packed in sugar solution whose concentration was at 50^{o}Bx showed a decrease to 0.49% of the titratable acidity content at the fourth week of storage, and later on, a progressive increase of the same towards the eighth and the twelfth week of storage. The control sample (S_0) showed a decrease (0.51%) in the acidity content towards the fourth week of storage, later on an

increase (0.80%) in the eighth week of storage and a further decrease (0.58%) in the twelfth week of storage.

4.3.4 Effect of syrup concentration and storage period on the beta carotene content on mango chunks

With increased storage period, there was a significant (P<0.05) decrease in the levels of beta carotene in all the samples (Table 4.10). The initial reading of the beta carotene content was 1.83mg/100ml. Addition of sugar syrup to 30^{o}Bx seemed effective in β-carotene retention. However, additional sugar, affected the β-carotene content negatively over time and the rate of β-carotene decrease, increased with increase in sugar concentration over the storage time.

4.3.5 Effect of syrup concentration and storage period on Ascorbic acid (Vitamin C) concentration in mango chunks

With increasing storage time, there was a significant (P<0.05) decrease in the ascorbic acid content in all the samples to the fourth week of storage (Figure 4.8). At the eighth and twelfth week of storage, there was a progressive increase of the content of the same. The initial content was 1.70g/l for all the samples. The control sample (S_0) had similar amount of ascorbic acid on the twelfth week of storage with the highest amount obtained from sample S_3 (50^{o}Bx sugar solution) during the same period of storage.

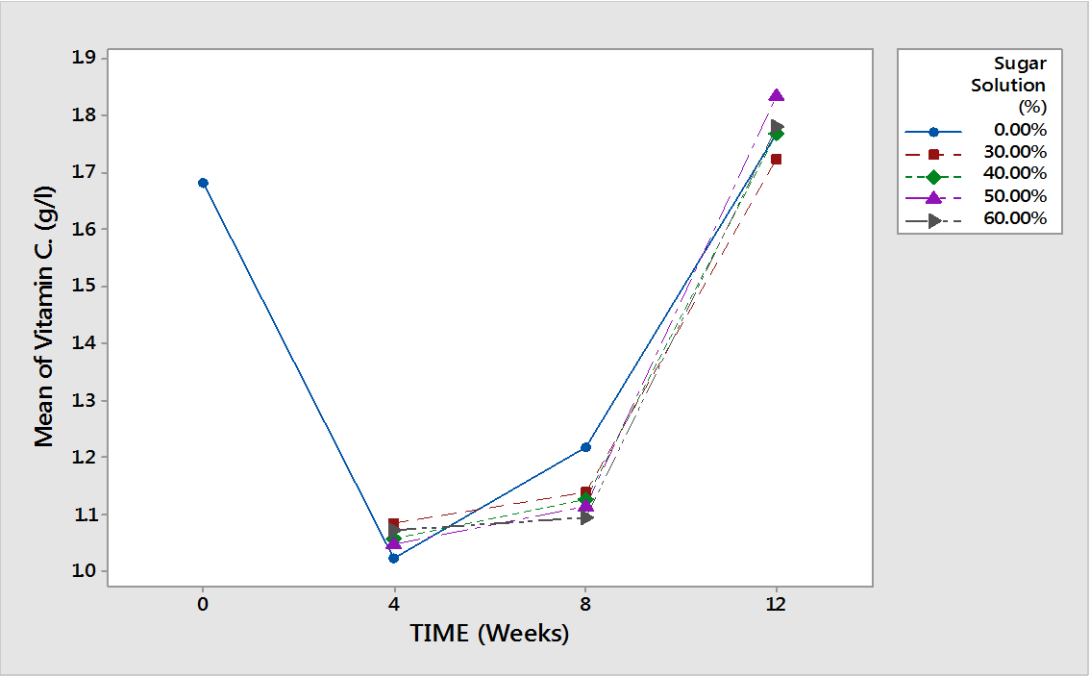


Figure 4.9 Effect of syrup concentration and storage period on vitamin C content in mango chunks

4.4 Discussion on laboratory experiment one and two

4.4.1 Effect of gum arabic levels on the physico-chemical properties of coated mangoes

There was a significant effect of the gum arabic coating on weight loss and hence the shelf life of the treated mangoes in contrast to the control. This may be as a result of gum arabic forming a semi-permeable barrier that blocks the stem end scar and the lenticels in the coated fruit against losing water vapours and gases consequently reducing transpiration (Ketsa and Prabhasavat, 1992). Baldwin *et al*. (1999) had also observed that carnauba wax coated mangoes had less weight loss because of decreased moisture loss. The control fruits (0% gum arabic coating) showed the highest percentage weight loss due to higher moisture loss and increased respiration through uninterrupted atmospheric column and lower relative humidity compared to the coated ones. The weight loss in control samples with time was similar to the results reported by Kramchote *et al*. (2008) and Mandal *et al*. (2018) for mangoes. Water content of fruits is a major factor in maintaining their quality. Therefore, low weight loss is important in maintaining the quality of fruits over a longer duration. This delayed senescence helps to extend the shelf life of fruits as demonstrated here that with gum arabic coatings, the fruits could be stored for 15 days compared to the control mangoes that spoilt within 10 days. The effect of concentration of gum arabic on weight loss was not clear, indicating that the lowest concentration used was effective in reducing the respiration rate.

The TSS of the control mangoes increased with the storage duration of the mangoes compared to the treatments that had TSS barely changing with duration. The TSS increment for the control was steep in the first 5 days after which it showed a drop afterwards. The sharp increase in TSS of the control mangoes happened possibly due to loss of water from the fruits and the ripening condition that results in the breakdown of complex carbohydrates into simple sugars hence increased TSS (Jain and Mukherjee, 2011), while for the treatments, the gum arabic film formed on the surface of mangoes slowed ethylene synthesis thus delaying ripening and ultimately TSS accumulation (Fan *et al*., 1999). TSS accumulation has been associated with ripening and the highest levels (18.00^{o}Bx) recorded here were similar to (18.65^{o}Bx) those reported by for the same variety of mangoes. After the starch had been completely hydrolysed, there was no further increase in sugar occurring in the control samples. Moreover, the sugars were primary substrates for respiration, along with other organic acids hence the reduced TSS after the 5^{th} day (Wills *et al*., 1980).

There was a fluctuation of the pH values of the surface coated and the control fruits during the storage period. The pH for the control samples increased steadily and this corresponded to reduced titratable acidity over the storage period. Organic acids such as citric and malic acids are primary substrates for respiration, hence, a decrease of acidity is expected in highly respiring fruits as seen in the control samples (El-Anany *et al*., 2009). On the other hand, for the treatments, pH increment was little which also corresponded with slight changes in titratable acidity. Gum coating modified the atmosphere around the fruit by forming a semi-permeable film that prevented the migration of moisture and/or gases across the coat. This prevented the development of the acids more effectively resulting to mangoes with lower pH values (higher titratable acidity) unlike the control samples (Yaman and Bayoindirli, 2002).

As observed, the ascorbic acid increased initially then decreased afterwards. The mangoes used were mature green hence unripe and had the lowest ascorbic acid. The increase in ascorbic acid up to day 5 indicated the ripening process and after they fully ripened, ascorbic acid concentration decreased; a show of senescence towards day 10 for the control and day 15 for the treatments (Sammi and Masud, 2007). These results were in agreement with the results obtained by Muhammad *et al*. (2014), who showed that the concentration of ascorbic acid is highest in the half ripe mango, followed by ripe mangoes then unripe mangoes have the least ascorbic acid concentration. The treatments caused ascorbic acid retention in mangoes during storage, which is in agreement with the results reported by Baldwin (1994). This retention could be due to the retardation of the oxidation process and also, the slow rate of conversion of L-ascorbic by ascorbic acid oxidase (Jain and Mukherjee, 2011). This shows that gum Arabic treatment is appropriate for ascorbic acid retention.

The change in ß-carotene concentration in the control mangoes for the first five days was minimal but the concentration increased significantly thereafter due to fruit ripening that is accompanied by colour change and ß-carotene synthesis. On the other hand, treatment with gum arabic inhibited ß-carotene synthesis in the fruits that retained the green color, similar to results reported by Fonseca *et al*. (2004). For the sample with 20% gum arabic treatment, the increased ß-carotene could be attributed to decaying that led to ß-carotene synthesis similar to ripening.

4.4.2 Effect of canning technology on the chemical properties of mango chunks during storage

Mango canning process involved washing of the mature green mangoes that was done to remove any surface contaminants. Peeling, pitting and cutting the mangoes into chunks followed after which the chunks were blanched at 90^{o}C for 2 min. Blanching was done prior to canning to minimize degradation of the sensory and nutritional quality of the fruit caused by enzymes such as ascorbic acid oxidase (AAO), polyphenol oxidase (PPO) and peroxidase (POD), naturally present in plant foods and which affect colour and produce off-flavours (Holzwarth *et al.,* 2013). The enzymes are also associated with reduction of the nutritive value of the fruit (Holzwarth *et al.,* 2013; Korbel *et al.,* 2013). During blanching, the inactivation of enzymes depends on both the time and temperature of the process. Under-blanching may enhance the activity of enzymes leading to deleterious situations than no blanching at all. Over-blanching on the other hand causes loss of vitamins, minerals, flavour and colour (Fellows, 2009). Hot packing of the chunks was then done and the sugar solutions of different concentrations prepared and drained into the glass jars before they were well sealed and taken to the retort for pasteurization. Pasteurization processes are designed to occur at specific conditions, usually either at high temperature and short time (HTST) or at low temperature and long time (LTLT). In this case, it was done at a temperature of 121^{o}C for 10 min (HTST) to inhibit microbial growth (Vasquez-Caicedo *et al.,* 2007; Munyaka *et al*., 2010; Lemmens *et al.,* 2013). Cooling followed soon after, and then the glass jars were stored in a clean room.

After the mango chunks had been pasteurized, cooled and stored at room temperature, there is expected mass transfer of the solutes and the solvents i.e. (a) Flow of water from the product to the solution, (b) transfer of solute from the solution to the product and (c) transfer of the product's own solutes (sugars) to the concentrated solution (Raoult-Wack, 1994). This qualified the syrup for analysis after the one-month interval for three months since the results obtained would be similar if the chunks were to be blended and the juice obtained and analyzed.

The equilibrium that was established within the twelve weeks of storage, according to the principle of osmosis between the sugar concentration in the sugar syrup and that of the chunks themselves, explained the sudden increase in the total soluble solids level during the storage period. Also, increase in TSS during storage might be due to acid hydrolysis of polysaccharides (pectin) (Luh and Wodroof, 1975).

Storage intervals and the different sugar levels in the pack solution (treatments) had significant effect on the titratable acidity of the mango chunks during storage, which also affected the pH of the same. The increase in percentage of the titratable acidity of the chunks stored in the glass jars may be due to the high storage temperatures experienced during storage period. It may also be due to the formation of acidic compounds by degradation or oxidation of reducing sugars. Break down of pectic bodies into acids such as D-galactouronic acid could also be attributed to this (Riaz *et al.,* 1989; Iqbal *et al.,* 2001; Hussan *et al.,* 2008). This also had an effect in pH hence the changes in the readings (decreasing trend). Change in pH is directly related to changes in acidity.

Mango fruits are considered rich source of carotenoids. Most studies have proved that beta-carotene is both the principal provitamin A carotenoid and the main pigment in mango (Wilberg and Rodriguez Amaya, 1995; Chen *et al.,* 2007; Masibo and He, 2009). Investigations have been done on the pigment and reports show that processing of fruits, which includes activities such as preparation, treatments and storage, may affect it, resulting to variations in the content and composition (Godoy and Rodriguez-Amaya, 1987; Cano and De Ancos, 1994; Mercadante and Rodriguez-Amaya, 1998; Pott *et al.,* 2003; Chen *et al.,* 2007; Vesquez-Caicedo *et al.,* 2007; Lemmens *et al.,* 2013). This is because; the beta carotene is degraded mainly by isomerization and oxidation reactions, where oxidation plays a key role in loss of beta carotenes (Rodriguez-Amaya, 1999).

The decrease in the beta carotene content in this study was therefore first initiated during the peeling and the cutting of the mangoes into chunks. Cutting induced both oxidation and isomerization of the beta carotene of the mango fruits by the presence of endogenous oxidative enzymes, light, metals, low pH and co-oxidation with lipid hydroperoxides due to the increased exposure of the chunks to oxygen (Rodriguez-Amaya, 1999). Auto-oxidation of beta carotene with oxygen could lead to the formation of epoxycarotenoids and apoxycarotenoids through a free radical mechanism, also, the oxidation process, leading to the geometric isomerization of both *cis* and *trans* isomers (E- and Z- Isomers), as reported by Rodriguez and Rodriguez-Amaya (2007). During blanching and sterilization, thermal degradation of the beta carotene occurred and was induced by the reversible *trans* and *cis* isomerization whose degree is related to the intensity and duration of the heat treatment conditions (Rock, 1997; Cheng and Huang, 1998).

Vitamin C [L-ascorbic (L-AA)] is a six-carbon lactone, synthesized from glucose by animals. It is a micronutrient for human nutrition (FAO, 2004). Humans are unable to synthesize L-

AA and this is due to the fact that they are deficient in L-gulonolactone oxidase, an enzyme which catalyzes the last step in L-AA formation (Nishikimi *et al.,* 1994). They must therefore meet the required vitamin C amount for normal body's metabolic functioning through a diet consisting of mainly fruits and vegetables as they are good sources of vitamin C. L-ascorbic acid is the principal biological active form of vitamin C in plant foods and is oxidized to dehydroascorbic acid (DHAA) (Figure 4.10) which also has vitamin C activity. They are defined together making up the total vitamin C in food (Santos and Silva, 2008; Wechtersbach and Cigic, 2007)

During processing and storage, L-AA is known to be a very labile vitamin and is easily oxidized to DHAA, with subsequent irreversible hydrolysis to 2,3-diketoglutonic acid (DKGA). This leads to loss of vitamin C activity (Santo and Silva, 2008; Barros *et al.,* 2010; Lima *et al.,* 2010). Vitamin C is water soluble and hence, it is easily leached. Its stability varies as a function of temperature and presence of metal ions, oxygen and enzyme (AAO) activity and light (Davey *et al.,* 2000; Wechtersbach and Cigic, 2007; Santos and Silva, 2008). It is therefore as a result of its heat sensitive nature that led to the degradation of Vitamin C in the mango chunks during the canning process as it was exposed to high temperatures (Figure 4.9). This hence led to its decrease in content after canning. At the same time, leaching of the vitamin C occurred into the canning media (in this case, sugar solution). Howard *et al.* (1999) also reported the same observation.

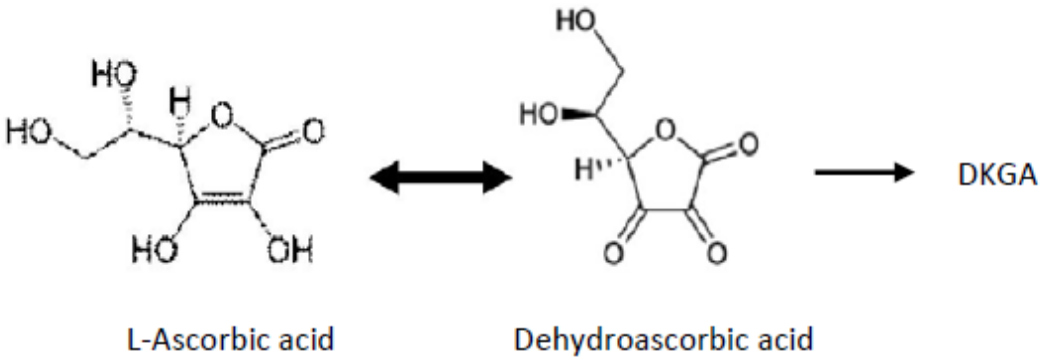


Figure 4.10 Structure of vitamin C and its conversion to diketoglutonic acid (DKGA)

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 **Conclusions**

i) Preservation methods used by mango farmers in Makueni County do not guarantee extension of shelf life.

ii) Gum arabic coating might be an effective local post-harvest treatment to extend shelf life while maintaining the nutritional qualities of mangoes during storage at room temperature. The mangoes coated can stay up to 15 days.

iii) Canning process is efficient in extending the shelf life of mangoes as it will make the fruits available throughout the year regardless of the season and it will also make it possible to store processed mangoes on shelves for several months without the need for refrigeration.

5.2 **Recommendations**

i) From this study, it is evident documenting research work will help provide reference for future researches

ii) Coating of whole mangoes by gum arabic needs to be adopted at the farm level as this would lead to their preservation. Further research can be done to determine the applicability of gum arabic on other tropical fruits.

iii) Canning technology is efficient in the preservation of mango chunks. It can be simplified in rural areas and can also be scaled up at the small and medium canning factories.

iv) More research should be done on the microbial and sensory qualities of mangoes coated with gum arabic and stored over a period of time and also, canned mango chunks stored for up to one year or more.

REFERENCES

Abe, K., Mathooko, F., Kiiyukia, C., Mwaniki, M., Mungai, C. and Koaze, H. (1997). *Surveillance of Postharvest Handling of Perishable Food Crops part I-case study of Kenya*.

Agricultural Business Development(ABD) (2011). *The Mango Sector in Eastern Kenya: Eastern Region Mango Census and Baseline Survey*. An Agricultural Business Development draft report validated at a stakeholders' forum, Nairobi, Kenya.

Ali, A., Maqbool, M., Ramachandran, S. and Alderson, P. G. (2010). Gum arabic as a novel edible coating for enhancing shelf-life and improving postharvest quality of tomato (*Solanum lycopersicum* L.) fruit. *Postharvest Biology and Technology*, *58*(1), 42-47.

Ali, B. H., Ziada, A., and Blunden, G. (2009). Biological effects of gum arabic: a review of some recent research. *Food and Chemical Toxicology*, *47*(1), 1-8.

Amwata, D. A. (2009). Climate Variability, Land-use and Livelihoods in Kiboko-Kibwezi observatory, Kenya. *Tunis: Observatoire du Sahara et du Sahel (OSS)*.

Azeez, O. S. (2005). Decolourization of gum Arabic using activated charcoal. *Leonardo Journal of Sciences*, *4*(7), 23-32.

Baker, I. (1991). Mango Quality Program. *Final Report for NT Horticultural Association, Mimeograph*.

Baldwin, E. A. (1994). Edible coatings for fresh fruits and vegetables: past, present, and future. *Edible Coatings and Films to Improve Food Quality*, *1*, 25.

Baldwin, E. A., Burns, J. K., Kazokas, W., Brecht, J. K., Hagenmaier, R. D., Bender, R. J., and Pesis, E. (1999). Effect of two edible coatings with different permeability characteristics on mango (Mangifera indica L.) ripening during storage. *Postharvest Biology and Technology*, *17*(3), 215-226.

Bally, I. S. (2006). *Mangifera indica* (mango). *Traditional Trees of Pacific Islands. Their Culture, Environment, and Use*, 441-464.

Barbosa, M. I. M. J., Borsarelli, C. D., and Mercadante, A. Z. (2005). Light stability of spray-dried bixin encapsulated with different edible polysaccharide preparations. *Food Research International*, *38*(8-9), 989-994.

Barlett, J. E., Kotrlik, J. W. and Higgins, C. C. (2001). Organizational research: Determining appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal*, *19*(1), 43

Barros, A. I. R. N. A., Silva, A. P., Gonçalves, B. and Nunes, F. M. (2010). A fast, simple, and reliable hydrophilicinteraction liquid chromatography method for the determination of ascorbic and isoascorbic acids. *Analyticaland Bioanalytical Chemistry*, 396, 1863-1875.

Bode, A. M., Cunningham, L., and Rose, R. C. (1990). Spontaneous decay of oxidized ascorbic acid (dehydro-L-ascorbic acid) evaluated by high-pressure liquid chromatography. *Clinical Chemistry*, *36*(10), 1807-1809.

Bosquez, E., Figueroa, S. C., Dominguez, J., Perez, L., Kerbel, C., and Diaz-de-Leon, F. (2000). Sap burn control by the application of different chemical compounds inmexican mango fruit with exportation quality. In *VI International Symposium on Mango509*,687-696.

Campbell, J. (1992). A guide to mangoes in Florida. Miami, Fairchild Tropical Garden, pp.227.

Cano, M. P. and De Ancos, B. (1994). Carotenoid and carotenoid ester composition in mango fruit as influencedby processing method. *Journal of Agricultural and Food Chemistry*, *42*, 2737-2742.

Carrillo-Lopez, A., F., Ramirez-Bushtamant, J.B., Valdez-Torres, R., Rojas-Villages and Yahi E. M.(2000). Ripening and quality changes in mango fruit as affected by coating with an edible film. *Journal of Food Quality*, *23*, 479-486.

Chen, B. H. and Huang, J. H. (1998). Degradation and isomerization of chlorophyll a and β-carotene as affectedby various heating and illumination treatments. *Food Chemistry*, *62*, 299-307.

Chen, J. P., Tai, C. Y. and Chen, B. H. (2007). Effects of different drying treatments on the stability of carotenoidsin Taiwanese mango (*Mangifera indica* L.). *Food Chemistry*, *100*, 1005-1010.

Cisneros-Zevallos, L. (2003). The Use of Controlled Postharvest Abiotic Stresses as a Tool for Enhancing the Nutraceutical Content and Adding-Value of Fresh Fruits and Vegetables. *Journal of Food Science*, *68*(5), 1560-1565.

Davey, M. W., Montagu M. V., Inzé, D., Sanmartin, M., Kannellis, A., Smirnoff, N., Benzie, I. J. J., Strain, J. J.,Favel, D. and Fletcher, J. (2000). Plant L-ascorbic acid: chemistry, function, metabolism, bioavailability andeffects of processing. *Journal of the Science of Food and Agriculture*, *80*(7), 825-860.

Dioha, I., Olugbemi, O., Onuegbu, T., and Shahru, Z. (2011). Determination of ascorbic acid content of some tropical fruits by iodometric titration. *International Journal of Biological and Chemical Sciences, 5*(5), 2180-2184.

El-Anany, A.M., Hassan, G.F.A. and Rehabali, F.M., (2009). Effects of edible coatings on theshelf-life and quality of Anna apple (*Malus domestica Borkh*) during cold storage. *Journal of Food Technology*. *7*, 5–11.

Elmanan, M., Al-Assaf, S., Philips, G.O., Williams, P.A., (2008). Studies of Acacia exudates gums: Part IV. Interfacial rheology of Acacia senegal and Acacia seyal. *Food Hydrocolloids22*, 682–689.

Fan, X., Blankenship, S. M., and Mattheis, J. P. (1999). 1-Methylcyclopropene inhibits apple ripening. *Journal of the American Society for Horticultural Science, 124*(6), 690-695.

FAO/WHO (Food and Agriculture Organization of the United States/World Health organization) (2004).Vitamins and mineral requirements in human nutrition. Report of joint FAO/WHO expert consultation. FAO,Rome: Bangkok, Thailand.

Fellows, P. (1988). Food processing technology principal and practice. Ellis Horwood Ltd., London, pp. 304-313.

Fellows, P. J. (2009). *Food processing technology: Principles and Practice,* 3rd Edition, Woodhead Publishing, Cambridge.

Franssen, L. R., and Krochta, J. M. (2003). Edible coatings containing natural antimicrobials for processed foods. In *Natural Antimicrobials for Minimal Processing of Foods* (pp. 250-262). Woodhead Publishing.

Gacula, M. and Singh, J. (1984). *Statistical Methods in Food and Consumer Research*, Orlando, Florida, Academic Press Inc.

García, J. M., Herrera, S., and Morilla, A. (1996). Effects of postharvest dips in calcium chloride on strawberry. *Journal of Agricultural and Food Chemistry, 44*(1), 30-33.

Gatambia, E (2006). *Assessment of potential and limitation of postharvest value addition of mango fruits in Eastern province*: A case study in Mbeere and Embu districts.In Transforming agriculture for improved livelihoods through agricultural product value chains. *Proceedings of the 12th KARI biennial scientific conference, Kenya Agricultural Research Institute, Nairobi, Kenya* (pp. 564-566).

Gathambiri, C.W., Karanja, C.N., and Kiiru, S.N. (2006). *Effects of Drying on the Quality of Mango Slices*. Proceedings of tenth Kenya Agricultural Research Institute Biennial Conference. Nairobi; Kenya.

Godoy, H. T. and Rodriguez-Amaya, D. B. (1987). Changes in individual carotenoids on processing and storageof mango (*mangifera indica*) slices and puree. *International Journal of Food Science and Technology*, 22(5),451-460.

Gor, C., Agong, S., Acheng, L., Akuno, W. and Andika, D (2012), the interface between mango value chain analysis and the socioeconomic determinants, *African Journal of Horticultural Science, 6*(1), 1-16.

Government of Kenya (GoK). (2010). Government of Kenya: *The Constitution of Kenya*. Revised Edition 2010 Published by the National Council for Law Reporting, Nairobi.

Griesbach, J. (2003). *Mango growing in Kenya*. World Agroforestry Centre, ICRAF, Nairobi, Kenya.

Guilbert, S. (1986). Technology and application of edible protective film's in food packaging and preservation: theory and practice. *Mathlouthi M.(ed).* . Elsevier Applied Science, New York, pp. 371–394.

Guin´e, R.P.F., Castro, J.A.A.M. (2002). Pear Drying Process Analysis: Drying Rates and Evolution of Water and Sugar Concentrations in Space and Time, *Drying Technology. 20*(7), 1515–1526.

Hadi, A. H., Elderbi, M. A., and Mohamed, A. W. (2010). Effect of gum arabic on coagulation system of albino rats. *International Journal of PharmTech Research, 2*, 1762-6.

Hoa, T. T. and Ducamp, M. N. (2008). Effects of different coatings on biochemical changes of 'cat HoaLoc' mangoes in storage. Postharvest Biology and Technology *48*(1), 150–152.

Hoa, T. T., Self, G., and Ducamp, M. N. (2010). Effects of hot air treatment on postharvest quality of 'cat Hoa loc'mangoes. *Fruits, 65*(4), 237-244.

Holzwarth, M., Wittig, J., Carle, R., and Kammerer, D. R. (2013). Influence of putative polyphenoloxidase (PPO)inhibitors on strawberry (*Fragaria* x *ananassa* Duch.) PPO, anthocyanin and color stability of stored purées.*LWT - Food Science and Technology Journal, 52*, 116-122.

Horticultural Crops Developing Authority (HCDA), (2010). Horticultural Crops Development Authority marketing newsletter, Issue No. 6, Vol. 5. Nairobi, Kenya. Available at http://www.hcda.or.ke/downloads/News%20Letters/june_2010.pdf.

Horticultural Crops Development Authority (HCDA), (2013). National Horticulture Validated Report 2013. Available at http://www.hcda.or.ke/Statistics/2013/Validated %20Horticulture%20Data%202013.pdf.

Howard, L. A., Wong, A. D., Perry, A. K., and Klein, B. P. (1999). β-Carotene and ascorbic acid retention in fresh and processed vegetables. *Journal of Food Science, 64*(5), 929-936.

Hussain, I., Zeb, A., Shakir, I., and Shah, A. S. (2008). Combined effect of potassium sorbate and sodium benzoate on individual and blended juices of apricot and apple fruits grown in Azad Jammu and Kashmir. *Pakistan Journal of Nutrition, 7*(1), 181-185.

IEA. (2010). *Youth Fact Book: Infinite Possibility or Definite Disaster*? Institute of Economic Affairs (IEA), Nairobi, Kenya.

Imeson, A. (2010). *Food Stabilisers, Thickeners and Gelling Agents*. Chichester, U.K.: Wiley-Blackwell Publishers.

Iqbal, S., Yasmin, A., Wadud, S., and Shah, W. H. (2001). Production, storage, packing and quality evaluation of guava nectar. *Pakistan Journal of Food Sciences (Pakistan)*.

Ishaq, M., Usman, M., Asif M., and Khan. I.A. (2004). Integrated pest management of mango against mealy bug and fruit fly. *International Journal of Agricultural Biology*, *6*: 452-454.

Islam, A. M., Phillips, G. O., Sljivo, A., Snowden, M. J., and Williams, P. A. (1997). A review of recent developments on the regulatory, structural and functional aspects of gum arabic. *Food Hydrocolloids, 11*(4), 493-505.

Jain, S. K. and Mukherjee, S. (2011). Enhancing keeping quality offruits in mango cv. Langra. *Indian Journal of Horticulture, 68*,142–144.

Jiménez-Atiénzar, M., Pedreño, M. A., Caballero, N., Cabanes, J. and García-Carmona, F. (2007). Characterization of polyphenol oxidase and peroxidase from peach mesocarp (Prunus persica L. cv. Babygold). *Journal of the Science of Food and Agriculture, 87*(9), 1682-1690.

Joel, D. M. (1980). Resin ducts in the mango fruit: a defence system. *Journal of Experimental Botany, 31*(6), 1707-1718.

Kader, A. A. (2002). *Postharvest Technology of Horticultural Crops* (3311): University of California Agriculture and Natural Resources.

Ketsa, S., and Prabhasavat, T. (1991). Effect of skin coating on shelf life and quality of'Nang Klangwan'mangoes. *Frontier in Tropical Fruit Research 321,* 764-770.

Khaliq, G., Mohamed, M., Ding, P., Ghazali, H. and Ali, A. (2016). Storage behaviour and quality responses of mango (*Mangifera indica L.*) fruit treated with chitosan and gum

arabic coatings during cold storage conditions. *International Food Research Journal, 23(Suppl),* S142-S142.

KNBS. (2009). Makueni District Multiple Indicator Cluster Survey 2008: Kenya National Bureau of Statistics (KNBS), Nairobi, Kenya.

Korbel, E., Attal, E., Grabulos, J., Lluberas, E., Durand, N., Morel, G., Goli, T. and Brat, P. (2013). Impact oftemperature and water activity on enzymatic and non-enzymatic reactions in reconstituted dried mango modelsystem. *European Food Research and Technology, 237*, 39-46.

Kramchote, S., Jirapong, C. and Wongs-Aree, C. (2008). Effects of 1-MCP and controlled atmosphere storage on fruit quality and volatile emission of 'Nam Dok Mai' mango. *Acta Horticulturae, 804,* 485-92.

Lalel, H. J., Singh, Z., and Tan, S. C. (2003). Aroma volatiles production during fruit ripening of 'Kensington Pride'mango. *Postharvest Biology and Technology*, *27*(3), 323-336.

Lamikanra, O. (2002). *Fresh-cut fruits and vegetables: science, technology, and market*: CRC Press.

Landrigan, M., Morris, S., Baker, I., Cole, S., and Kuppelweiser, W. (1991). Postharvest studies with mangoes. *Techical Annual Report 1989, 90*, 93-97.

Lechaudel, M and Joas, J. (2007). An overview of pre-harvest factors influencing mango fruit growth, quality and postharvest behavior. *Brazillian Journal of Plant Physiology, 19(4)*, 287-298.

Lemmens, L., Tchuenche, E. S., Loey, A. M. V. and Hendrickx, M. E. (2013). Beta-carotene isomerization inmango puree as influenced by thermal processing and high-pressure homogenization. *European Food Research Technology, 236*, 155-163.

Lichtenthaler, H. K. (1987). Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. *Methods in Enzymology, 148*, 350-382

Lim, T.K. and Kuppelweiser, W. (1993). Mango sapburn amelioration in theNorthern Territory. *Acta Horticulturae, 341*, 518-527.

Lima, J. R., Elizondo, N. J. and Bohuon, P. (2010). Kinetics of ascorbic acid degradation and colour change inground cashew apples treated at high temperatures (100-180 °C). *International Journal of Food Science and Technology, 45*, 1724-1731.

Loveys, B. R., Robinson, S. P., Brophy, J. J. and Chacko. E. K. (1992). Mango Sapburn: Components of fruit sap and their role in causing skin damage. *Australian Journal of Plant Physiology, 19*,449-457.

Luh, B. S., Woodroof, J. G., and Bors, L. (1975). *Commercial vegetable processing 2nd Edition,*New York, U.S.A, Van Nostrand Reinhold.

Majidi, H., Minaei, S., Almasi, M., and Mostofi, Y. (2011). Total soluble solids, titratable acidity and repining index of tomato in various storage conditions. *Australian Journal of Basic and Applied Sciences*, 5(12), 1723-1726.

Mandal, D., Sailo, L., Hazarika, T. K., and Shukla, A. C. (2018). Effect of edible coating on shelf life and quality of local mango cv. Rangkuai of Mizoram. *Research on Crops, 19(3)*, 419-424.

Masibo, M. and He, Q. (2009). Mango bioactive compounds and related nutraceutical properties-a review. *FoodReviews International, 25*, 346-370.

Mazumdar, B. C., and Majumder, K. (2003). *Methods on physicochemical analysis of fruits*. University College of Agriculture Calcutta University. pp. 108-109.

Mercadante, A. Z. and Rodriguez-Amaya, D. B. (1998). Effects of ripening, cultivar differences, and processingon the carotenoid composition of mango. *Journal of Agricultural and Food Chemistry, 46,* 128-130.

Meurant, N. (1991). Bowen mango field day. *Mango Care Newsletter*, *3*.

Mitra SK, Baldwin, E. A. (1997) Mango. In: Mitra SK (ed) Postharvest physiology and storage of tropical and subtropical fruits. CAB International, New York, pp 85–122.

MOA, (2001). *Annual report 2000*. Nairobi, Kenya: Ministry of Agriculture.

MOA, (2002). *Horticulture annual report 2001*. Nairobi, Kenya: Ministry of Agriculture.

Mocak, J., Jurasek, P., Phillips, G. O., Varga, S., Casadei, E., and Chikemai, B. N. (1998). The classification of natural gums. X. Chemometric characterization of exudate gums that conform to the revised specification of the gum arabic for food use, and the identification of adulterants. *Food Hydrocolloids, 12*(2), 141-150.

Motlagh, S., Ravines, P., Karamallah, K.A. and Ma Q. (2006). The analysis of Acacia gums using electrophoresis. *Food Hydrocolloids20*, 848–854.

Muchira, K., Gathambiri, W., Gitonga, J., Kamau, M., Njuguna, K., Kiiru, N., Muchui, N. and Munyaka, A. W., Oey, I., Loey, A.V. and Hendrickx, M. (2010). Application of thermal inactivation of enzymes during vitamin C analysis to study the influence of acidification, crushing and blanching on vitamin C stability in Broccoli (*Brassica oleracea L var. italica*). *Food Chemistry, 120,* 591-598.

Munyaka, A. W., Oey, I., Loey, A.V. and Hendrickx, M. (2010). Application of thermal inactivation of enzymesduring vitamin C analysis to study the influence of

acidification, crushing and blanching on vitamin Cstability in Broccoli (*Brassica oleracea L var. italica*). *Food Chemistry, 120,* 591-598.

Musyoka, S. N., and Mutia, G. M. (2016). The status of fish farming development in arid and semi-arid counties of Kenya: case study of Makueni County. *European Journal of Physical and Agricultural Sciences. South Eastern Kenya University, Kenya*.

Narayana, C.K., Pal R. K., and Roy S. K. (1996). Effect of pre-storage treatments and temperature regimes on shelf life and respiratory behaviour of ripe Beneshanmango. *Journal of Food Science and Technology* Mysore. *33*, 79-82.

Ndungu, J. M., Pole, F. N., and Katama, C. K. (2008). Value chain analysis: a case study of mangoes in Tana delta. In *Proceedings of the 11th KARI biennial scientific conference, Kari, Nairobi, Kenya*, pp. 10-14.

Nishikimi, M., Fukuyama, R., Minoshima, S., Shimizu, N. and Yagi, K. (1994). Cloning and chromosomalmapping of the human nonfunctional gene for L-gulono-ɤ-lactone oxidase, the enzyme for L-ascorbic acidbiosynthesis missing in man. *The Journal of Biological Chemistry, 269*(18), 13685-13688.

Okoth, E., Sila, D., Onyango, C., Musembi, W., and Mathooko, F. (2013). Evaluation of physical and sensory quality attributes of three mango varieties at three stages of ripeness, grown in lower Eastern Province of Kenya-part 1.

Olivas, G. I., and Barbosa-Cánovas, G. V. (2005). Edible coatings for fresh-cut fruits. *Critical Reviews in Food Science and Nutrition*, *45*(7-8), 657-670.

Pongener A, Mahajan B V C and Singh H. (2011). Effect of different packaging films on storage life and quality of peach fruits under cold storage conditions. *Indian Journal of Horticulture 68***,** 240–5.

Pott, I., Marx, M., Neidhart, S., Muhlbauer, W. and Carle, R. (2003). Quantitative determination of β-carotenestereoisomers in fresh, dried and solar-dried mangoes (*Mangifera indica* L.). *Journal of Agricultural and Food Chemistry, 51*, 4527-4531.

Rangana, S. (1979). *Manual of analysis of fruit and vegetable products*. Tata McGraw-Hill Publishing Company Limited, New Delhi.

Raoult-Wack AL (1994) Recent advances in the osmotic dehydration of foods. *Trends in Food Science and Technology, 5*, 255-260.

Rathore, H. A., Masud, T., Sammi, S., and Soomro, A. H. (2007). Effect of storage on physico-chemical composition and sensory properties of mango (*Mangifera indica* L.) variety Dosehari. *Pakistan Journal of Nutrition*, *6*(2), 143-148.

Riaz, R. A., Ali, A., and Saleem, M. (1989). Studies on the preparation and storage stability of comminuted kinnow fruit beverage base. *Pakistan Journal of Scientific and Industrial Research (Pakistan) 32*(8), 574-578.

Rock, C. L. (1997). Carotenoids: biology and treatment. *Pharmacology & Therapeutics*, *75*(3), 185-197.

Rodriguez-Amaya, D. B. (1999). Changes in carotenoids during processing and storage of foods. *ArchivosLatinoamericanos de Nutricion*, *49*(1-S), 38-47.

Rodriguez, E. B. and Rodriguez-Amaya, D. B. (2007). Formation of apocarotenals and epoxycarotenoids from b-carotenebychemical reactions and by autoxidation in model systems and processed foods. *Food Chemistry,101*, 563-572.

Rojas-Graü, M. A., Soliva-Fortuny, R., and Martín-Belloso, O. (2009). Edible coatings to incorporate active ingredients to fresh-cut fruits: a review. *Trends in Food Science & Technology*, *20*(10), 438-447.

Rose, J. K. C., Catala, C., Gonzalez-Carranza, Z. H. and Roberts, J. A. (2003). Cell wall disassembly. *Annual Plant Reviews*, *8*, 264–324.

Saengnil, K., Lueangprasert, K., and Uthaibutra, J. (2011). Sunlight-stimulated phenylalanine ammonia-lyase (PAL) activity and anthocyanin accumulation in exocarp of'Mahajanaka'mango. *Maejo International Journal of Science and Technology*, *5*(3), 365.

Sagar, V. R., and Kumar, P. S. (2010). Recent advances in drying and dehydration of fruits and vegetables: a review. *Journal of Food Science and Technology*, *47*(1), 15-26.

Sammi S., and Masud T. (2007). Effect of different packaging systems on storage life and quality of tomato (*Lycopersicon esculentum* var. Rio Grande) during different ripening stages. *Journal of Food Safety 9*, 37–44.

Santos, P. H S. and Silva, M. A. (2008). Retention of vitamin C in drying processes of fruits and vegetables – Areview. *Dry Technology*, *26*, 1421-1437.

Ščetar, M., Kurek, M. and Galić, K. (2010). Trends in Fruit and Vegetable Packaging – a Review. *Croatian Journal of Journal of Food Technology, Biotechnology and Nutrition*, *5*, 69-86.

Sharma, R. and Singh, R. (2000). Harvesting, postharvest handling and physiology of fruits and vegetables. *Postharvest Technology of Fruits and Vegetables, 1*, 94-147

Shiferaw, B. A., Obare, G. A., and Muricho, G. (2006). *Rural institutions and producer organizations in imperfect markets: Experiences from producer marketing groups in semi-arid eastern Kenya* (No. 577-2016-39211).

Simmons, S. L., Hofman, P. J., Whiley, A. W., and Hetherington, S. E. (1998). Effects of preharvest calcium sprays and fertilizers, leaf: fruit ratios, and water stress on mango fruit quality. In *ACIAR PROCEEDINGS* (Vol. 81, pp. 19-26). Australian Centre for International Agricultural Research.

Thinh, D. C., Uthaibutra, J. A. M. N. O. N. G., and Joomwong, A. D. I. S. A. K. (2013). Effect of storage temperatures on ripening behavior and quality change of Vietnamese mango cv. Cat Hoa Loc. *International Journal Biotechnoogy Research*, *3*, 19-30.

Vásquez-Caicedo, A. L., Schilling, S., Carle, R., and Neidhart, S. (2007). Effects of thermal processing and fruit matrixon β-carotene stability and enzyme inactivation during transformation of mangoes into puree and nectar. *Food Chemistry*, *102*, 1172-1186.

Vivas, N., Vivas de Gaulejac, N., Nonier, M. F., and Nedjma, M. (2001). Effect of gum arabic on wine astringency and colloidal stability. *Progres Agricole et Viticole (France) 118* (8), 175-176.

Wechtersbach, L. and Cigić, B. (2007). Reduction of dehydroascorbic acid at low pH. *Journal of Biochemical Biophysical Methods*, *70*, 767-772.

Wilberg, V. C. and Rodriguez-Amaya, D. B. (1995). HPLC quantitation of major carotenoids of fresh andprocessed guava, mango and papaya. *LWT - Food Science and Technology Journal*, *28* (5), 474-480.

Wills, R. B. H., Bambridge, P., and Scott, K. J. (1980). Use of flesh firmness and other objective tests to determine consumer acceptability of Delicious apples. *Australian Journal of Experimental Agriculture*, *20*(103), 252-256.

Yahia, E. M.(1998). Modified and controlled atmospheres for tropical fruits. *Horticultural Reviews-Westport then New York-*, *22*, 123-183.

Yaman, Ö., and Bayoındırlı, L. (2002). Effects of an edible coating and cold storage on shelf-life and quality of cherries. *LWT-Food science and Technology*, *35*(2), 146-150.

APPENDICES

Appendix 1: Mango value chain Baseline survey

The aim of this study is to identify social and governance issues that inhibit improvement of the performance of the mango value chain in order to develop a framework that can guide the commercial operators and policy makers to create environment for decent work and ensure socioeconomic development and sustainability

Section 1: General information

1. General information	
Name of the enumerator	
Date of interview	
County	
Sub-County	
Location	
Sub-Location	
Village	
GPS coordinates of farmer's residence	
Household Serial Number	
Name of the Team Leader	

Section 2: General household information

2.1. Name of respondent	
2.2. Respondent gender	1= Male [ ], 2 = Female [ ]
2.3. Is respondent head of household	1= Yes [ ], 2 = No [ ]
2.4. If no, relationship to household head	1= Spouse [ ], 2 = Son/daughter [ ], 3 = Parent [ ], 4 = Son/daughter in-law [ ], 5 = Sibling [ ], 6=Other relative [ ]
2.5. Educational level	1= Respondent [ ] 2= Household head[ ]
2.6. Age (years)	1= Respondent [ ] 2= Household head[ ]
2.7. Marital status	1= Respondent [ ] 2= Household head[ ]
2.8. Household size	1= No. of females[ ] 2= No. of males [ ] 3= No. below 15 [ ] 4= No. above 65years [ ]
2.9. Main occupation	1=Respondent [ ] 2= Household head[ ]

Codes

2.4 Relation to household:	**2..7 Marital status:**	**2.5 Education level:**	**2.9 Occupation:**
1= Spouse [ ], 2 = Son/daughter [ ], 3 = Parent [ ], 4 = Son/daughter in-law [ ], 5 = Sibling [ ], 6=Other relative [ ]	1=Married living with spouse, 2=Married but spouse away, 3=Divorced/separated, 4=Widow/widower, 5=Not married, 6=Other (specify)……..	1=No formal education, 2=Primary), 3=Secondary, 4= Post-Secondary 5=University level) 6= Other(indicate)	1=None, 2=Farming, 3=Salaried employment, 4=Self-employed off-farm, 5 =Farm worker, 6= Off-farm worker, 7=Casual, 8=Housekeeping, 9=Other (Specify)_____

Section 3: Decision making in the household

3.1 Who takes decisions in allocating land for mango production? 1= HHD Head, 2=Spouse, 3=Children, 4.All HHD members, 5= Others (Specify)….

3.2 Who takes decisions in processing of Mangoes? 1= HHD Head, 2=Spouse 3=Children, 4.All HHD members, 5= Others (Specify)….

3.3 Who takes decisions in marketing Mangoes? 1= HHD Head, 2=Spouse, 3=Children, 4.All HHD members, 5= Others (Specify)….

3.4 Who takes decisions in using proceeds from mango sales? 1= HHD Head, 2=Spouse, 3=Children, 4.All HHD members, 5= Others (Specify)….

Section 4: Mango Crop production

4.1 List in order of importance 3 major varieties that you grew last year (Jan-Dec 2017)

.

Crop	Season one			Season 2		
	Acreage	Yield (kgs/bags/acre)	Purpose	Acreage	Yield (kgs/bags /acre)	Purpose

Input use in mango production (Jan-Dec 2017)

4.2 Area under mango trees (acres)	
4.3 Main cropping system (1 = Monocrop , 2 = Intercrop* 3= Mixed cropping)	
4.4 Land preparation (consider an acre)	
4.4.1 Method of land preparation (1= Using oxen, 2 = Using tractors, 3 = Using manual labor	
4.4.2. If using **oxen** (1 = Own, 2 = Hired)	
4.4.3 Total cost of preparation in Shs per acre in 2016	
4.4.4 If **manual** labor,type (1 = Family, 2 = Hired, 3=both)	
4.4.5 Gender predominantly involved (1 = Male, 2 = Female, 3=Children, 4= Both male and female, , 5 = all members))	
4.4.6 Number of males (hired____, family_____)	
4.4.7 Number of females (hired_____, family_____)	
4.4.8 Average man days spent per acre	
4.4.9 Average payment per man day	
4.5. Yield (kgs)	
4.5.1.Quantity produced in kgs/acre	
4.5.2. Proportion consumed at home in kgs	

4.5.4. Proportion given out in kgs	
4.5.5. Proportion lost	
4.5.6. Proportion sold	
4.5.7. Price per unit kg ***(in Shs)***	

*State the proportions

Section 5: Mango production constraints

5.1. Constraint	5.2. Rank of constraint (1=Mild, 2=Severe, 3=Very severe, 4= Not a problem)	5.3. Major coping mechanism
1=Low soil fertility		
2=Pests		
3=Diseases		
4=Weeds		
5=Vermins		
6=Lack of improved crop varieties		
7=Lack of access to inputs		
8=High cost of inputs		
9=High climate variability		
10=Small land holding		
11=Lack of labor		
12=Lack of markets		
13=Lack of information		
14=Others (specify)_____		

Section 6: Value addition along the mango value chain

Question	*Indicate methods/tools used*	Indicate tools used
Do you undertake any mango value addition		
Cleaning		
Sorting		
Transporting		
Ripening		
Storage		
Other specify		
6.1. What problems do you face during storage of mango? 1. Pests 2. Molds 3. Thieves 4. Bad weather 5. Others (specify), 6.2. If pests , name the storage pests in order of importance		
6.3. Proportion lost during harvesting		
6.4. Do you package your mango fruits? 1=Yes 2=No 6.5. If yes, how are the products packaged (packaging materials)? 1= bags , 2= Plastic bags 3=plastic containers , 4=Metallic containers, 5=other specify_)		
6.6. How is the spoilt mango fruit used? Manure, 2= Animal feeds 3 =other specify_)		

Section 7 A. Sales of Mango fruits during the last 1 year (Jan-Dec 2017)

7.1 Where do you normally sell your fresh Mango?

Farm gate (01) _ _ _ Rural market (02) _ _ _ Urban market (03) _ _ _ Both 01 and 02 (04) _ _ _ _ Both 01 and 03 (05) _ _ _ _ Both 02 and 03 (06) _ _ _ _

7.2 Who buys your fresh mango fruits? 1=Institutions, 2=Wholesalers, 3=Retailers, 4=Consumers, 5=Processors, 6=Others(specify)

7.3 How do you determine the price at which you sell your mangoes? 1 negotiation [ ] 2 buyer determines [ ] 3 broker determines [ ] 4 Other, specify [----------]

7.4 How are you paid for the mangoes you sell 1 Cash on spot[ ],2 Cash Mpesa[ ] 3 Credit[ ] 4 Cheque[ ]

7.5 Where do you normally sell your processed products?

Farm gate (01) _ _ _ Rural market (02) _ _ _ Urban market (03) _ _ _ Both 01 and 02 (04) _ _ _ _ Both 01 and 03 (05) _ _ _ _ Both 02 and 03 (06) _ _ _ _

7.6 If you sold your mango fruits away from the farm, how did you transport them to the market?

Codes: 1=Vehicle, 2= Bicycle, 3= Motorcycle, 4= Animal draught power, 5= Human (on the head/back), 6= Boat, 7= Wheel burrow/carts, 8=other (specify)

7.7 How far is the nearest market where you sell your mango from your home? _ _ _ _ _ _ _ _km

7.8 How much time do you take to get to the nearest market? _ _ _ _ _ _

7.9 How is marketing done? 1 = Individual, 2 = Group marketing,

7.10 Who markets the mangoes? 1= HHD Head, 2=Spouse, 3=Children, 4.All HHD members, 5= others (Specify)….

7.11 Who sets the product prices? 1= HHD Head, 2=Spouse, 3=Children, 4.All HHD members, 5= others (Specify)….

7.12 Do you have contract arrangements with the buyers? 1 = Yes [ ], 2 = No [ ]

7.13 If yes, what type of contracts? 1 = Signed contract 2 = Informal/word of mouth 3 = other (specify)

7.14 who negotiated for the supply contracts?

7.15 Do you experience challenges in marketing your mango fruits? Yes (01) _ _ _ _ No (2) _ _ _ _

7.16 If yes, what challenges do you encounter?

7.17 .1 Constraint	7.18.2. Rank of constraint (1=Mild, 2=Severe, 3=Very severe)	7.19.3. Coping mechanism
1=Poor roads		
2= high transport costs		
3=low prices		
4=low demand		
5= Poor storage facilities		
6=Lack of markets		
7=high rate of spoilage of cassava		
8=High processing costs		
9=Lack of market information		
10=High local taxes (road taxes and market dues)		
11=Unorganized farmers		
12=Thieves		
13=Others (specify)_____		

Section 8: Preservation

8.1 At what point do you preserve the mangoes? _____

_____

_____

8.2 How do you preserve them? _____

_____

_____

_____

8.3 How long do the preserved mangoes stay?_____

8.3(b) Does the preservation method add value to the mangoes?_____

_____

8.4 What are the costs incurred during the preservation?_____

8.5 What are the challenges encountered with the preservation method (s) used?_____

_____

_____

_____

8.6 Where did they learn the preservation method (s) from?_____

_____

_____

8.7 How is the environment contributing to the mode of preservation method (s) used?___

_____

_____

_____

8.8 Do you encounter losses in the process?_____

8.8 (b) If yes, what are the quantities lost?_____

8.8 (c) What could be the causes for the losses? _____

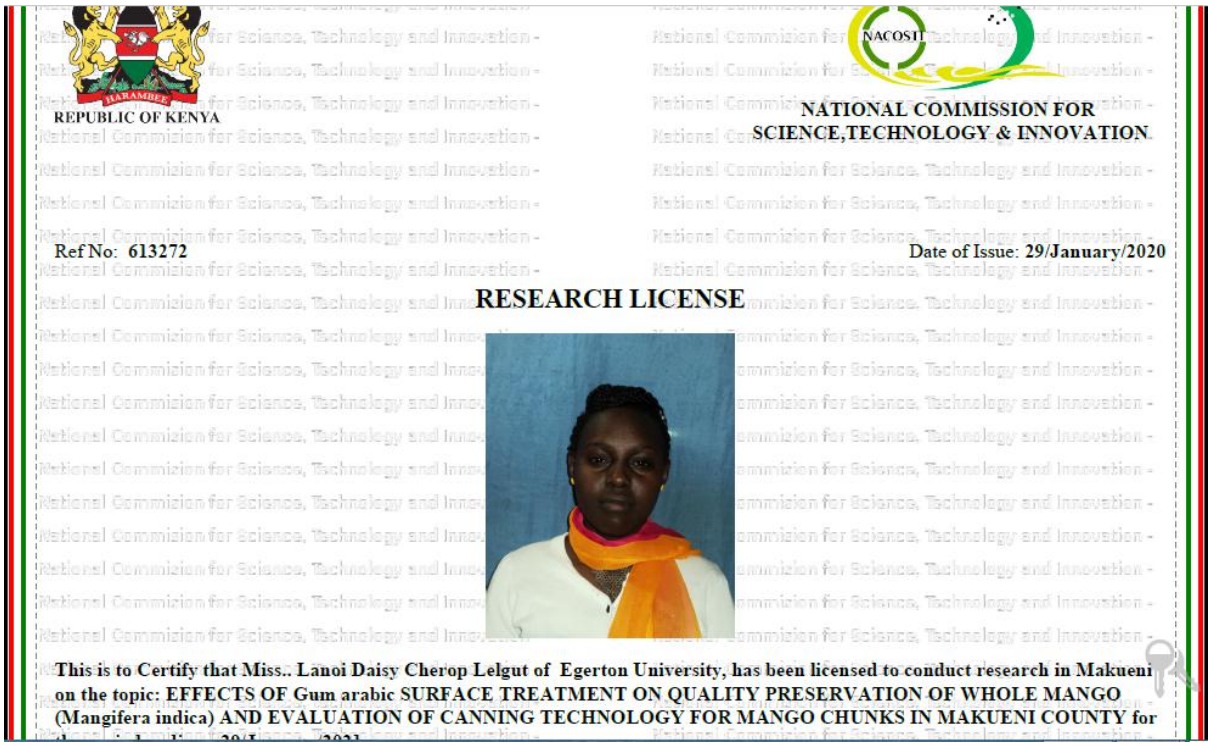
_____

_____

_____

_____

Appendix 2: NACOSTI Certificate



REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 613272

Date of Issue: 29/January/2020

RESEARCH LICENSE

This is to Certify that Miss.. Lanoi Daisy Cherop Lelgut of Egerton University, has been licensed to conduct research in Makueni on the topic: EFFECTS OF Gum arabic SURFACE TREATMENT ON QUALITY PRESERVATION OF WHOLE MANGO (Mangifera indica) AND EVALUATION OF CANNING TECHNOLOGY FOR MANGO CHUNKS IN MAKUENI COUNTY for

Appendix 3. Research Paper

J Food Sci Technol
https://doi.org/10.1007/s13197-019-04032-w

ORIGINAL ARTICLE

Effect of edible gum Arabic coating on the shelf life and quality of mangoes (*Mangifera indica*) during storage

Lelgut Lanoi Daisy[1] · **John Masani Nduko**[1] · **W. Matofari Joseph**[1] · **S. Mulwa Richard**[2]

Revised: 4 July 2019 / Accepted: 13 August 2019

Abstract This study evaluated the effect of treatment with gum Arabic edible coatings on shelf life and quality parameters of mangoes during 20 days at room temperature. Apple variety of mangoes of uniform size were obtained from small holder farms in Makueni County, Kenya and dipped in various concentrations of gum Arabic solutions [0, 10, 15 and 20% (w/v)] for 1 h, ensuring the coating solution uniformly covered the surface. Control fruits were dipped in distilled water only. The fruits were then air-dried on trays, packed in cardboard boxes and stored at room temperature (23 ± 2 °C) and normal relative humidity (45–60%). Changes in weight loss, ascorbic acid content, ß-carotene, total soluble solids (TSS), titratable acidity (TA) and pH were determined using standard methods. Gum Arabic coatings (all levels) significantly ($p < 0.05$) reduced weight loss, delayed increase in TSS and development of ß-carotene, while retaining ascorbic acid in the mangoes during storage compared to the controls. Gum Arabic treatments resulted into higher TA that corresponded with low pH in the mangoes compared to the control. Ripening was slower with gum Arabic treatments and a shelf life of 15 days was obtained for gum Arabic-treated mangoes compared to less than 10 days for the control. Gum Arabic coatings demonstrated gas and water vapour barrier properties, hence extending the shelf life of mangoes while maintaining quality. Gum Arabic treatment can therefore serve as an alternative preservation method for mangoes at farm and transit levels without affecting quality parameters; giving farmers more revenue and reducing post-harvest losses.

Keywords Gum Arabic · Mangoes · Post-harvest losses · Edible coatings

Introduction

The mango (*Mangifera indica*), among the tropical fruits, has great market potential in the fresh form due to its sensorial characteristics and difficulty for immediate consumption. Fresh mangoes are highly appreciated for their flavour, taste, pleasant aroma and nutritional value (Shahnawz et al. 2012). The relatively short ripening period and reduced post-harvest life are however, the limiting factors influencing the economic value and utilization of mangoes in the tropics (Narayana et al. 1996). Mangoes are climacteric fruits; they cannot be preserved for long periods after harvesting at room temperature as they ripen within 2–10 days after harvest (Amin et al. 2008). During ripening, a series of metabolic activities occur resulting to chemical changes, increased respiration, change in structural polysaccharides leading to fruit softening, degradation of chlorophyll and carotenoids biosynthesis, starch hydrolysis to sugars hence ripening of fruits with softening of texture to acceptable quality (Herianus et al. 2003)

Appendix 4. Certificate of conference paper presentation

FOOD SCIENCE & TECHNOLOGY
PLATFORM OF KENYA

Certificate of Attendance

This certificate is awarded to

Daisy Lanoi Lelgut

for attending and presenting an oral paper in **The 2nd FoSTeP-K Conference themed 'Industrial Innovation and Research for Food Safety in Africa.'** held on 2nd - 3rd, October 2019 in Nairobi Kenya

Nicanor Odongo
Secretary General
FoSTeP-K

This certificate is issued without any alteration whatsoever

Dr. George Ooko Abong'
Chairman
FoSTeP-K