COMPARATIVE STUDY ON THE EFFECTIVENESS OF SODIUM METABISUPHITE, ACETIC ACID AND LEMON JUICE IN PRESERVATION OF DRIED MANGOES AND TOMATOES

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN FOOD QUALITY AND SAFETY ASSURANCE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2015

ABSTRACT

Mango and tomato are widely grown in the World. The present study was carried out to compare the effectiveness of three preservatives in retaining their quality attributes of mango and tomato and substituting the use of sodium metabisulphite with either the lemon juice or acetic acid. The three preservatives were sodium metabisulphite (0.1%), acetic acid (0.5%) and lemon juice (0.5v/v) studied at the respective level in bracket. Mango and tomato slices were dried in the walk - in solar dryer to attain the moisture range of 17 – 22% and packed in polythene package. The Completely Randomized Design (CRD) was used to assess the effectiveness of three preservatives while Randomized Complete Block Design (RCBD) was used in sensory evaluation test. Both descriptive and consumer test by the use of trained and untrained panelist respectively were done to assess the sensory profile and consumer acceptability. Microbial analysis for the total bacteria count and shelf life prediction by using linear model equation at different storage temperatures (35 and 45^{o}C) were carried out. The results showed that sodium metabisulphite and lemon juice were the best in retaining the sensory attributes assessed. The reduction of microbial load for all the three types of preservatives was promising as they all lied within the acceptable values. The extensions of shelf life of the dried products were best achieved using sodium metabisulphite and lemon juice as they had longer shelf life than acetic acid treated samples, the results showed mango treated with sodium metabisulphite and lemon juice is shelf stable for 501 days while the one treated with acetic acid was shelf stable for 457 days at 25^{o}C. The results also showed that mango have longer shelf life ($1^{1/}2$ years) than tomato ($^{1}/2$ year) at 25^{o}C and 28^{o}C. The use of lemon juice was encouraged due to its effectiveness, cheapness, availability and positive health effects to the human body.

DECLARATION

I, Joel Mhanga do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution for a degree award.

Joel Mhanga **Date**

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The above declaration is confirmed;

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ACKNOWLEDGEMENTS

My sincere appreciation goes to my supervisor, Prof. B. Chove, who guided me right from the time of proposal development to the end of this study. I am grateful to Mbeya University of Science and Technology (MUST) for giving me this opportunity to study, I am also thankful to Government of Tanzania for proving the scholarship through the Higher Education Students Loan Board (HESLB). Special thanks also go to Professors B. Chove, B. Ndabikunze and Dr. Anna Temu for giving me an opportunity to be attached to their DANIDA PROJECT. I also thank Mr S. Mwanyika, Mama Mapunda and Mama Mbije, for their tireless support, advice and encouragement during the research period. All my colleagues, especially, Joseph Runyogote, Anna Mhalu and Honi Buzo. You were always there for me whenever things would become tough, but also encouraging me during all the time of my research work. In fair honesty, it is impossible to mention everyone. I am immensely indebted for their help in and outside of the study, but to those I didn’t mention, thank you and may all be blessed.

DEDICATION

This work is dedicated to my lovely wife Diana Mwangoka who despite her loneliness has always been my source of inspiration and happiness, to my mother Conjetha Lunyungu my father Aaron Mhanga, my beloved children Emmanuela, Jonathan and Jackson and my friend Zaharan Mgina whose support and motivation enabled me to conduct and complete this study.

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LIST OF ABBREVIATIONS AND SYMBOLS

AOAC	Association of Official Analytical Chemists
ATP	Adenosine triphosphate
BC	Before Christ
BHA	Butylated hydroxyanisole
BHT	Butylated hydroxytoluene
CFU	Colony forming unity
DNA	Dioxy ribonucleic Acid
FAO	Food and Agriculture Organization
FDA	Food and Drug Adminstration
ISO	International Organization for Standardization
MAFC	Ministry of Agriculture and Food Cooperatives
NACl	Sodium Chloride
PC	Principal Component
PCA	Principal Component Analysis
PPO	Poly phenol oxidase
RNA	Ribose nucleic Acid
SD	Standard deviation
TBHQ	Tert – Butyl hydroquinone
TBS	Tanzania Bureau of Standards
URT	United Republic of Tanzania
USAID	United States of America Agency for International Development
USDA	United States of America Dietary Agency
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Tomato (*Lycopersicon esculentum*.); one of the basic foods in most societies in the World (Naika *et al.*, 2005). It is either consumed raw to maximize the nutritional usefulness, or used as an additive to vegetables to improve taste and colour (Perumal, 2007). It is also processed and packed as tomato paste, tomato sauce, tomato ketchup, tomato juice, tomato concentrate, chili sauce, tomato puree, tomato chutney (Takeoka *et al.*, 2001). Tomatoes are now eaten freely throughout the World. They contain the carotene lycopene, one of the most powerful natural antioxidants. In some studies, lycopene, especially in cooked tomatoes, has been found to help prevent prostate cancer (Stevens and Rick, 1986). Tomato varieties are also rich in health valued food components such as ascorbic acid (vitamin C), vitamin E, folate and dietary fibre (Davies and Hobson, 1987).

The mango (*Mangifela indica*) or "Indian mango" grows well under (warm) tropical and sub-tropical climates with long and dry season (over three months) followed by sufficient rains (Morton,1987). They are grown over 60 countries and account for about fifty percent of the tropical fruits produced and traded worldwide, with India, Pakistan, South China and Malaya being the main producers (Hussain *et al.*, 2002). The growing demand in Europe can be explained by their exotic reputation, its healthiness (Vitamin A and C), energy (carbohydrates) and its role in maintaining healthy blood sugar levels (Ajila *et al.*, 2010). In the Middle-East (especially in the United Arab Emirates) the religious control on alcohol increases the demand for fruit-juices (mango often being the most popular juice) (Dazydelian, 2008). The mango fruit can be eaten as ripe or processed into a range of products such as juices, jams, pulps, achars, chutney and others. The unripe green fruit can also be eaten or processed into different products (Bally, 2006).

Among the major challenge facing production and marketing of fruits and vegetables is the rapid quality deterioration, reduced shelf-life (Ramos *et al*., 2013; Siddiqui *et al*., 2011; Allende *et al*., 2004) and seasonality (Idah and Aderibigbe, 2007). The quality deterioration of fruits and vegetable leads into undesirable changes which are characterized by changes in color, texture, flavour, and nutritive value (Kader, 2005). Overall, the management of these quality challenges may result in reductions in availability, edibility, quality as well as wholesomeness, contributing to the incidence of postharvest food losses and subsequent financial losses (Mahajan *et al*., 2014; Kader, 2005). The post-harvest loss for fruit and vegetable in developing countries is estimated to be 30-40% (Karim and Hawlader, 2005). Some of the major factors contributing to these post-harvest losses are inadequate post-harvest handling, lack of appropriate processing technology, poor storage facilities and poor infrastructures (Perumal, 2007). High levels of postharvest losses coupled with increasing global market demand for fruits and vegetables press the need for appropriate postharvest technologies to reduce quality loss and extend shelf-life of whole and minimally processed produce (Kader, 2005).

One way by which this can be achieved is through the use of chemical preservatives. These chemicals are substance of no nutritional significance (Joshua, 2000). They are added to foods as antimicrobial agents to preserve them from deterioration and extend shelf life (Jay, 2005). However these chemicals should not have toxic effect on human cells (Mahindru, 2000). Furthermore, it has to be economical and should not have an effect on taste and aroma of the original food or any substance in food nor encourage the development of resistance strains. Most preservatives are inhibitory at acceptable level (Frazier and Weshtoff, 2002).

As one of the most promising postharvest technologies to reduce food losses and retain food qualities researchers have examined various aspects of the application of chemicals. The most common classical preservative agents are the weak organic acids, for example acetic lactic, benzoic and sorbic acid. These molecules inhibit the outgrowth of both bacterial and fungal cells and sorbic acid is also reported to inhibit the germination and outgrowth of bacterial spores (Sofos and Busta, 1981; Blocher and Busta, 1985). Some acids and salts are effective inhibitors of microbial growth and are intentionally added to many foods as preservatives. Other acids are added to food to prevent or delay the growth of the pathogenic bacteria (Dziezak, 1986). In solution, weak acid preservatives exist in a pH-dependent equilibrium between the undissociated and dissociated state. Preservatives have optimal inhibitory activity at low pH because this favours the uncharged, undissociated state of the molecule which is freely permeable across the plasma membrane and is thus able to enter the cell and therefore, the inhibitory action is classically believed to be due to the compound crossing the plasma membrane in the undissociated state (Booth and Kroll, 1989). However the benefits and safety of many artificial food preservatives is the subject of debate among academics and regulators specializing in food science, toxicology, and biology. Natural food preservatives are highly encouraged as they are safe when used in preservation (Daniel, 2007). Therefore, this study was carried out to assess the effectiveness of chemical and natural preservatives in preserving fruits and vegetables (tomatoes and mangoes) in order to promote their application in food processing industry so as to reduce food losses and increase the availability throughout the year.

1.2 Problem Statement and Justification

Despite the numerous advantages for preservation, sodium metabisulphite is very expensive in Tanzania (500g ranges from Tsh. 40 000 to 65 000) and hence most of the small food processors fail to afford it, in addition the literature demonstrate it as being associated with a number of biotic problems among which are allergic reactions in certain sulfite-sensitive individuals, resulting in broncho constriction, shortness of breath, wheezing, coughing, gastrointestinal disturbances, rapid swelling of the skin, flushing, tingling sensations and shock. Again the uses of sodium metabisulphite have been associated with the prevention of some of the vitamin B eaten from being made available to the body. Lack of vitamin B_1 causes many ill-effects. Sodium metabisulphite also causes calcium deficiency in the body when it is consumed with the food (Dean *et al.*, 2003).

On the other hand, the use of acetic acid and lemon juice i.e. natural citric acid is thought to be cheaper compared to the use of sodium metabisulphite. The use of acetic acid and flesh lemon juice will also reduce the number of biotic health problems as noted when using sodium metabisulphite and hence making consumers having a wide choice of product varieties. However, there is little information on the scope and effectiveness of acetic acid and lemon juice in food preservations.

There is a need therefore to investigate and compare the effectiveness of sodium metabisulphite acetic acid and lemon juice in food preservation. The information obtained from this study will be useful to the small scales food processors as well as the consumers.

1.3 Objectives of the Study

1.3.1 General objective

To determine the effectiveness acetic acid and lemon juice as substitutes for sodium metabisulphite in retaining the quality and safety attributes of dried tomatoes and mangoes.

1.3.2 Specific objectives

i. To assess the organoleptic attributes of dried tomato and mango preserved by the acetic acid and lemon juice.

ii. To assess the microbial stability of dried tomato and mango preserved by the acetic acid and lemon juice.

iii. To predict the shelf life of dried tomato and mango preserved by the acetic acid and lemon juice.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction to Fruits and Vegetables

Fruit and vegetables are rich sources of micronutrients, fibers, vitamins and high contents of phytochemicals such as anthocyanins, carotenoid, polyphenols and flavonoids which have been reported to possess antioxidant properties. This makes them important components of the daily human diet (Rico *et al*., 2007; Allende *et al*., 2006). Consumption of fruits and vegetables is associated with a number of nutritional and health benefits, and is highly recommended as health diets to fight against inactive life style and degenerative diseases such as cancer, cardiovascular diseases and ageing (Ramos *et al*., 2013; Rico *et al*., 2007).

According to FAO/WHO (2003) up to 2.7 million lives could potentially be saved each year by with sufficient intake of fruits and vegetables. Fruits can be defined in several ways; botanically fruits are the mature ovaries of the plant with their seeds. The definition includes all grains legumes nuts and seeds and the common vegetable-fruits such as cucumber olives, peppers and tomatoes. When the culinary role is considered fruits can be defined as the flesh edible part of plant, trees, bushy or vine that usually eaten or served as a dessert and has a sweet taste. Fruits are higher in organic acids and sugar than vegetable (Vaclavik and Christina, 2008). They can be used as breakfast beverage or side-dish, lunch side dish or dessert, snack food between meals or dinner dessert. Raw and canned fruits are also used as appetizers, salads ingredients and side dishes (International Agency for Research on Cancer, 2003).

Vegetables are the edible succulents' parts of plants; they can be consumed raw or cooked, generally with a main dish, in a mixed dish, as appetizer or in a salad (Vaclavik and

Christina, 2008). Vegetable include edible stems and stalks, roots, tubers, bulb, leaves flowers. Since the definition of vegetables generally centres on its use, a plant may be a vegetable in one country but a fruit, weed, an ornamental or medicinal plant in another country depending on the crop. For example tomato is a vegetable in Asia but fruit in Europe (Asian Vegetable Research and Development Center, 1990). Fruits and vegetables may be processed into beverages or vegetable starches, eaten fresh or lightly processed, dried, pickled or frozen. They impart their own characteristics flavour, colour and texture to the diets and undergo changes during storage and cooking (Vaclavik and Christina, 2008).

A wide range of fruits and vegetable are grown in Tanzania climatic conditions (Ngereza *et al*., 2007). The common fruits grown are pineapples, passion, citrus fruits, mangoes, pears, bananas and peaches, while the vegetable commonly grown include the spinach, cabbage, tomatoes, okra, amaranths’, Chinese, onions and others (Ministry of Agriculture and Food Cooperative, 2009). However the study will only concentrate on mango fruit and tomato vegetable.

2.1.1 Mango (*Mangifera indica*)

The mango is a juicy stone fruit belonging to the genus *Mangifera*, consisting of numerous tropical fruiting trees, cultivated mostly for edible fruit. The majority of these species are found in nature as wild mangoes. They all belong to the flowering plant family *Anacardiaceae*. The mango is native to South and Southeast Asia, from where it has been distributed worldwide to become one of the most cultivated fruits in the tropics. The center of diversity of the *Mangifera* genus is in India (Morton, 1987).

Mangoes are originated in Indian subcontinent (present day India and Pakistan) and Burma (Kostermans and Bompard, 1993). It is the national fruit of India, Pakistan, and the

Philippines, it is the national tree of Bangladesh. Mangoes have been cultivated in South Asia for thousands of years (Ensminger, 1994) and reached East Asia between the fifth and fourth centuries BC. By the 10th century AD, cultivation had begun in East Africa (Ensminger, 1994).

Mangoes are popular due to excellent flavor, delicious taste and high nutritive value (shahnawz *et al*., 2009). There are over 1000 different varieties of mangoes throughout the world (Bally, 2006). Mangoes are widely used in cuisine, they can be processed in a range of products such as achars, chutneys, jams, pulps, and juices and canned frozen or dried. Sour unripe mangoes are used in chutneys, *athanu*, picklesside dishes, or may be eaten raw with salt, chili, or soy sauce (Devika, 1995).

The 14th-century Moroccan traveler Ibn Battuta reported it at Mogadishu (Watson, 1983). Cultivation came later to Brazil, the West Indies, and Mexico, where an appropriate climate allows its growth (Ensminger, 1994). The mango is now cultivated in most frost-free tropical and warmer subtropical climates; almost half of the world's mangoes are cultivated in India alone, with the second-largest source being China (Devika, 1995) Mangoes are also grown in Andalusia, Spain (mainly in Málaga province), as its coastal subtropical climate is one of the few places in mainland Europe that allows the growth of tropical plants and fruit trees. The Canary Islands are another notable Spanish producer of the fruit. Other cultivators include North America (in South Florida and California's Coachella Valley), South and Central America, the Caribbean, Hawaii, south, west, and central Africa, Australia, China, Pakistan, Bangladesh, and Southeast Asia. Though India is the largest producer of mangoes, it accounts for less than 1% of the international mango trade; India consumes most of its own production (USAID-India, 2006).

The Food and Agriculture Organization of the United Nations estimates worldwide mango production at 42 million metric tons in 2012. India is the largest producer of mangoes with 36% of the world's production. Mango being a highly perishable fruit possesses a very short shelf life and reach to respiration peak of ripening process on third to fourth day after harvesting at ambient temperature (Narayanan *et al*., 1996). The shelf life of mango varies among its varieties depending on storage conditions. This short Shelf life seriously limits the long distance commercial transport of this fruit (Gomer-Lim, 1997). Usually after harvesting the ripening process in mature green mango takes nine to twelve days (Herianus *et al*., 2003).

In Tanzania mangoes are grown in all regions with the total area under cultivations of 99176 hectares and annual average production of 342.5 thousands metric tons per year (United Republic of Tanzania, 2006). The tree of mango normally bears the fruit after 4 to 6 years of plantations, it requires hot dry periods to set and produce a good crop. The varieties grown in Tanzania are the Sindano, Dodo, Bolibo, Mawazo, Muyini and others (MAFC, 2009).

- **Mango compositions**

Fresh mango contains a variety of nutrients, but only vitamin C and folate are in significant amounts of the Daily Value as 44% and 11%, respectively (United States of America Dietary Agency, 2010). Mango is also a good source of dietary fiber, vitamin C, and provitamin A carotenoid (Ajila *et al*., 2010). Numerous phytochemicals are present in mango peel and pulp, such as the triterpene, lupeol which is under basic research for its potential biological effects (Chaturvedi *et al.,* 2008) An extract of mango branch bark called Vimang, containing numerous polyphenols (Rodeiro *et al*., 2006) has been studied in elderly humans (Pardo-Andreu *et al*., 2006). Mango peel pigments under study include carotenoid, such as the provitamin A compound, beta-carotene, lutein and alpha-carotene(Gouado *et al.,* 2007; Berardini *et al.,* 2005) and polyphenols, such as quercetin, kaempferol, garlic acid, caffeic acid, catechins and tannins(Mahattanatawee *et al*., 2006; Singh *et al*., 2004). Mango contains a unique xanthonoid called mangiferin (Andreu *et al*., 2005).

Phytochemicals and nutrient content appears to vary across mango cultivars (Rocha Ribeiro *et al*., 2007). Up to 25 different carotenoid have been isolated from mango pulp, the densest of which was beta-carotene, which accounts for the yellow-orange pigmentation of most mango cultivars (Chen *et al*., 2004). Mango leaves also have significant polyphenols content, including xanthonoid, mangiferin and garlic acid (Barreto *et al*., 2008).

The flavor of mango fruits is constituted by several volatile organic chemicals mainly belonging to terpene, furanone, lactone, and ester classes. Different varieties or cultivars of mangoes can have flavor made up of different volatile chemicals or same volatile chemicals in different quantities (Pandit *et al*., 2009; Macleod and Pieris, 1984).

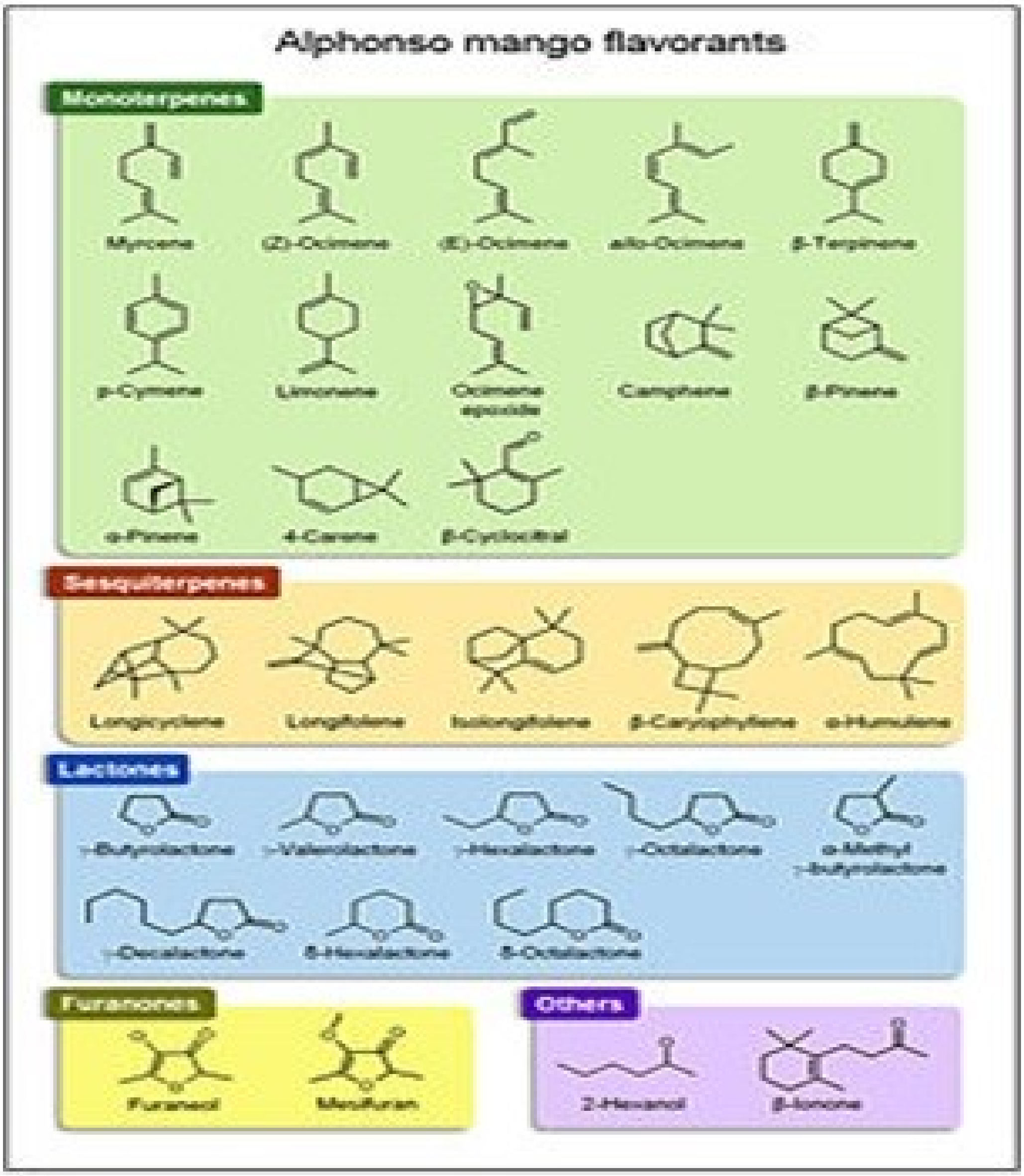

Figure 1: Major flavour chemicals of 'Alphonso' mango from India

In general, New World mango cultivars are characterized by the dominance of δ-3-carene, a monoterpene flavorant; whereas, high concentration of other monoterpenes such as (Z)-ocimene and myrcene, as well as the presence of lactones and furanones, is the unique feature of Old World cultivars. (Kulkarni *et al.,* 2012; Pandit *et al.,* 2009; Narain *et al.*, 1998). In India, 'Alphonso' is one of the most popular cultivars, in which the lactones and furanones are synthesized during ripening; whereas terpenes and the other flavorants are present in both the developing (immature) and ripening fruits stages (Idstein and Schreier, 1985; Gholap and Bandyopadhyay, 1977). Ethylene, a ripening-related hormone well known to be involved in ripening of mango fruits, causes changes in the flavor composition of mango fruits upon exogenous application. (Chidley *et al.,* 2013; Lalel *et al*., 2003) In contrast to the huge amount of information available on the chemical composition of mango flavor, the biosynthesis of these chemicals has not been studied in depth; only a handful of genes encoding the enzymes of flavor biosynthetic pathways have been characterized to date (Kulkarni *et al.,* 2013; Singh *et al.,* 2010; Pandit *et al.,* 2010).

Many literatures have demonstrated the health benefits of mangoes in the human body. According to Diana (2012), the following are the health benefits in the human body:

Mango fruit is rich in pre- biotic, dietary fibres, vitamin, minerals and polyphenolic flavonoids antioxidant compounds. According to research study mango fruit has been found to protect against colon, breast, leukemia and prostate cancers. Several trial studies suggest that polyphenolic antioxidant compounds in mango are known to offer protection against breast and colon cancers (Diana, 2012).

Mango fruit is an excellent source of vitamin A and flavonoids like beta- carotene, alpha-carotene and beta cryptoxanthin, 100 g of fresh fruits provides 765 IU or 25 % of recommended daily level of vitamin A. Together these compounds have been known to have antioxidant properties and are essential for vision. Vitamin A is also required for maintaining healthy mucus membrane and skin. Consumption of natural fruits rich in carotenes is known to protect the body from lung and oral cavity cancers. Fresh mango is good source of potassium whereby 100 g fruits provide 156 mg of potassium. Potassium is an important component of cell and body fluids that helps controlling heart rate and blood pressure. It is also a very good source of vitamin B6 (Pyridoxine) vitamin C and vitamin

E. Consumption of food rich in vitamins C helps the body to develop resistance against infectious agents and scavenge harmful oxygen free radicals.

Further it composes moderate amounts of copper. Copper is co- factor for many vital enzymes including cytochromes c-oxidase and superoxide dismutase, copper is also required for the production of red blood cells (Diana, 2012). In additional mango peel is also rich in phytonutrients such as the pigments antioxidants like carotenoid and polyphenols. The general composition of ripe mango on fresh weight basis per 100 g is summarized in a Table 1:

Table 1: Chemical composition of raw mango (content per 100g)

Proximate			**Vitamins**			**Minerals**		
Nutrient	**(g)**	**% RDA**	**Nutrient**	**(mg)**	**%RDA**	**Nutrient**	**(mg)**	**%RDA**
Carbohydrates	17	13	Folates	14 µg	3.5	Sodium	2	0
Protein	0.5	1	Niacin	0.584	3.5	Potassium	156	3
Total Fat	0.27	1	Pantothenic acid	0.160	1	Calcium	10	1
Cholesterol	0 mg	0	Pyridoxine	0.134	10	Copper	0.1	12
Dietary Fiber	1.80	4.5	Riboflavin	0.057	4	Iron	0.1	1.5
sugars	9.9		Thiamin	0.058	5	Magnesium	9	2
			Vitamin C	27.7	46	Manganese	0.03	1
			Vitamin A	765IU	25.5	Zinc	0.04	0
			Vitamin E	1.12	7.5			
			Vitamin K	4.2µg	3.5			
						Phyto-nutrients	(µg)	
						Carotene-β	445	-
						Carotene-α	17.0	-
						Crypto-xanthin-β	11.0	-
						Lutein-zeaxanthin	0	-
						Lycopene	0	-

Source: (USDA National Nutrient data base, 2010)

2.1.2 Tomatoes (*Lycopersicon esculentum*)

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetables worldwide and it belongs to the nightshade family, *Solanaceae* (Shankara *et al.,* 2005). Tomato has its origin in the South American Andes and it was brought to Europe by the Spanish conquistadors in the sixteenth century and later introduced from Europe to southern and eastern Asia, Africa and the Middle East (Shankara *et al.,* 2005). Tomato is botanically a fruit however it is considered a vegetable for culinary purposes (Ganesan *et al.,* 2012).

According to FAO (2005) the global production of tomatoes (fresh and processed) has been increased by 300 % in the last four decades and the leading tomato producers are in both tropical and temperate region. There are around 7,500 tomato varieties grown for various purposes. Heirloom tomatoes are becoming increasingly popular, particularly among home gardeners and organic producers, since they tend to produce more interesting and flavorful crops at the cost of disease resistance and productivity (Allen, 2008). Tomato is a versatile product that can be eaten fresh or processed into wide range of products (Permul, 2007). Tomatoes can be processed into various foods such as i) tomato preserves such as whole peeled tomatoes, tomato paste, tomato juice, tomato pulp, tomato puree and pickled tomatoes, ii) dried tomatoes such as tomato flakes, and tomato powder iii) tomato based food such as tomato soup, tomato sauce and ketchup (Takeoka *et al.,* 2001).

About 161.8 million tonnes of tomatoes were produced in the world in 2012. China, the largest producer, accounted for about one quarter of the global output, followed by India and the United States (FAO, 2012).

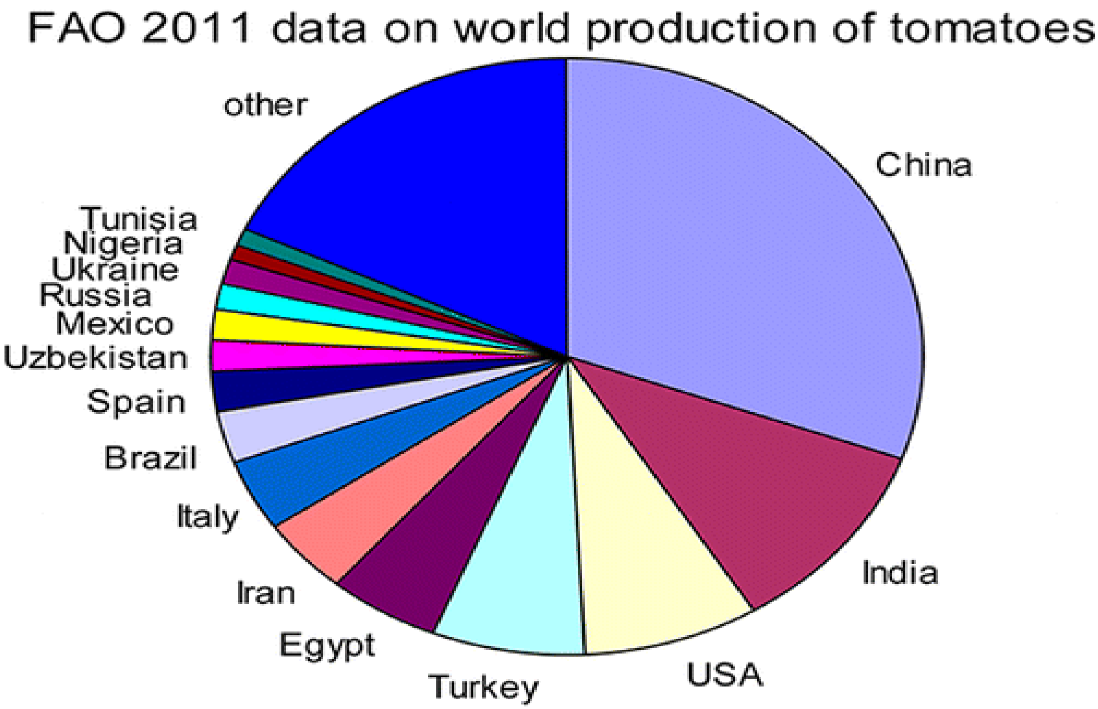

Figure 2: World production of tomatoes (Source FAO, 2012)

The world dedicated 4.8 million hectares in 2012 for tomato cultivation and the total production was about 161.8 million tones with an average world farm yield of 33.6 tonnes per hectare (FAO, 2014). Tomato farms in the Netherlands were the most productive in 2012 with a nationwide average of 476 tonnes per hectare, followed by Belgium - 463 tonnes per hectare and Iceland - 429 tonnes per hectare (FAOSTAT, 2012).

Tomato is one of the most cultivated vegetable in Tanzania where is mostly grown in Kilimanjaro, Mbeya, Iringa, Morogoro, Arusha, Tanga and Dodoma (Nyambo, 2009; MAFC, 2009). The total area under cultivation of this vegetable is 31913 hectares with annual average production of 12.9 thousands metric tons per year (URT, 2006). There are two types of tomatoes grown in Tanzania. These are tall and intermediate varieties (Nyambo, 2009). Regardless of the types the most common varieties grown in Tanzania are Money maker, Tanya, Roma, VF, Marglobe, Tengeru 97, Mshumaa and others (Mbega *et al.,*2012; Shenge *et al.,* 2010).

2.1.2.1 The composition of tomato

Tomatoes are one of the important vegetables/fruits in our diet, since they are rich in health valued food components such as carotenoid (lycopene), ascorbic acid, (vitamin C), vitamin E, folate and dietary fibre (Davies and Hobson, 1987). The general composition of ripe tomato on dry weight basis per 100g is summarized in Table 2.

Table 2: Chemical composition of raw tomato (content per 100g)

Proximate			Vitamins			Minerals		
Nutrient	**(g)**	**% RDA**	**Nutrient**	**(mg)**	**%RDA**	**Nutrient**	**(mg)**	**%RDA**
Carbohydrates	3.9	3.0	Folates	15 µg	4.0	Sodium	5.0	>1
Protein	0.9	1.6	Niacin	0.594	4.0	Potassium	237	5.0
Total Fat	0.2	0.7	Pyridoxine	0.080	6.0	Calcium	10.0	1.0
Cholesterol	0 mg	0	Thiamin	0.037	3.0	Iron	0.3	4.0
Dietary Fiber	1.2 g	3.0	Vitamin A	833 IU	28.0	Magnesium	11.0	3.0
			Vitamin C	13	21.5	Manganese	0.15	6.5
			Vitamin E	0.54	4.0	Phosphorus	24.0	3.0
			Vitamin K	7.9 µg	6.5	Zinc	0.17	1.5
						Phyto-nutrients	(µg)	-
						Carotene-ß	449	-
						Carotene-α	101	-
						Lutein-zeaxanthin	123	-
						Lycopene	2573	-

Source: (USDA National Nutrient database, 2010)

2.1.2.2 Potential health benefits of tomatoes

Some studies have indicated that the lycopene in tomatoes may help prevent cancer, but taken overall the research into this subject is inconclusive (American Cancer Society, 2010). There has been some research interest in whether the lycopene in tomatoes might help in managing human neurodegenerative diseases (Rao and Balachandran, 2002). The lycopene from tomatoes has no effect on the risk of developing diabetes, but may help relieve the oxidative stress of people who already have diabetes (Valero *et al.,* 2011). Lycopene has also been shown to improve the skin's ability to protect against harmful UV rays. A study done by researchers at Manchester and Newcastle universities revealed that tomato can protect against sunburn and help keeping the skin looking youthful (Maccrae, 2008).

2.1.2.3 Tomato toxicity

Leaves, stems, and green unripe fruit of the tomato plant contain small amounts of the toxic alkaloid tomatine (Mcgee, 2009) They also contain solanine, a toxic alkaloid found in potato leaves and other plants in the nightshade family (Barceloux, 2009) Use of tomato leaves in herbal tea has been responsible for at least one death (Barceloux, 2009). However, levels of tomatine in foliage and green fruit are generally too small to be dangerous unless large amounts are consumed, for example, as greens. Small amounts of tomato foliage are sometimes used for flavouring without ill effect, and the green fruit is sometimes used for cooking, particularly as fried green tomatoes (Mcgee, 2009).

Tomato plants can be toxic to dogs if they eat large amounts of the fruit, or chew plant material (Brevitz, 2004). The U.S. Centers for Disease Control and Prevention (CDC) announced tomatoes might have been the source of a salmonellosis outbreak causing 172 illnesses in 18 states. Tomatoes have been linked to seven salmonella outbreaks since 1990.

2.2 Overview of the Preservation Technology

The quality of food can be adversely affected by physical, chemical, biochemical and microbiological processes. Quality deterioration caused by microorganisms may include a wide range of types of spoilage that are undesirable commercially, because they limit shelf life or lead to quality complaints, but are safe from a public health point of view. More seriously, the presence or growth of infectious or toxinogenic microorganisms (foodborne pathogens) represent the worst forms of quality deterioration, because they threaten the health of the consumer (International Commission of Microbiological Specification for Food, 1996).

The quality of produce cannot be improved after harvest; nevertheless it remains possible to slow down the rate of undesirable changes and maintain the quality for a longer time (Kim *et al*., 2010). Quality is an illusive, ever-changing concept. In general, it is defined as the degree of fitness for use or the condition indicated by the satisfaction level of consumers, it can also be defined using many factors, including appearance, yield, eating characteristics, and microbial characteristics, but ultimately the final use must provide a pleasurable experience for the consumer (Sebranek, 1996). When food has deteriorated to such an extent that it is considered unsuitable for consumption, it is said to have reached the end of its shelf life. In studying the shelf life of foods, it is important to measure the rate of change of a given quality attribute (Singh, 1994). In all cases, safety is the first attribute, followed by other quality.

The product quality attributes can be quite varied, such as appearance, sensory, or microbial characteristics. Loss of quality is highly dependent on types of food and composition, formulation (for manufactured foods), packaging, and storage conditions (Singh, 1994). Quality loss can be minimized at any stage of food harvesting, processing, distribution, and storage. When preservation fails, the consequences range broadly from minor deterioration, such as color loss, to food becoming extremely hazardous (Gould, 1989).

Quality deterioration caused by microorganisms may include a wide range of types of spoilage that are undesirable commercially, because they limit shelf life or lead to quality complaints, but are safe from a public health point of view. More seriously, the presence or growth of infectious or toxinogenic microorganisms (foodborne pathogens) represent the worst forms of quality deterioration, because they threaten the health of the consumer (ICMSF, 1996). Therefore, while the aim of effective food preservation is to control all forms of quality deterioration, the overriding priority is always to minimize the potential for the occurrence and growth of food spoilage and food poisoning microorganisms (ICMSF, 1996).

Table 3: Major quality loss mechanisms

Microbiological	Enzymatic	Chemical	Physical	Mechanical
Micro organism growth	Browning	Color loss	Collapse	Bruising due to vibration
Off flavors	Colour change	Flavor loss	Controlled release	Cracking
Toxin production	Off flavors	Non enzymatic browning	Crystallization	Damage due to pressure
		Nutrient loss	Flavor encapsulation	
		Rancidity	Phase changes	
		Oxidation reduction	Recrystallization	
			Shrinkage	
			Transport of component	

Source: (Gould, 1989)

Food preservation in the broad sense of the term refers to all measures taken against any spoilage of food. In its narrower sense, however, food preservation connotes processes directed against food spoilage due to microbial or biochemical action. Preservation technologies are based mainly on the inactivation of microorganisms or on the delay or prevention of microbial growth. Consequently they must operate through those factors that most effectively influence the survival and growth of microorganisms (ICMSF, 1980). Preservation usually involves preventing the growth of bacteria, fungi, and other microorganisms, as well as retarding the oxidation of fats which cause rancidity. It also includes processes used to inhibit natural ageing and discolouration that can occur during food preparation such as the enzymatic browning reaction in apples after they are cut (Jean, 1994). Some preservation methods require the food to be sealed after treatment to prevent recontamination with microbes; others, such as drying, allow food to be stored without any special containment for long periods. Common methods of applying these processes include drying, spray drying, freeze drying, freezing, vacuum-packing, canning, preserving in syrup, sugar crystallization, food irradiation, and adding preservatives or inert gases such as carbon dioxide (Hamid *et al*., 2012). The main reason for food preservation is to overcome inappropriate planning in agriculture, produce value-added products, and provide variation in diet (Rahman, 1999).

Factors used for food preservation are called '*hurdles*' and there are numerous hurdles that have been applied for food preservation. Potential hurdles for use in the preservation of foods can be divided into physical, physicochemical, microbial derived and miscellaneous hurdles (Leistner and Gorris, 1995). The need for food preservation will remain for all time if the world is to cater for the global population which is ever increasing at an alarming geometric progression (FAO/WHO, 1994).The need for food preservation will increase as new food sources are expected to cater for the ever-increasing global human population (Kumar and Panneerselvam, 2007).

2.2.1 Food preservation methods

Based on the mode of action, the major food preservation techniques can be categorized as (1) slowing down or inhibiting chemical deterioration and microbial growth, (2) directly inactivating bacteria, yeasts, molds, or enzymes, and (3) avoiding recontamination before and after processing (Gould, 1989; Gould, 1995).

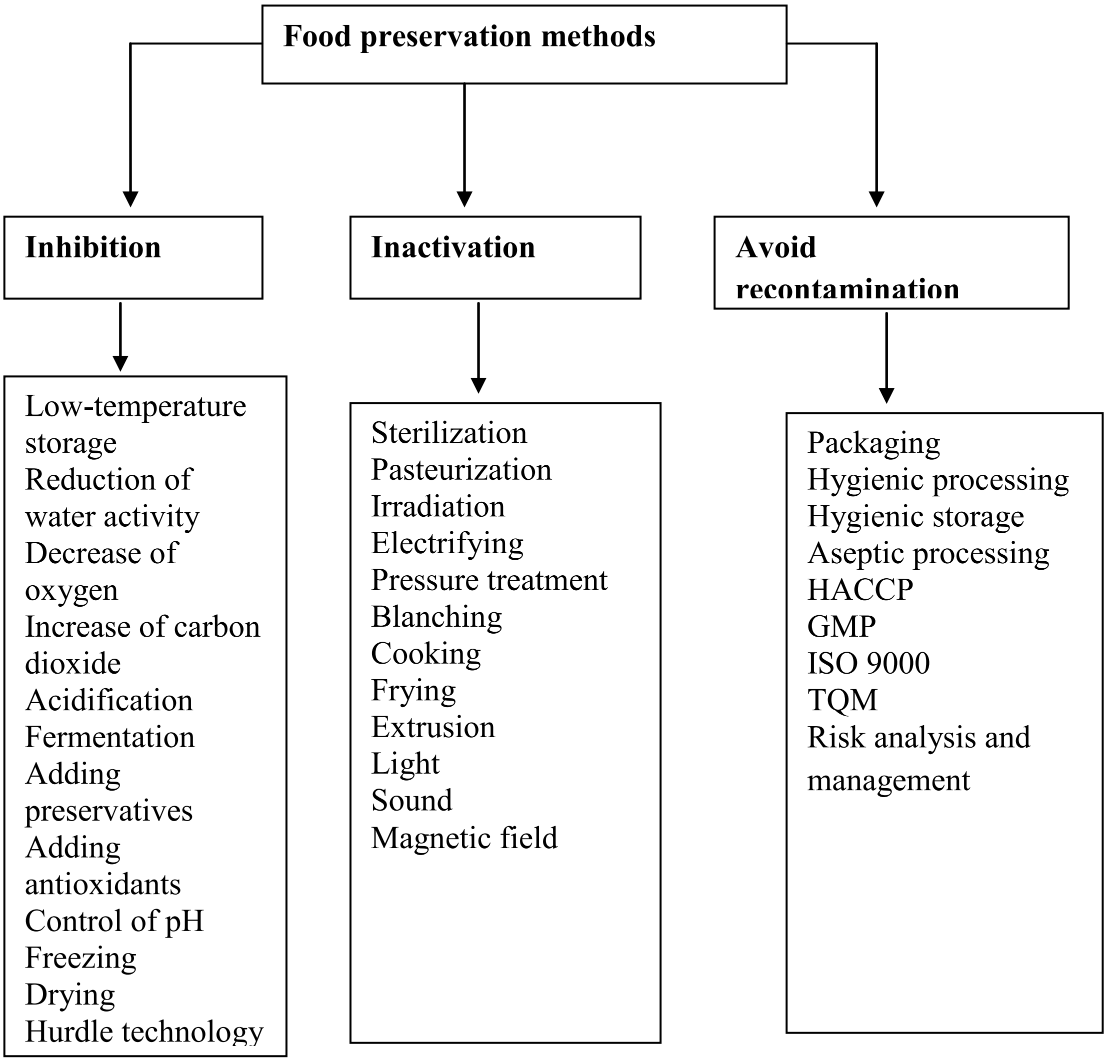

Figure 3: Food preservation methods: Source (Gould, 1995)

Preservatives are often added to food to prevent their spoilage, or to retain their nutritional value and/or flavor for a longer period. The basic approach is to eliminate microorganisms from the food and prevent their growth. This is achieved by methods such as a high concentration of salt, or reducing the water content. This inhibits spoilage of the food item by microbial growth. Preservatives can be divided into two types, depending on their origin. Class I preservatives refers to those preservatives which are naturally occurring, everyday substances. Examples include salt, honey and wood smoke. Class II preservatives refer to preservatives which are synthetically manufactured (Dalton and

Louisa, 2002). Preservatives can be categorized into three general types: (1) antimicrobials such as nitrites and nitrates prevent botulism in meat products; Sulfur dioxide prevents further degradation in fruits, wine and beer. Benzoates and sorbates are anti-fungals used in jams, salads, cheese and pickles. (2) Antioxidants that slow or stop the breakdown of fats and oils in food that happens in the presence of oxygen (Oxidation) leading to rancidity. Examples of anti-oxidants include BHT, BHA, TBHQ, and propyl gallate, a third type block the enzymatic processes such as ripening occurring in foodstuffs even after harvest. E.g. Erythorbic acid and citric acid stop the action of enzyme phenolase that leads to a brown color on the exposed surface of cut fruits or potato. (McCann *et al.,* 2007).

2.2.2 Use of chemicals

The use of chemicals in foods is a well-known method of food preservation. Wide varieties of chemicals or additives are used in food preservations to control pH, as antimicrobes and antioxidants, and to provide food functionality as well as preservation action. Many legally permitted preservatives in foods are organic acids and esters, including sulfites, nitrites, acetic acid, citric acid, lactic acid, sorbic acid, benzoic acid, sodium diacetate, sodium benzoate, methyl paraben, ethyl paraben, propyl paraben, and sodium propionate(Brul and Cooke, 1999). When a weak acid is dissolved in water, equilibrium is established between undissociated acid molecules and charged anions, the proportion of undissociated acid increasing with decreasing pH. The currently accepted theory of preservative action suggests inhibition via depression of internal pH. Undissociated acid molecules are lipophilic and pass readily through the plasma membrane by diffusion. In the cytoplasm, approximately at pH 7.0, acid molecules dissociate into charged anions and protons. These cannot pass across the lipid bilayer and accumulate in cytoplasm, thus lowering pH and inhibiting metabolism (Marriott, 1999).

There are several limitations to the value of organic acids as microbial inhibitors in foods, (1) They are usually ineffective when initial levels of microorganisms are high, (2) Many microorganisms use organic acids as metabolizable carbon sources, (3) There is inherent variability in resistance of individual strains, (4) The degree of resistance may also depend on the conditions (Davidson and Harrison, 2002). Nitrides and nitrates are used in many foods as preservatives and functional ingredients (Branen *et al*., 2002)

These are critical components used to cure meat, and they are known to be multifunctional food additives and potent antioxidants. Many plants contain compounds that have some antimicrobial activity, collectively referred to as “green chemicals” or “biopreservatives” (Smid and Gorris, 1999). It has also been demonstrated that many of the chemical food preservatives are decomposed or converted into other by-products such as sulphites, disulphides or sulphides and many more have a variety of biological effects that could be antimicrobial, antioxidizing or chelating (Armando and Pilar, 2006). Many scientific investigations have shown that some of these chemical preservatives used, especially those with antimicrobial functions have adverse effect on health in different test systems (Turkoglu, 2007). Interest in naturally occurring antimicrobial systems has expanded in recent years in response to consumers’ requirements for fresher, more natural additive free foods (Gould, 1995).

A range of herbs and spices are known to possess antibacterial activity as a consequence of their chemical composition. Antimicrobial agents can occur in foods of both animal and vegetable origin. Herbs and spices have been used for centuries by many cultures to improve the flavor and aroma of foods. Essential oils show antimicrobial properties, and are defined by Hargreaves as a group of odorous principles, soluble in alcohol and to a limited extent in water, consisting of a mixture of esters, aldehydes, ketones, and terpenes.

They do not only provide flavor to the product, but also preservation activity. When a chemical is used in preservation, the main question is how safe is it? There should be a risk–benefit analysis. Antimicrobial agents or preservatives are diverse in nature, but legal, toxicological, marketing, and consumer considerations have created a trend such that both the number and amount of preservatives in use are diminishing rather than increasing (Fuglsang *et al.,* 1995).

Scientific studies have identified the active antimicrobial agents of many herbs and spices. These include eugenol in cloves, allicin in garlic, cinnamic aldehyde and eugenol in cinnamon, allyl isothiocyanate in mustard, eugenol and thymol in sage, and isothymol and thymol in oregano (Mothershaw and Al-Ruzeiki, 2001). Natural substances such as salt, sugar, vinegar, alcohol, and diatomaceous earth are also used as traditional preservatives. Certain processes such as freezing, pickling, smoking and salting can also be used to preserve food. Another group of preservatives targets enzymes in fruits and vegetables that continue to metabolise after they are cut. For instance, citric and ascorbic acids from lemon or other citrus juice can inhibit the action of the enzyme phenolase which turns surfaces of cut apples and potatoes brown. Most foods contain enzymes or natural chemicals, such as acids or alcohols that cause them to begin to lose desirable characteristics almost immediately after harvest or preparation. In addition, a host of environmental factors, such as heat and the presence of microorganisms, acts to change foodstuffs in ways that may harm the food product.

Food preservation traditionally has three goals: the preservation of nutritional characteristics, the preservation of appearance, and a prolongation of the time that the food can be stored (Hamid *et al.,* 2012). Traditional methods of preservation usually aim to exclude air, moisture, and microorganisms, or to provide environments in which organisms that might cause spoilage cannot survive (Daniel, 2007). Traditional methods of preservation usually aim to shut out air, moisture, and microorganisms (Aworh, 2008).

2.3 Overview of Food Preservatives

2.3.1 Sodium metabisulphite

Sodium metabisulphite is also known as E223 in the food industry. Food items containing this preservative are some fruit juices, concentrated soft drinks, beer and wine. Sulphites are primarily used as antioxidants or antimicrobial agents to prevent or reduce the discolouration of light coloured fruits and vegetables. Sodium metabisulphite is an excellent anti-melanosis additive for sea food (Omar, 1998). It can decrease the vitamin composition, especially of vitamin B_1 in food; as an additive, non-sensitive are safe (Luck *et al*., 1997).

Sodium metabisulphite has a chemical formula of $Na_2S_2O_5$, and is commonly used in the salt form due to its high solubility in water. Sulfur dioxide, the active antimicrobial form, is a colorless gas that was first used to treat wines in Rome and was used to treat cider in the 17^{th}century (Davidson and Juneja, 1990). Sulfites are commonly used as antimicrobials in dried fruits, fruit juices, wines, sausage, fresh shrimp, and acid pickles, but also protect against browning reactions and chemically induced color changes (Davidson and Juneja, 1990). Generally, sulfur dioxide is used at 0.01% to 0.2 % to temporarily preserve fruit products and at 50 to 100 ppm in grape juices used for wine. Sulfites are allowed in vegetable juices at a level of 100 ppm and are allowed at 1,000 ppm in fruit juices. Suggested levels of sulfur dioxide in juice concentrates are from 350 to 600 ppm sulfur dioxide (Furia, 1986; Zoecklein *et al*., 1995). In 1986, the FDA required labeling on any product containing more than 10 ppm sulfites (Warner *et al*., 2000; Ough, 1993). The maximum level of sulfur dioxide allowed in wine was set at 350 mg/L by the regulating body for the US alcoholic beverage industry and Bureau of Alcohol, Tobacco, and Firearms. The oral lethal dose (LD50) is 1000 to 2000 mg sulfur dioxide per kilogram body weight (Davidson and Juneja, 1990; Zoecklein *et al*., 1995).

- **Mechanism of action**

Sodium metabisulfite is most effective at a pH below 4.0, because of the more active, undissociated form (Ough, 1993). Although the undissociated acid contributes the majority of the antimicrobial activity, the bound portion of sulfur dioxide at levels greater than 50 ppm may be inhibitory to certain bacteria including lactic acid bacteria (Zoecklein *et al*., 1995). The sulfites are used primarily in fruit and vegetable products to control three groups of microorganisms: acetic acid producing and malolactic bacteria, fermentation and spoilage yeasts, and molds on fruits (Wedzicha, 1984). It has been shown to inhibit juice and wine bacteria, yeasts, and molds; however yeasts and molds are more resistant to this antimicrobial (Ough, 1993; Zoecklein *et al.,* 1995). Sulfur dioxide is reported to be more inhibitory to Gram-negative rods such as E. coli and Pseudomonas as compared to Gram-positive rods (Rose and Pilkington, 1989). Sulfur dioxide is not only used as an antimicrobial but also has other functions such as protection against oxidative, enzymatic, and non-enzymatic browning reactions and inhibition of chemically induced color loss. Sulfur dioxide is also used to sanitize equipment.

In wine, the concentration of sulfur dioxide used depends on the cleanliness, maturity, and general condition of grapes, but 50-100 ppm is generally employed (Davidson and Juneja, 1990). Growth inhibition and lethal effects of sulfur dioxide are most intense when the acid is in the molecular free (un-ionized) form. Bound forms of sulfur generally have lowered antimicrobial activity. In grape juice, bound forms of sulfurous acid have about $1/30^{th}$ the antimicrobial effectiveness of the free form of sulfur dioxide (Zoecklein *et al.,* 1995). Against some bacteria, concentrations of 1-2 ppm are bacteriostatic, but higher concentrations are needed to be bactericidal. Levels of 1-10 μg/ml sulfites prevent lactic acid bacterial spoilage in fruit products at pH 3.5 or less (Ough, 1993).

The antimicrobial action of sulfur dioxide is based on its interference with various cell components (Davidson and Juneja, 1990). Cell damage may occur from the interaction with sulfhydryl groups and linkages in the structural proteins and interactions with enzymes, cofactors, vitamins, nucleic acids, and lipids (Furia, 1986). Sulfur dioxide cleaves disulfide linkages in proteins and changes the molecular confirmation of enzymes, which modifies the active site or destroys its coenzymes. Sulfites may also damage cell metabolism and membrane function by peroxidizing lipids.

One or more of these factors may result in inhibition or death of the microbial cell (Ough, 1993). Sulfur dioxide may also react with end products or intermediate products and inhibits enzyme chain reactions. It destroys the activity of thiamine and thiamine-dependent enzymes by cleavage and produces cytotoxic effects by cross-linking individual nucleic acid residues or nucleic acid residues and proteins. Sulfur dioxide may react with RNA leading to interference in protein synthesis resulting in inhibition of growth, and in B. subtilis, its mechanism of action may result from DNA breakdown (Wedzicha, 1984; Zoecklein *et al.,* 1995). It has also been suggested that the antimicrobial action of this compound is due to its strong reducing power that results in a reduction in oxygen tension to a point below that of which aerobic microorganisms can grow.

The addition of sodium metabisulfite (a source of sulfur dioxide) delayed C. botulinum outgrowth in perishable canned, commuted pork that was temperature abused at 27ºC (Wedzicha, 1984). Levels above 120 mg/L of total sulfur dioxide decreased the incidence of malolactic fermentation, with lower pH values increasing the effectiveness of the sulfur dioxide. Approximately 10 ppm sulfur dioxide was lethal to Leuconostoc; however Lactobacillus and Pediococcus were shown to be more tolerant to sulfur dioxide (Zoecklein *et al.*, 1995).

There is a little research relating to the antimicrobial ability of sodium metabisulfite on *Alicylobacillus Acidoterrestris*. Splittstoesser *et al*. (1998) stated that sulfur dioxide did not sensitize *Alicylobacillus Acidoterrestris* spores to heat at 100 ppm and below. However, Walls and Chuyate (2000) stated that *Alicyobacillus Acidoterrestris* spores at 4 log spore/ml did not grow in white grape juice that contained metabisulphites, but in grape juice without metabisulfite, spores germinated within 1-2 weeks when inoculated at levels 2 and 4 log spores / ml into juices.

2.3.2 Acetic acid

Acetic acid is one of the important weak acids which had long history in chemical industries. Acetic acid (CH_3COOH) is one of the simplest organic carboxylic acid. This colourless weak acid is characterized by distinctive sour taste and pungent smell. Nowadays, this acid is considered as one of the key intermediate for many industries including: chemical, detergent, wood and food industries (Hassan *et al.,* 2011). As a food additive it is approved for usage in many countries, including Canada, the EU, USA and Australia and New Zealand. As a chemical reagent, biological sources of acetic acid are of interest but generally uncompetitive. Vinegar is dilute acetic acid, often produced by fermentation and subsequent oxidation of ethanol (UK Food Standards Agency, 2011).

In the food industry, acetic acid is used under the food additive code E260 as an acidity regulator and as a condiment (UK Food Standards Agency, 2011). The most common organic acids are the carboxylic acids, whose acidity is associated with their Carboxyl group (Dibner and Butin, 2002). Acetic acid is used in food preservation since of their effect on bacteria.

Currently, the production of acetic acid is carried out by chemical means using petrochemical feedstock or by the traditional approach of fermentative alcohol conversion using specific type of acetic acid bacteria (Kim *et al*., 2002). Among different chemical methods used, methanol carboxylation is the dominant production technology and accounting for over 65% of global capacity followed by ethylene oxidation, and alkane oxidation processes. Nowadays, acetic acid is an important as intermediate compound for the industrial production of different chemicals such as vinyl acetate polymer, cellulose acetate, terephthalic acid, dimethyl terephthalate, acetic acid esters/acetic anhydride and calcium magnesium acetate. All these products are made from petroleum-derived acetic acid (Kim *et al*., 2002). In spite of the fact that biological process for acetic acid production account for only 10% of global market production, it remain important process as many countries law stipulate that food grade vinegar must come from biological origin (fermentation).

Therefore, optimization of biological process for acetic acid production is one of the most important industrial research and subject for study by many researcher groups using either free or immobilized cell systems (Lu *et al.,* 1999). For this bioprocess, there are several bacteria which can contribute to the production of acetic acid. Acetic acid bacteria were divided into five to six genera of which *Acetobacter* and Gluconabacter species can tolerate high concentration of acetic acid, which explain their use in vinegar production (Yamada *et al*., 2000).

- **Mechanism of action**

Acetic acid is considered as to be a generally recognized as a safe compound and is comparable to other compound such as Hydrogen Peroxide, bicarbonate, and carbonate salt, chlorine and sugar analogs because they leave low or no detectable residues, they degrade rapidly and metabolize quickly in plant tissues (Barkai-Goran, 2001). Acetic acid has been used for many years in the food industries to inhibit microbial growth and as an acidulant (Doores, 1990). The mode of action of an acid is related to the undissociated portion of the molecule and is more important than any change in pH brought by the addition of an acid. Dissociated forms of weak acids are not absorbed by micro-organisms to any great extend (Dorees, 1990). The key basic principle on the mode of action of acetic acid is that non dissociated (non-ionized) can penetrate the bacteria cell wall and disrupt the normal physiology of certain types of bacteria that presented as pH- sensitive, meaning that they cannot tolerate a wide internal and external pH gradient (Patanen and Morz, 1999). Antibacterial activity of acetic acid is attributed to direct pH reduction of the substrate, depression of the intracellular pH by ionization of the undissociated acid molecule or disruption of substrate transport by alteration of cell membrane permeability (Ikawa, 1995) and therefore PH dependent (Institute of Food Technologists, 1990).

2.3.3 Lemon juice

Food acids also help to extend shelf life by making the environment unfavorable for microbial growth. In addition, preservatives such as sodium benzoate and /or potassium Sorbate are more effective in acid systems. In wine applications acidulants are often needed to reduce the pH and enhance fermentation and flavour development (Hawkin Watts Limited, 1996).

Lemons are commonly used in a variety of functions such as medicines, cleaning agents, culinary product in a wide variety of food and drinks and it is also used in short food preservation as antioxidant in many fruits and tubers crops due to the presence of ascorbic acid (Gulsen and Roose, 2001). The juice of the lemon is about 5% to 6% citric acid, which gives lemons a sour taste. The distinctive sour taste of lemon juice makes it a key ingredient in drinks and foods such as lemonade (Gulsen and Roose, 2001).

Citric acid is a weak organic acid occurring naturally in many fruits, especially in citrus fruits, also found in animal fluids and tissue. It is very soluble and used as an additive in many drinks.

The role of citric acid in drinks is to improve taste and flavour, antioxidant and to maintain stability (preservative enhancement) (European Citric Acid Manufacturers Association, 2013). Citric acid contains three carboxylic acid groups; 2-hydroxy-1, 2, 3-propanetricar-boxylic acid. In human physiologic blood pH and urine, it found mainly as the trivalent anion. Citrate salts are used to deliver minerals in biologically available forms these include dietary supplements and medications. In lemons and limes; citric acid is the most concentrated comparing with other fruits (Penniston *et al.,* 2008). The production of ATP in the citric acid cycle is the major source of citric acid in vivo from endogenous metabolism in the mitochondria (Seltzer *et al.,* 1996).

The modest increase in urinary citrate excretion has been associated with gastrointestinal absorption of citric acid from dietary sources, citrate is the most abundant organic ion found in urine (Kang *et al*., 2007; Qiu and Wedzicha, 2004).

Citric acid is found in fruits such as lemons, limes, peaches, plums, grapefruit and oranges. Citric acid is responsible for the tart taste in many citrus fruits and can be extracted by adding calcium oxide, which forms calcium citrate. Citric acid promotes healthy digestion, may prevent urinary tract infections, and is a natural preservative, according to (Meredith, 2000).

- **Mode of action**

Citrus fruits extracts have also been applied successfully to fruits and vegetables (Fisher and Phillips, 2008). For example, lemon extract was applied for the inhibition of some spoilage microorganisms, such as Bacillus licheniformis, *Lactobacillus spp., Pichia subpelliculosa, Saccharomyces cerevisiae and Candida lusitaniae*, the minimum inhibition concentration is 100to 150 ppm (Conte *et al.,* 2007).

Citric acid has the highest inhibitory effect due to its ability to diffuse through the cell membrane, penetrating the weak non dissociated acid within the bacterial cell membrane of the exterior cell wall of the bacterial organism. This leads to an accumulation of the acid within the cell cytoplasm, acidification of the cytoplasm, disruption of the proton motive force, and inhibition of substrate transport (Vasseur *et al.,* 1999).

2.4 Overview of Shelf Life

Shelf life is defined as the period in which a product should maintain a predetermined level of quality under specified storage conditions (Michael and Robinson, 2000). It is a measure of microbiological safety and stability of a food product, which in turn determined both food quality and food safety of a product. Many fresh fruits and vegetable have shorter shelf life of only days before they are unsafe or undesirable for consumption (Bruhn *et al*., 2007). At room temperature it ranges from 1-2 days in banana, asparagus and mushroom; 2-4 days in avocado, cucumbers, eggplant, grapes, lettuce and pineapple; 4-6 days in apricots, grapefruit, lemons, oranges, pears, peppers, spinach, tomatoes and water melon; and more than 7 days in apples beets, cabbage, carrots, onions and potatoes (Romine, 2009).

2.4.1 Factors affecting shelf life of fruits and vegetable

Some of the major factors affecting storage stability and shelf life of raw and processed foods include moisture contents, and water activity, storage temperature, time, light, and packaging materials (Swanson, 2009). Moisture loss or uptake is one of the most important factors that control shelf life of foods. As water activity in a foodstuff decreases the number and growth rate of microbial species able to grow in that environment also decreases (Idah and Aderibigbe, 2007). Below the limit of 0.60, no microbial proliferations occur, browning is minimized and the product becomes fully stable in that respect. However very few specialized yeast and moulds are able to grow below a_w 0.70, the limit that is usually regarded as safe for prolonged storage.

2.4.2 Packaging materials

Packaging materials have great influence of on the shelf life of the product (Hii and Law, 2010). The packaging of dehydrated fruits and vegetables must protect the product against moisture, light, air, dust, micro flora, foreign odor, insects and rodents (Robertson, 2010). It should also provide strength and stability to maintain original product size, shape, and appearance throughout storage, handling, and marketing. Such material must not contain toxic substances that make the food unsafe (Robertson, 2010).

Rozis (1997) noted that the choice of packaging materials depends on several factors such as the kind of foodstuff, the storage conditions, the materials protective qualities and the materials availability and cost. It is suggested that using vacuum sealing will greatly extend shelf life 2-3 times longer than conventional methods (Deni, 2001).

2.4.3 Shelf life prediction and kinetics of deteriorative reactions in dried foods

The quantitative approach to shelf life prediction requires that the deteriorative mechanisms limiting shelf life of the specific food be identified and that the index of deteriorative reaction be measures as a function of time. Since the chemical reactions in food can be very complex it is usually easier to examine a reaction from purely mathematical or semi empirical approach based on chemical laws rather than on a mechanistic approach in which each step must be known (Labuza and Kamman, 1983).

The loss of quality for most foods can be presented by a mathematical equation 1:

$$\pm \frac{\delta A}{\delta \theta} = KA^n \qquad (1)$$

Where: A = the quality factor measured, θ = time, k = a constant which depends on temperature and water activity, n = a power factor called order of the reaction which defines whether the rate is dependent on the rate is dependent and

$\pm \frac{\delta A}{\delta \theta}$ = the rate of change of time. A negative sign is used if the deterioration is loss of A and positive if it is for production of undesirable products.

For quality changes in foods the reaction order has generally been shown to be either 0 or 1 depending on the reaction involved (Pope, 1980; Labuza, 1982). If n = 0 the reaction said to be zero order with respect to A. This means that the rate of loss of A is constant and independent of the concentration of A. zero order reaction is mainly applicable to non-enzymatic browning in dried foods and lipid oxidation in dried foods and snacks (Labuza, 1982). When n = 1 the reaction first order whereas the loss of quality is dependent on the amount of A left. The deterioration which falls in first order reaction includes vitamin and protein loss in dried foods and vegetable rancidity in dried foods (Labuza, 1982). In sum studies reaction were described by non-linear equations such as polynomial equations (Smoot and Nagy, 1980).

2.5 Factors Affecting the Kinetics of Reactions in Dried Foods

2.5.1 Temperature

Increases in temperature are known to accelerate deteriorative reactions in food and thus reduce shelf life of food. Temperature is assumed to follow the Arrhenius equation 2.

$$K = K_o \exp^{(Ea/RT)} \quad \text{……………………………………………………..….. (2)}$$

Where: K= rate constant, Ko= pre exponential constant, Ea = Activation Energy, R = Gas constant and T = Absolute temperature.

Arrhenius equation is the best approach in modeling temperature dependence (Saguy and Karel, 1980). The Arrhenius model unlike other model of temperature dependence has a thermodynamic basis (Labuza and Kamman, 1983). The activation energy is generally derived from the slope of a plot of natural logarithm of rate of constant (k) versus the inverse of absolute temperature and depends on compositional factors such as water activity, moisture content and solid concentration. When the reaction mechanism changes with temperature the activation energy may vary substantially.

Large statistical errors are commonly associated with the calculations of the temperature dependence of the reactions. Some studies have suggested methods of analyzing kinetic data which provide statistically more reliable results (Cohen and Saguy, 1985). Arrhenius plot can also be used to establish shelf life plots of specific products based on a known end point quality deterioration value (Labuza and Kamman, 1983). There could be many limitations besides statistical errors in using the Arrhenius and shelf life plots to predict shelf life at lower temperature.

Generally the problem occurs because some reactions which predominate at higher temperature do not pre dominate at lower temperature (Labuza and Riboh, 1982).

2.5.2 Water activity

Water a major constituent of food influence the rate of deteriorative reactions in foods; however water activity is more useful in expressing the rates of reactions as depicted in equation 3.

$$A_W = P/P_o \ldots\ldots (3)$$

Where: aw = water activity, P = partial pressure of water in foods and P_o = vapour pressure of water.

Although water activity is considered to be a far better indicator of food stability than water content, it must be emphasized that water activity is the only one parameter defining the reactivity of water molecule within solid food systems (Gilbert, 1986), however sum other factors such as oxygen concentrations, pH, water mobility and the type of solute can have the influence on the food degradation (Fennema, 1985). Many studies have demonstrated the influence of water activity on non-enzymatic browning reactions in foods however the influence of water activity on pigment stability in food were reported by Von Elbe (1987).

With reference to the kinetic equations given above Labuza (1982) demonstrated the effects of water activity on rate constant (k), concentration of reaction species (A) and reaction order (n). A number of relationships have been suggested to demonstrate the dependence of reaction rates on water activity and moisture content. A complex functional relationship was reported between the rate of food quality deterioration and moisture content (Saguy and Karel, 1980). It should be noted that a deteriorative reactions in food system is inevitably a multfactorial process of which water activity is only one factor.

It is when the water component is the rate limiting factor that water activity can be expected to have a direct influence (Van den Berg and Bruin, 1981).

One problem that is encountered when determining the effect of water activity on the rate of deteriorative reactions is that water activity may be affected by other factors such as temperature. For dried products a change in temperature may not only affect the rate of reaction but also affects the water activity and hence making the interpretation of data much more complicated.

Aside from affecting models of deterioration and their rates water activity also affects moisture transfer thorough certain packaging materials (Labuza, 1982).

2.5.3 Oxygen

Many foods deteriorate due to reaction with oxygen. The deteriorations which can be caused by oxygen include lipid oxidation, aerobic degradation of ascorbic acid, development of off flavors and non-enzymatic browning. For dried food which are susceptible to oxidative deterioration the influence of oxygen is of major importance particularly when dealing with packaging materials which are permeable to oxygen, however the effect of oxygen is simply a question of total amount available for reaction with food components (Saguy and Karel, 1980). If the amount is limited to a level that causes no significant effect in the food and no additional oxygen coming into contact with the food then the reaction rate is irrelevant.

2.6 Mode of Deterioration

The key to the application to the kinetics to the prediction of quality loss is selection of the major model of deterioration measurement of some quality factor related to this mode and then application of mathematical models to make the needed predictions.

A review of the studies made on the deteriorations of quality in dried mango and tomato is presented below.

2.6.1 Mango

Since industrial capacities for the processing of highly perishable mangoes into storable products are limited due to seasonal over production of the fruits, drying of excess and partly defected mangoes is a promising preservation technique, meeting the processing requirements of small and medium-size producer (Pott *et al*., 2005). Beside traditional sun drying by direct solar radiation, solar dryers and conventional overflow dryers are presently used by small-scale enterprises to reduce the water activity. Consequently, drying usually needs at least 20 h, resulting in low drying capacities or high investments, respectively. Observed quality deficiencies of the dried fruits caused by these long term processes were mainly discoloration, such as browning or bleaching, and cracked or scorched products, while insufficient drying limits the shelf life of the product due to microbial spoilage. Drying air temperature and drying time were shown to be the primary factors influencing product color and water activity (Pott *et al*., 2005).

The rehydration capacity and color characteristics are considered as the most important quality parameters for the dehydrated products. The rehydration capacity is used to express ability of the dried material to absorb water. The largest part of the dehydrated products must be rehydrated during their final use. Rehydration is a process performed in order to obtain an adequate restitution of raw material properties when dried material is in contact with water (Taiwo *et al.,* 2002). In some foods, as dry fruits for breakfast, the rehydration velocity is very important in the judgment of its quality (Ramallo and Mascheroni, 2012). The first quality judgment made by a consumer on a food at the point of sale is its visual appearance. Appearance analyses of foods are used in maintenance of food quality throughout and at the end of processing. Color is one of the most important appearance attribute of food materials, since it influences consumer acceptability. Abnormal colors, especially those associated with deterioration in eating quality or with spoilage, cause the product to be rejected by the consumer (Avila and Silva, 1999). The deterioration of the color attributes with drying conditions has been widely studied in a large number of fruits, mainly in apple (Mandala *et al.,* 2005), kiwifruit (Maskan, 2001), cherries (Ohaco *et al.,* 2001) and pineapple (Ramallo and Mascheroni, 2012).

Normally the lightness for mango slices decreases with drying temperature and drying time. Since it is a measure of the color in the light-dark axis this falling value indicates that the samples were turning darker. It has been stated that the variation in the brightness of dried samples can be taken as a measurement of browning (Avila and Silva, 1999). It is clear that browning increases with an increase in drying temperature and time (Wang and Chao, 2002). Some studies demonstrated that the major causes of color change are due to carotenoid degradation and non-enzymatic browning (Maillard).

2.6.2 Tomato

In drying process, fresh tomato can be cut in different shapes such as halves, thin slices and quarters and dried tomato products have different applications such as they can be used in pizza and in different vegetable and spicy dishes (Zanoni *et al*., 1999). During drying, the moisture content is reduced and deterioration of the dried products is prevented within a period of time regarded as the safe storage period. Therefore, considering the safe storage conditions for the reduction of quality losses, storage conditions such as temperature, time and packaging are important factors for the color stability.

Many undesirable quality changes could occur in the dried products during drying and storage (Maskan, 2001). The color of tomato is an important quality index concerning consumer acceptance (De Sousa *et al*., 2008; Dermesonlouoglou *et al.,* 2007). A common problem in dried samples is browning and brown color products are not attractive and are not desired by the consumers (Demirbüker *et al*., 2004; Cemeroğlu and Acar, 1986).

Lycopene is the main coloring agent for the red color of the tomatoes (Lavelli and Scarafoni, 2011; D'Sousa *et al.*, 2008). Nguyen and Schwartz (1999) indicated that lycopene is susceptible to chemical changes when exposed to light and heat because of the presence of a long chain of conjugated carbon–carbon double bonds. Oxygen plays an important role on non-enzymatic or enzymatic browning of the products and if oxygen in the package of the product increase color changes accelerates during storage period. Additionally, temperature and light have increasing effect on browning of carotenoids (Cemeroğlu and Acar, 1986). Color reductions in sun-dried tomatoes might be due to the isomerization and autoxidation of lycopene (Anguelova and Warthesen, 2000). Moreover, color changes might be attributed to non-enzymatic browning or Maillard reactions (Cernîşev, 2010). Therefore this study is attempted to use browning measurement as the quality index of degradation of the dried mango and tomato and hence the prediction of shelf life basing on the measurement of browning in terms of absorbance measurement.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

This study was carried out at Sokoine University of Agriculture (SUA). The preparations, drying of fruits and vegetables, addition of preservatives and packaging of the dried product were done at Danida project premises while the microbiological, sensory analysis and shelf life study of the products were carried at Horticultural and Food Science laboratories, respectively.

3.2 Materials

3.2.1 Raw materials

Fruits, Mango (*Mangifera indica*) and tomato (*Lycopersicum esculentum*) were purchased from Morogoro Municipal Market. The Mangoes bought were from Tanga, Morogoro and Mwanza regions while the tomatoes were from Morogoro region.

3.2.2 Chemicals

Lemons were purchased from Morogoro Municipal Market and the lemon juice was extracted at Danida Project premises. Sodium metabisulphite, Acetic acid, Plate Count Agar, Peptone water and Petri dishes for microbiological analysis were purchased from tintometer GmbH, (Lovibond) W.T.W. Germany, Kasablanka Corporation. Merk Chemicals, Rohm Haas.

3.3 Methods

3.3.1 Research design

A purposively sampling procedure was used to acquire the mango and tomato for fruits and vegetable from the Morogoro Municipal Market. Samples were divided into four groups; one group was held as the control and the other three groups were added with the preservatives; sodium metabisulphite, Acetic acid and lemon juice.

A Completely Randomized Design (CRD) was used to study the effectiveness of the preservatives on microbiological safety, retention of sensory attributes and shelf life stability. The effectiveness of the preservatives on the above parameters were assessed and compared. The expression for this design is shown in equation 4.

$y_{ij} = \mu i + i + ij$ ……………………………………………………………………………(4)

Where $\mu = \mu + i$, i= 1, 2….., t, j=1,2…., μ= overall mean, i= ith treatment effect and, ij= random effect due to jth replication receiving ith treatment.

Randomized Complete Block Design (CRBD) was used in the sensory analysis of the preserved products and the principal factors were preservative type and the assessors. The effects of the factors were assessed. The expression is depicted in equation 5.

$y_{ij} = \mu + iţ + \beta j + ij$ ……………………………………..…………………………………....(5)

Where; μ= overall mean, $iţ$ = the ith treatment effect, $j\beta$ = the jth block effect and ij = the random effect.

3.3.2 Application of preservatives and drying procedure

Fruits and vegetables were washed, peeled and sliced longitudinal in a ranging size of 5 to 8 mm thick and each sample was divided into small portions (King'ori *et al*., 1999). The portions were then soaked in the preservatives which were in liquid form at room temperature (Codex Stn 192 – 1995). The contact time between samples and preservatives was 8 minutes in a concentration of 1,000 mg/ltr/kg which was 0.1% sodium metabisulphite, 5,000 mg/ltr/kg which was 0.5% acetic acid and one (1) litre flesh lemon juice/kg. The concentration of lemon juice in terms of citric acid was adjusted to 0.5 (v/v) by titrimetric methods due to variability in maturity and variety of lemon fruits to be used. (Codex Stn, 192– 1995). The samples were subjected to the solar dryer with temperature ranging from 30-50^0 C for about 2 days for drying until the required moisture content was attained i.e. 15% MC (King'ori *et al*., 1999). The dried pieces of fruits and vegetables were packed in polyethylene bags and stored at 4°C prior to analysis. The procedure is shown in the Fig. 4:

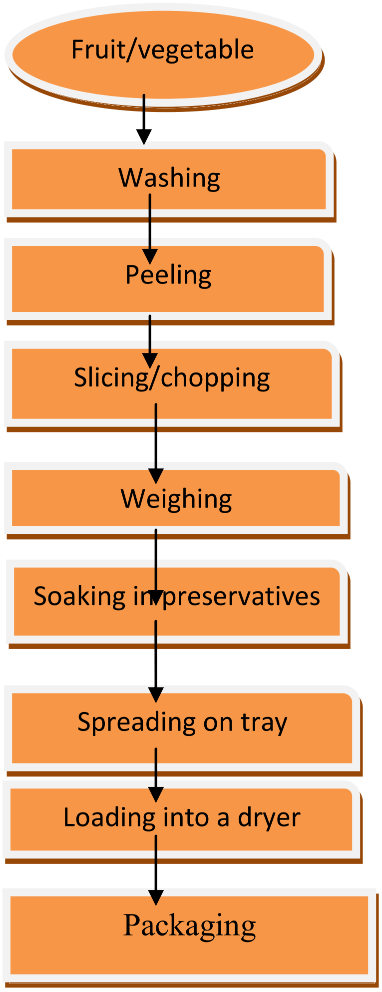

Figure 4: General flow sheet for fruit drying (modified from King'ori*et al*., 1999)

3.3.3 Determination of moisture content of fruits and vegetable

The moisture was determined according to standard oven drying method explained by AOAC (1995). The sample was first weighed (W_1) transferred into a pre-weighed crucibles (W_2) and oven dried at 110^{0}C for overnight. Then the crucibles with contents were cooled in a dessicator and re-weighed (W_3).The amount of moisture in percentage was calculated using equation 6.

$$\% \text{ Moisture content} = \frac{W1 - (W3 - W2)}{W1} \times 100 \quad \ldots\ldots(6)$$

Where; W1 = Weight of a fresh sample, W2 = Weight of the empty crucibles and

W3 = Weight of the crucible with a dry sample

3.3.4 Sensory evaluation

3.3.4.1 Quantitative Descriptive Analysis (QDA)

A descriptive sensory profiling was conducted at the Department of Food science and Technology by trained sensory panel of 10 assessors, comprising of 7 males and 3 females with the age ranging from 22 to 29 according to the method described by Lawless and Heyman (2010). The assessors were selected and trained according to ISO Standard (1993). In a pre-testing session the assessors were trained in developing sensory descriptors and the definition of the sensory attributes. The assessors developed a test vocabulary describing differences between samples and they agreed upon to a total number of attributes on color hue, sweetness, texture, whiteness, and aroma as indicated in table 4 below: An unstructured line scale was used for rating the intensity of an attribute .The left side of the scale corresponded to the lowest intensity of each attribute (value 1) and the right side corresponded to the highest intensity (value 9) as attached in appendix.

Descriptive analysis was carried out in two sessions, in the first session assessors evaluated 4 samples of fruits in which one sample was the control and three samples were added preservatives. The second session involved the analysis of 4 samples of vegetable/fruit which comprised of a single control sample and three preserved samples, therefore descriptive analysis were done in total of eight samples of the products under the study. The samples were coded with 3-digit random numbers from stastical tables of random numbers and the samples were served to each panelist in a randomized order and instructed to rate the colour hue, sweetness, texture, whiteness and aroma attributes. Water was served alongside the samples for rinsing the mouth before evaluating another sample during the test. Thus the average responses were used in the univariate and multivariate analyses.

Table 4: Definitions of sensory attributes used in descriptive sensory analysis

	Attribute	Definition
Colour	Colour hue	Yellow/ any colour of egg York of indigenous chicken
	Whiteness	Degree of white in the color
Aroma	Fruity (mango/tomato)	Aromatics associated with fresh fruit(mango/tomato)
Taste	Sweetness	The taste associated with sucrose solution (Reference 0.1% sucrose)
Texture	Hardness	Resistance of the sample during pressing

Source: (Lawless and Heyman, 2010).

3.3.4.2 Consumer test

The test was carried out in the Department of Food science Laboratory by 70 untrained consumers aged 18 and above years in groups of 20 using a 9 point hedonic scale (where 1 =dislike extremely and 9 =like extremely) as described by Lawless and Heyman (2010). The samples were sliced into pieces of uniform thickness coded with three digit random numbers using statistical random tables and served to the panelist at 10:00 am with clean drinking water in a randomized manner. The judges were instructed to rate the taste, color aroma, texture and overall acceptability attributes indicating the degree of liking or disliking by putting a number as provided in the hedonic scale according to their preference. The test was done in two days and each judge evaluated 4 samples in a day.

3.3.4.3 Relationship between sensory and consumer data (preference mapping)

The preference mapping was evaluated by combining the descriptive data and hedonic data obtained from all judges and the direction of the degree of liking of the products were assessed based on the attributes which drove the panelists to like the product. Preference mapping was done to study the relationship between descriptive data and hedonic liking from the consumers.

3.3.5 Microbiological analysis (total bacteria count)

Total number of microorganisms were analyzed according to the ISO 4833 (2003) procedures. Plate count Agar for total bacteria enumeration was used in this study. The Agar dissolving and diluting media were prepared as described by the producer.

1g of dry blended sample was put in a test tube with 10 ml peptone water to give 10^0 dilutions. The test tubes were placed for few seconds before the samples were diluted to 10^{-1}, 10^{-2}, 10^{-3} up to 10^{-5} dilutions. About 12 ml to 15 ml of the plate count agar (PCA) at 44 °C to 47 °C was poured into each Petri dish, then 1ml of the sample from the test tube diluted 1 up to 5 was put in the Petri dish and mixed with the media by the gentle rotation of the Petri dish and the mixture was allowed to solidify by leaving the Petri dishes standing on a cool horizontal surface. After complete solidification prepared dishes were inverted and placed them in the incubator at 30 °C ± 1 °C for 72 hours. After the specified incubation periods the colonies were counted. The counted and number of colony forming units (CFU) per milliliter were calculated using the following formula;

$$CFU/ml = \frac{\sum C}{(n1+n2)d} \quad (7)$$

Where; $\sum C$ = is the sum of colonies counted on the dishes retained, n1 = is the number of dishes retained in the first dilution, n2 = is the number of dishes retained in the second dilution and d = is the dilution factor corresponding of the first dilution.

3.3.6 Prediction of shelf life

The determination of shelf life was done by measuring the absorbance which express as the extent of non-enzymatic browning in dried samples. The dried fruit samples were first packed in polythene bags and then subjected into different temperatures which were 35°C and 45°C in the oven dryers. The samples were left in that temperatures for 28 days however the small amount of the sample were taken after every 7days for the measurement of the absorbance (browning measurement) as per the modification of the ADOGA methods of browning measurement.

3.3.6.1 Browning measurement

The extent of Non enzymatic in dried samples was determined in terms of the absorbance by extraction of brown pigment of the dried samples. The measurement of absorbance is primarily a measure of non-enzymatic browning that may occur during processing and storage.

3.3.6.2 Procedure

A 2g of a sample of dried mango and tomato powder was weighed into the beaker and mixed with 0.5g of filter- aid (celite). One hundred(100 mls) of 10%Nacl solution was then added to the dry samples, first adding 5 to 10ml and stirring to form a slurry, then adding the reminder of the NaCl solution. The mixture was allowed to stand for 15 min with occasional stirring. The mixture was then filtered through whatman no. 50 filter paper. The rehydrated dried sample and filter aid was allowed to settle in the bottom of the filter paper. The filtrate was then taken separately after 25 min of filtration, the absorbance of the filtrate was determined at 430 nm. The spectrophotometer was standardized with filtered 10% NaCl solution.

Then a graph of absorbance versus time of storage were used to determine the shelf life of products at 35^{o}C and 45^{o}C from the regression equation while a plot of log of shelf life obtained versus temperature predicted the shelf life of the products at room temperature as per linear model equation.

3.3.7 Statistical data analysis

The data were analyzed by using R statistical package (R Development core team, Version 3.0.3) for one way and two way analysis of variance to determine the significant difference and interactions between the factors means at ($p<0.05$). Means were separated by post hoc pair wise test (Turkeys Honest Significant Difference at $P<0.05$. The results were presented in Tables, bar charts, spider plots and bi plots as mean ± SD. Principal Component analysis (PCA) was performed using R statistical package (R Development core team, Version 3.0.3). PCA was used to study the main sources of systematic variations in the average sensory descriptive data. The sample difference in relation to the attributes was analyzed by the panel check software. The relationship between descriptive data and hedonic data were analyzed by consumer check software where the direction of liking of the consumers was evaluated. Correlation loading plots were applied with cycles indicating 50 and 100% explained variance respectively. In the correlations loading products were included to improve the visual interpretation as described by Martens (2001).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Moisture Content

4.1.1 Mango moisture content

Results for the mean moisture content for the dried mangoes treated with preservatives and the control are shown in Table 5. The results show that variation between moisture content was significant ($P<0.05$) with the control sample having low moisture content than all treated samples, also the results revealed that the sample treated with sodium metabisulphites have higher moisture content than the mango treated with acetic acid or lemon juice which showed no significant difference.

Table 5: Moisture content of dry mango after 24-36 hours of drying

Product	Treatment	Moisture (%)
Mango	Control	17.5 ± 0.7^{a}
	Acetic Acid	19 ± 0.0^{b}
	Lemon Juice	19 ± 0.0^{b}
	Sodium Metabisulphite	22 ± 0.0^{c}

Data presented as mean ± SD

Means in the column with different superscript small letters indicate significant difference at ($p<0.05$).

4.1.2 Tomato moisture content

The moisture content of dried preserved tomato samples and control sample are shown in Table 6. The results show significant differences ($p<0.05$) between the samples. The samples preserved with sodium metabisulphite scored lower in moisture content than the samples preserved with acetic acid or lemon juice, however the control sample was seen to contain higher moisture content than the treated samples which were sodium metabisulphite, lemon juice or acetic acid.

Table 6: Tomato moisture content of dry tomato after 24-36 hours of drying

Product	Treatment	Moisture (%)
Tomato	Sodium metabisulphite	17.5±0.7[a]
	Acetic acid	19.5±0.7[b]
	Lemon juice	19±0.0[b]
	Control	20±0.0[b]

Data presented as mean ± SD

Means in the column with different superscript small letters indicate significant difference at ($p<0.05$).

The variation in moisture content are mainly influenced by the factors such as air velocity, temperature, relative humidity, surface area exposed to drying air and the initial moisture content present in the sample (Donald, 2012). However most of the results for moisture content of dried mango and tomato agree with the literature that most dried fruits and vegetable should have about 20% moisture content when dried, this amount of moisture makes the dried fruits or vegetable to be not hard or brittle when eating and this level of moisture content is considered to be safe for storage (Harrison and Andress, 2000).

4.2 Water Activity

4.2.1 Water activity of mango

The results for water activity for the four samples of mango are shown in Figure 5. The results show the higher level of water activity for the sample treated with sodium metabisulphite than the sample treated with acetic acid or lemon juice and the control samples were seen to have low water activity. However all samples had water activity below 0.6 which is considered to be not favorable for any microbial growth.

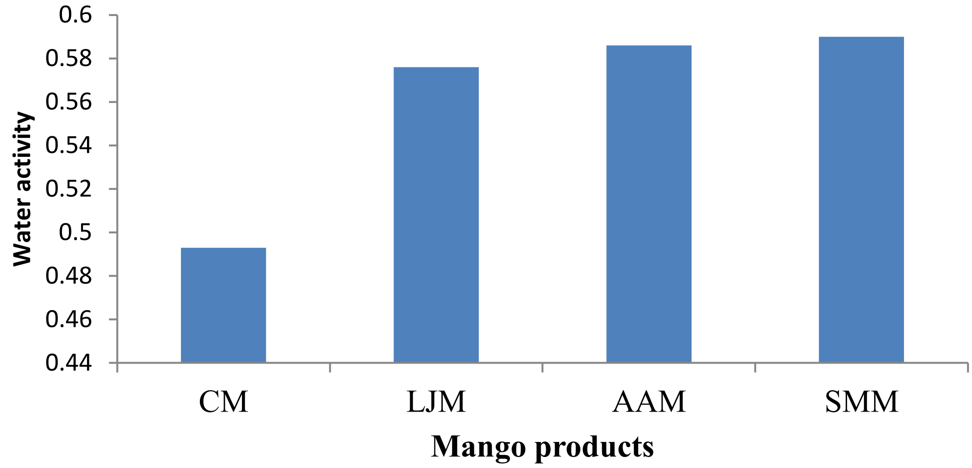

Figure 5: Water activity of mango treated with preservatives and the one which is the control sample. Each bar represents the actual figure of water activity as detected by the moisture meter.

Where; CM is Control mango, LJM is Lemon juice treated mango, AAM is Acetic acid treated mango and SMM is Sodium metabisulphite treated mango

4.2.2 Water activity of tomato

The results for water activity for the four samples of tomato are shown in Figure 6. The result shows that sodium metabisulphite scored less in water activity followed by lemon juice, acetic acid and control samples. However all samples had water activity below 0.6 which is considered to be not favorable for any microbial growth.

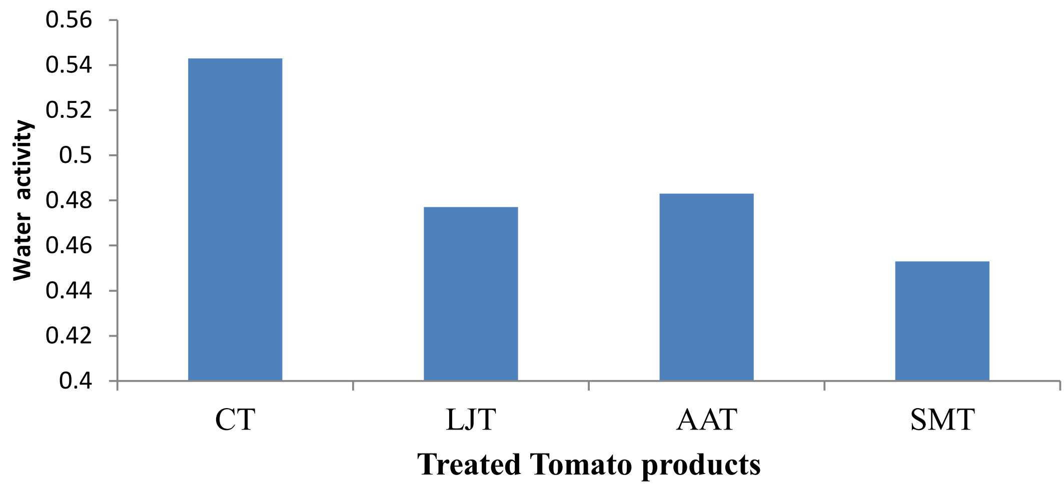

Figure 6: Water activity of tomato treated with preservatives and the one which is the control sample. Each bar represents the actual figure of water activity of tomato as detected by the moisture meter.

Where; CT is Control tomato, LJT is Lemon juice treated tomato, AAT is Acetic acid treated tomato and SMT is Sodium metabisulphite treated tomato.

In general the results of water activity in this study goes in line with the finding by Jay, (1992) that, dried fruits and vegetable products with moisture content between 13 – 25% have water activity less than 0.8 which is safe for microbial growth especially bacterial contamination.

4.3 Sensory Quality

4.3.1 Mango quantitative descriptive analysis

4.3.1.1 Panel performance

The panelists were clustered this indicates that the panel performance was good. Discrimination ability was also good since most of the panelists were found in the outer circle (i.e descrimination ability > 50%) as shown in Figure 7, however the perfomance of the panelists in aroma and texture was a a bit poor.

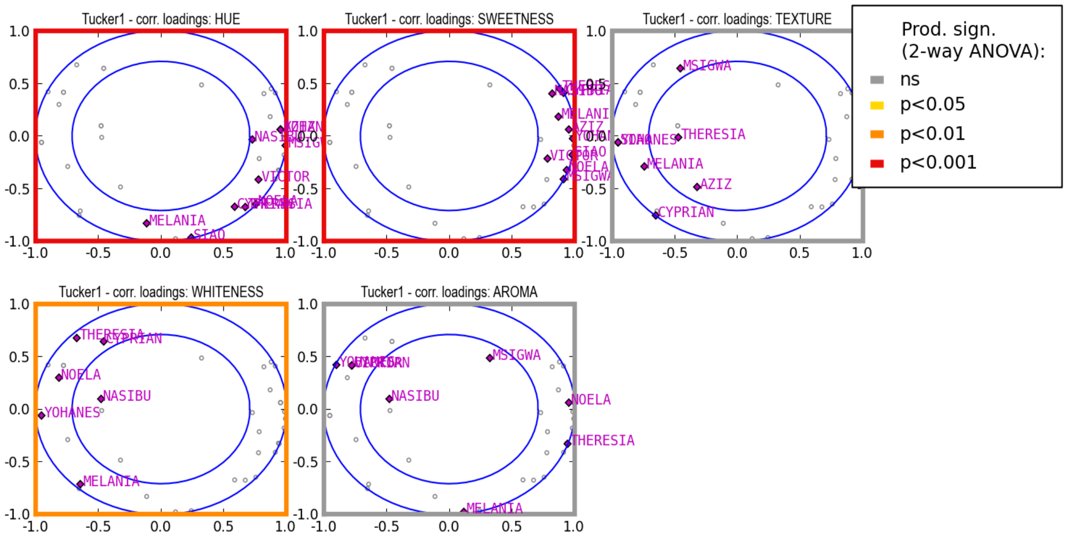

Figure 7: Panel performance on discrimination during descriptive sensory testing of mango

4.3.1.2 Sample difference

The mean intensity ratings of descriptive attributes of mango samples are shown in figure 8. The results indicated a significant difference at ($p<0.05$) in mean score of some of the attributes of the preserved mango samples and control, however the samples preserved with lemon juice and Sodium metabisulphite had no significant difference in all the attributes assessed but they all differed significantly with the acetic acid preserved sample in the attribute aroma, color and taste. The results also showed no significant difference for the acetic acid preserved sample and control in most of the attributes assessed.

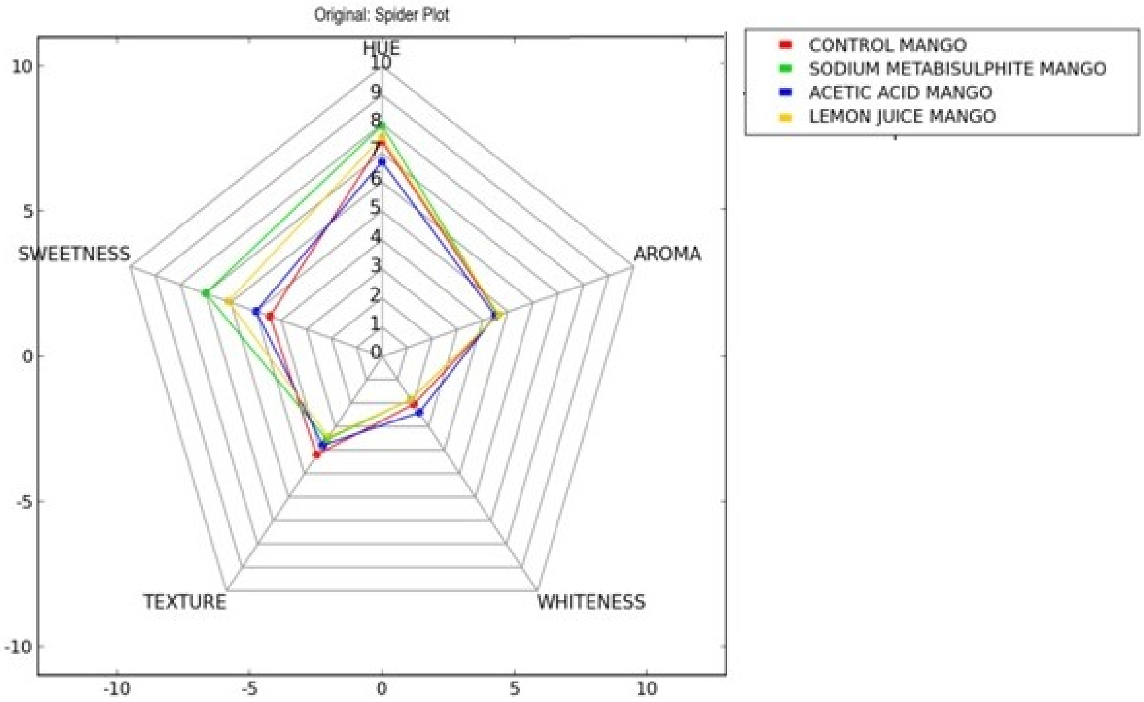

Figure 8: Spider plot showing the mean score of attributes between mango samples

Table 7: Mean hedonic scores for the mango samples

Product	Aroma	Color	Taste	Texture
AA Mango	6.5±12[a]	6.6±1.6[a]	6.5±1.7[a]	6.6±1.6[b]
SM Mango	7.2±1.2[b]	7.4±1.4[b]	7.5±1.2[b]	7.0±1.5[b]
LJ Mango	7.2±1.3[b]	7.2±1.5[ab]	7.4±1.2[b]	7.0±1.2[b]
CT Mango	6.6±1.5[a]	6.9±1.4[ab]	6.1±1.8[a]	5.9±1.8[a]

The values are presented as mean ±SD

The different superscript along the columns indicate values are significantly different at ($p<0.05$)

Where; AA Mango is the sample treated with acetic acid, SM Mango the sample treated with Sodium metabisulphite, LJ Mango the sample treated with lemon juice and CT Mango is the control sample

The results of the sample differences above agree with some studies. According to Harrison and Andress (2000), the pre-treating of fruits and vegetable with ascorbic acid, citric acid, salt solution, blanching or sulphiting can reduce the effect of color loss which is caused by the browning reactions. These pre-treatments can also destroy the presence of hazardous micro- organisms during drying (Swanson, 2009).

4.3.1.3 Principal component of descriptive sensory data

In Fig. 9 shows a bi- plot with two first significant principal components from the principal component analysis (PCA) on the average sensory attributes. Principal component 1 accounted for 89.1% of the variation while principal component 2 accounted for 9.6% of the variations. The mango preserved by lemon juice and Sodium metabisulphite were separated from the mango samples preserved by acetic acid and the control samples. Lemon juice and sodium metabisulphite mango samples were positively correlated with the attributes aroma, colour hue and sweetness however they correlated negatively with the attributes whiteness and texture. The mango samples preserved by acetic acid and the control mango samples correlated positively with texture and whiteness. The results show that the variation between the mango samples was explained by sweetness aroma and hue attributes on the right hand side of PC1 while texture and whiteness explained the variation between samples on the left hand side. In PC2 the variation between mango samples was explained by attributes texture, aroma and hue in on one side while whiteness and sweetness explained the variation of the sample on the other side.

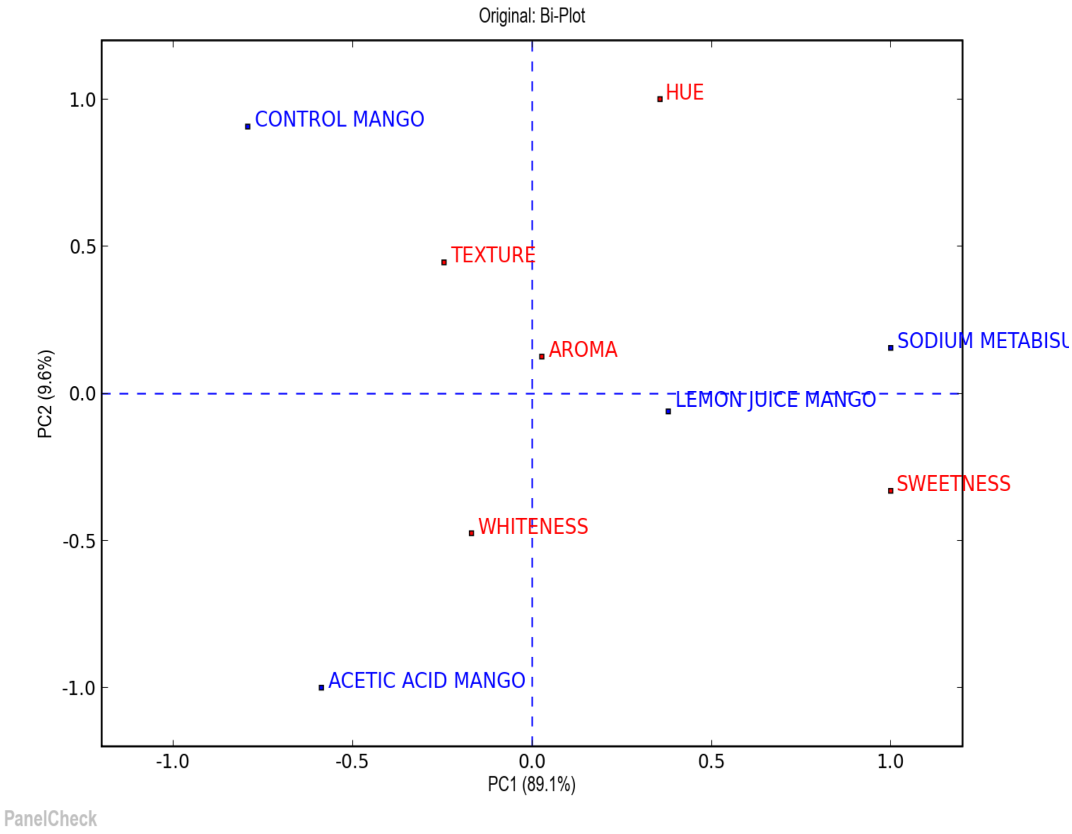

Figure 9: Bi – plot from PCA of descriptive sensory data of the mango samples

4.3.1.4 PCA scores

The data in Fig. 10 shows the variation between the mango samples; whereas there was great difference between control sample and the sample preserved by sodium metabisulphite along PC1 while in PC2 the magnitude of difference were highly seen to the sample preserved with the acetic acid and the control sample.

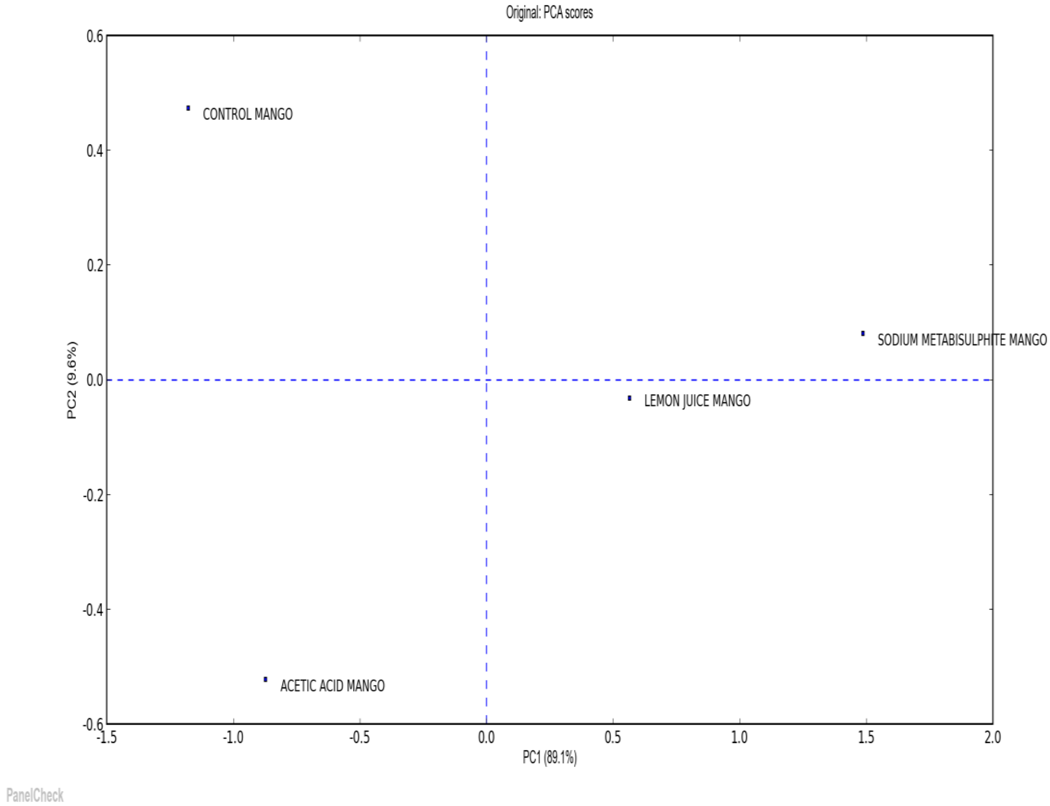

Figure 10: The PCA scores showing the variation between the mango samples

4.3.2 Consumer tests

4.3.2.1 Consumer characteristics

Table7 shows characteristics of the panel consumer. The results showed that, out of 70 consumers, 52 (74%) were male while 18 (26 %) were female with age group ranged from 20-30 and 31- 40 years. The results also revealed that 58 (83%) were the bachelor degree students, 8 (11%) were the diploma students and 4 (6%) were the masters students. Out of these, 29 (41%) were the frequent consumers of the product, while 41 (59%) were not the frequent user of the product. This implies that the panel was dominated by male, young people and degree students, most of them were not frequent user of the products.

Table 8: Consumer characteristic

Characteristics	Category	Frequency	Percentage (%)
GENDER	Male	52	74
	Female	18	26
Total		**70**	**100**
AGE	20 -30	65	93
	31 -40	05	7
Total		**70**	**100**
EDUCATION LEVEL	Bachelor degree	58	83
	Diploma	8	11
	Masters degree	4	6
Total		**70**	**100**
FREQUENT USER	Yes	29	41
	No	41	59
Total		**70**	**100**

The results above show that most of the panelists involved in sensory testing were male (72%), this has an implication that the results obtained from this evaluation were gender sensitive because it is the outcome of male opinions towards the product, again it was noted that most of the panelist are not the frequent user of the product; therefore if the product is to be launched then more of the promotions and advertisement is needed to make people aware of the product and hence capturing the market. However the results seems to be reliable because the test were done without biasness, for the product were new to almost many panelists i.e the negative attitude towards the product were largely removed. Also most of the panelist who did the evaluation were between the ages of 20 – 30, therefore when launching the product the target market should base on that age, it will be easier to capture them than other age groups.

4.3.2.2 Hedonic test

Mean hedonic scores for the analyzed samples of mango are shown in Table 8. The consumers showed significant difference at ($p<0.05$) in some of the attributes evaluated.

Sodium metabisulphite and lemon juice mangoes scored higher in all attributes which are aroma, color, taste, Texture and overall acceptability than their counterparts' samples evaluated. Control sample scored low for taste texture, and overall acceptability, this implies that preservatives have effects on color retention of the product and color is the key driver of product acceptability.

4.3.2.3 Hedonic liking or overall acceptability

The mean score for the hedonic liking are shown in table 9: the results show that the consumers showed significant difference at ($p<0.05$) in hedonic liking whereas Sodium metabisulphite mango sample and lemon juice preserved mango sample scored almost the same, followed by the acetic acid mango sample which scored 6.7 and the control mango sample which scored lower than all.

Table 9: Mean score for the mango hedonic liking

Product	Overall accept.
AA Mango	6.7 ± 1.4^{ab}
SM Mango	7.4 ± 1.2^{c}
LJ Mango	7.3 ± 1.3^{bc}
CT Mango	6.2 ± 1.7^{a}

The values are presented as mean ±SD

The different superscript along the columns indicate values are significantly different at ($p<0.05$).

4.3.3. Relationship between descriptive and hedonic data (preference mapping)

The Figure 11 shows the relationship between hedonic data and descriptive data from a consumer check using descriptive data as X-variables and liking rated by the consumers as *Y*-variables. The results show that most of the consumers fall in the right hand side of the vertical – axis implying that, the acceptance values of these consumers go in the direction of Sodium metabisulphite mango sample and the mango treated with lemon juice associated with sweetness, aroma and color hue attributes. The mango treated with lemon juice was closely associated with color hue and aroma while the Sodium Metabisulphite sample closely associated with sweetness. Acetic acid mango and control sample were less preferred by the consumers and they were closely associated with the whiteness and texture (hardness).

Therefore the attributes hue, sweetness and aroma are the key attributes which drove the consumer to like the products, this goes in line with the statement that colour and appearance are the initial quality attributes that attract person to a food product and thus considered as an index of the inherent good quality of foods associated with the acceptability of food (Methakhup *et al.,* 2005).

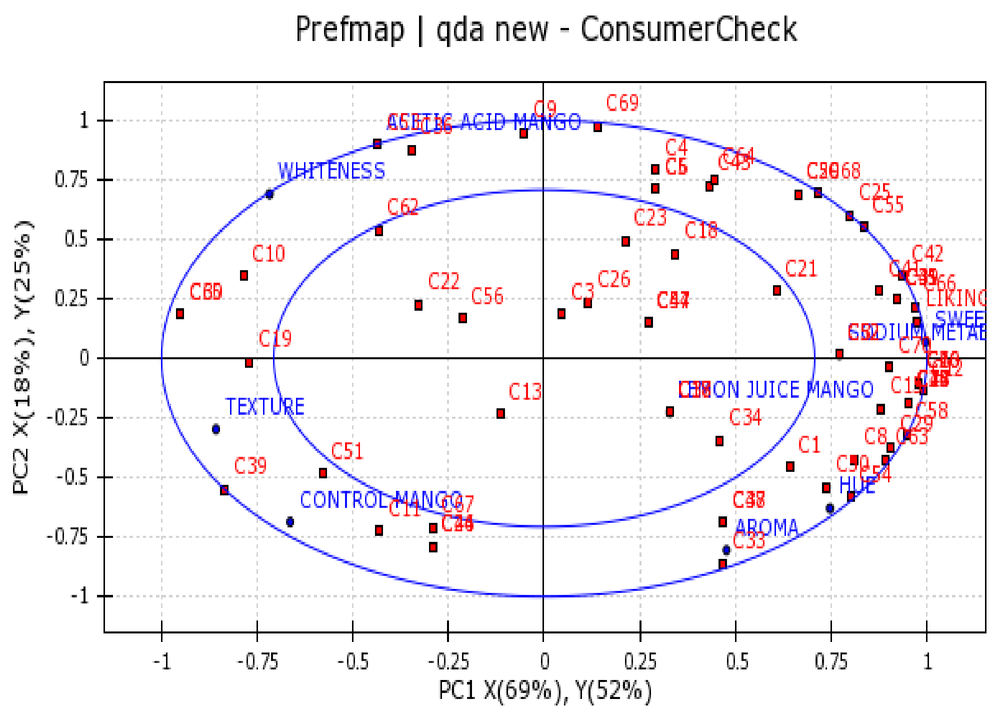

Figure 11: Correlation loadings from a consumer check of mango products with descriptive data as X variables and hedonic rating as Y variables

4.3.4 Tomato quantitative descriptive analysis

4.3.4.1 Panel performance

The panelists were clustered this indicates that the panel performance was good. Discrimination ability was also good since most of the panelists were found in the outer circle (i.e descrimination ability > 50%) as shown in Fig. 12, however the perfomance of the panelists in aroma and texture and aroma was a a bit poor.

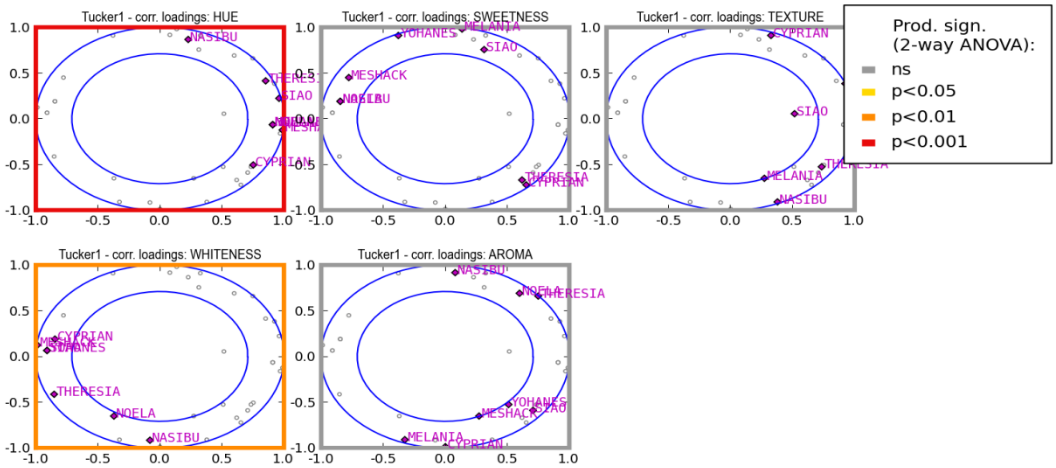

Figure 12: Panel performance on discrimination during descriptive sensory testing of tomato

4.3.4.2 Sample difference

The mean intensity ratings of descriptive attributes of tomato samples are shown in Fig.13. The results indicated no significant difference at ($p<0.05$) in mean score of aroma, taste and texture attributes assessed for the preserved and control tomato samples. The tomato samples preserved with lemon juice, sodium metabisulphite and acetic acid showed significant difference with the control sample in color attribute implying that preservatives have effect on color retention of the products.

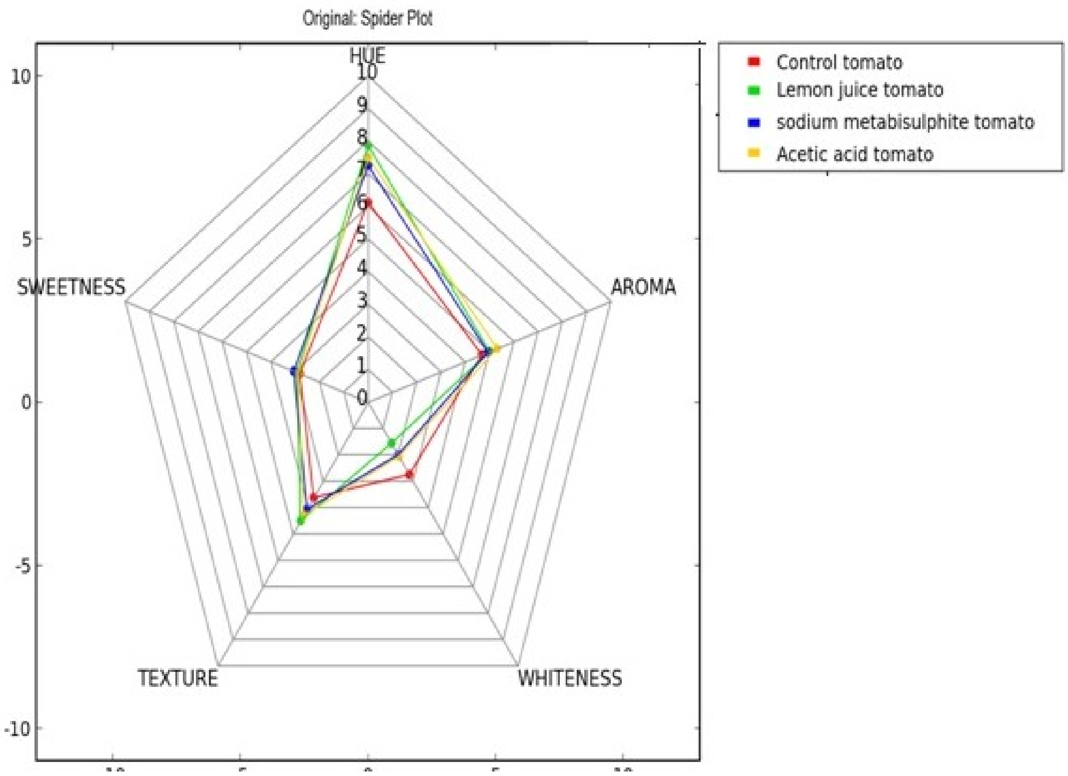

Figure 13: Spider plot showing the mean score of attributes between tomato samples

Table 10: Mean hedonic scores for the tomato samples

Product	Aroma	Color	Taste	Texture
AA Tomato	6.2±1.4[a]	6.6±1.5[ab]	6.5±13[a]	6.0±1.7[a]
SM Tomato	6.3±1.5[a]	6.8±1.5[ab]	6.4±1.5[a]	5.9±1.7[a]
LJ Tomato	6.3±1.4[a]	7.0±1.4[b]	6.3±1.6[a]	6.2±1.4[a]
CT Tomato	5.9±1.6[a]	6.2±1.7[a]	6.3±1.6[a]	6.1±1.4[a]

The values are presented as Mean ± SD

The different superscript along the columns indicate values are significantly different at ($p<0.05$)

Where; AA Tomato is the sample treated with acetic acid, SM Tomato is the sample treated with Sodium metabisulphite, LJ Tomato the sample treated with lemon juice and CT Tomato is the control sample

The results of the sample differences above agree with some studies. According to Harrison and Andress (2000), the pre-treating of fruits and vegetable with ascorbic acid, citric acid, salt solution, blanching or sulphiting can reduce the effect of color loss which is caused by the browning reactions. These pre-treatments can also destroy the presence of hazardous micro- organisms during drying (Swanson, 2009).

4.3.4.3 Principal component of descriptive sensory data

Fig. 14 shows a bi- plot with two first significant principal components from the principal component analysis (PCA) on the average sensory attributes. Principal component 1 accounted for 94.6% of the variation while principal component 2 accounted for 4.5% of the variations. The tomato preserved by lemon juice, acetic acid and sodium metabisulphite was separated from the control sample. Lemon juice, acetic acid and sodium metabisulphite tomato samples were positively correlated with texture, Hue, aroma and sweetness attributes however they correlated negatively with whiteness. Control tomato samples correlated positively with the attribute whiteness. The results show that the variation between samples were explained by Hue, Texture, sweetness and aroma attributes on the left hand side of PC1 while whiteness explained the variation between samples on the right hand side of PC1. In PC2 the variation between samples was explained by aroma, whiteness, texture and hue attributes in one side while sweetness explained the variation of the samples on the other side of the PC2.

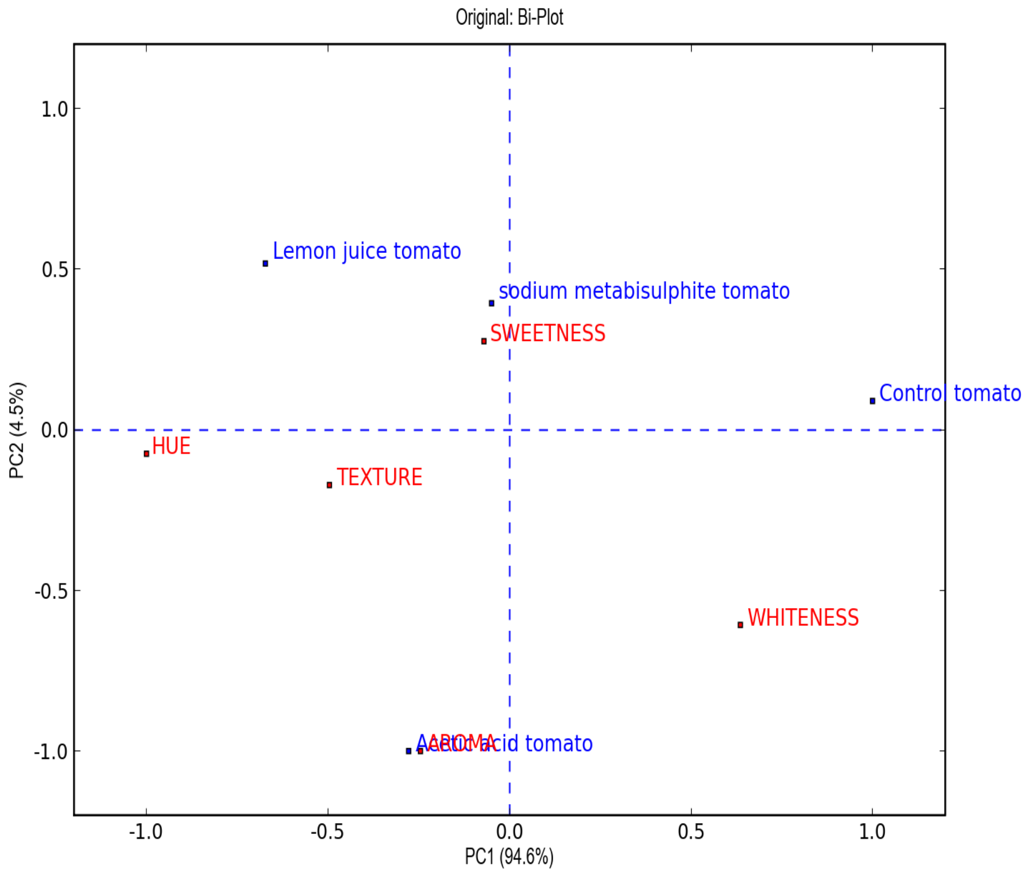

Figure 14: Bi – plot from PCA of descriptive sensory data of the Tomato samples

4.3.4.4 PCA scores

The data in figure 15 shows the variation between the tomato samples: there was great variations between the tomato samples preserved with lemon juice and the control sample along PC1 while in PC2 the magnitude of difference were highly observed by the tomato samples preserved with the acetic acid and the samples preserved with lemon juice.

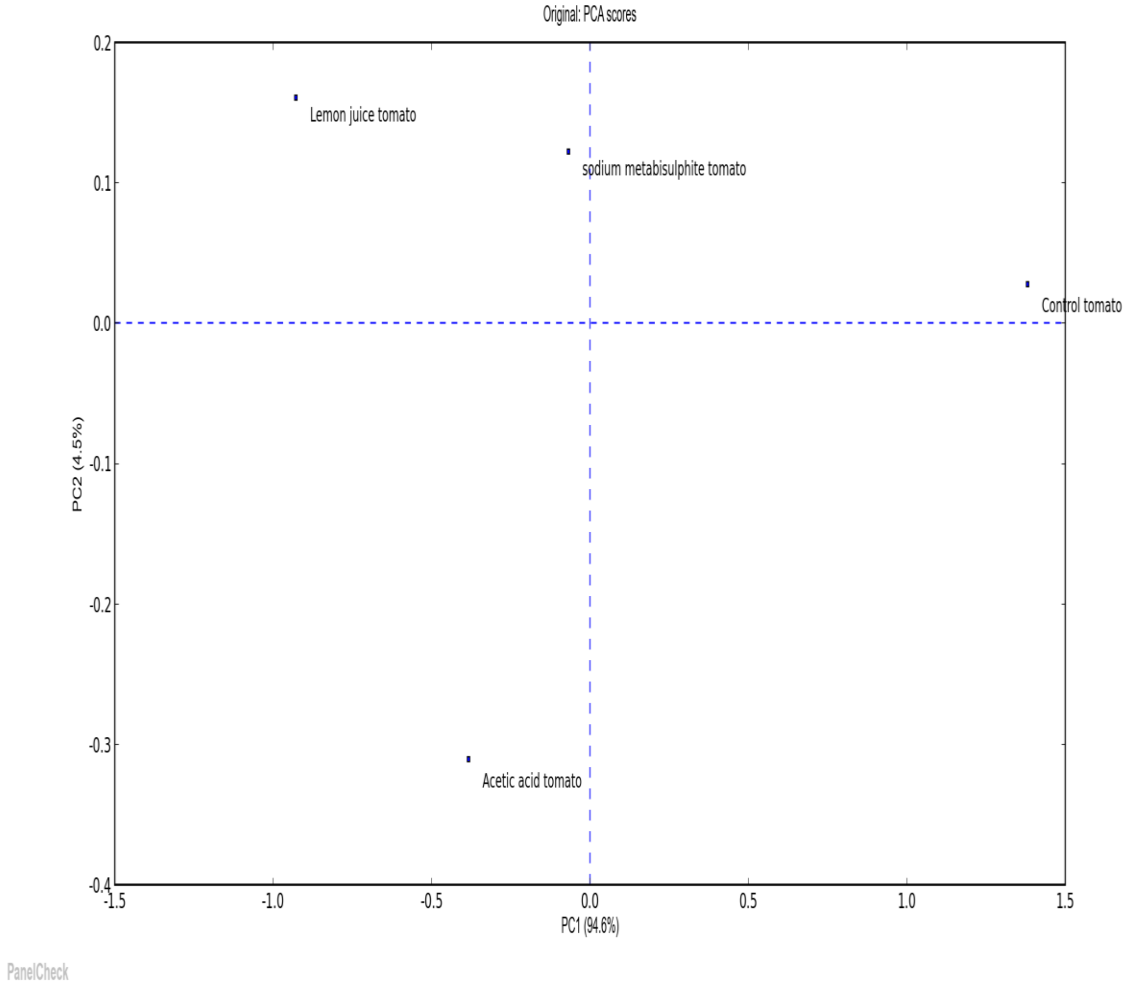

Figure 15: The PCA scores showing the variation between the tomato samples

4.3.5 Consumer studies

4.3.5.1 Consumer characteristics

Table 10 shows characteristics of the panel consumer. The results showed that, out of 70 consumers, 47 (67%) were male while 23 (33%) were female with age group ranged from 20-30, 31- 40 and above 50 years. The results also revealed that 59 (84%) were the bachelor degree students and 11 (16%) were the masters degree students. Out of these, 32 (46%) were the frequent consumers of the product, while 38 (54%) were not the frequent user of the product.

Table 11: Consumer characteristics

Characteristics	Category	Frequency	Percentage (%)
GENDER	Male	47	67
	Female	23	33
Total		**70**	**100**
AGE	20 -30	63	90
	31 -40	6	9
	Above 50	1	1
Total		**70**	**100**
EDUCATION	Bachelor degree	59	84
	Masters degree	11	16
Total		**70**	**100**
FREQUENT USER	Yes	32	46
	No	38	54
Total		**70**	**100**

The results above show that most of the panelists involved in sensory testing were male (67%), this has an implication that the results obtained from this evaluation were gender sensitive because it is the outcome of male opinions towards the product, again it was noted that most of the panelist are not the frequent user of the product; therefore if the product is to be launched then more of the promotions and advertisement is needed to make people aware of the product and hence capturing the market. However the results seems to be reliable because the test were done without biasness because the product were new to almost many panelists i.e the negative attitude towards the product were largely removed. Also most of the panelist who did the evaluation were between the ages of 20 – 30, therefore when launching the product the target market should base on that age, it will be easier to capture them than other age groups.

4.3.5.2 Hedonic test

Mean hedonic scores for the analyzed samples of tomato are shown in Table 11. With the exception of the attribute color which showed significant difference at ($p<0.05$), consumers showed no significant difference in all the remaining attributes evaluated. Lemon juice tomatoes scored higher in attribute color than other counterparts' samples evaluated; however the mean score in other attributes were almost the same.

4.3.5.3 Hedonic liking

The mean score for the hedonic liking are shown in Table 12: the results show that the consumers didn't show any significant difference at ($p<0.05$) however the tomato preserved with lemon juice scored high mean which is 6.4 followed by acetic acid preserved tomato which scored 6.3 whereas the control and sodium metabisulphite samples scored similar mean which was 6.1.

Table 12: Mean scores for the tomato hedonic liking

Product	**Overall accept.**
AA Tomato	6.3 ± 1.6^{a}
SM Tomato	6.1 ± 1.6^{a}
LJ Tomato	6.4 ± 1.6^{a}
CT Tomato	6.1 ± 1.4^{a}

Data presented as mean ± SD

Means in the column with different superscript small letters indicate significant difference at ($p<0.05$).

4.3.6 Relationship between descriptive and hedonic data (preference mapping)

The Fig. 16 shows the relationship between hedonic data and descriptive data from a consumer check using descriptive data as X-variables and liking rated by the consumers as Y-variables. The results show that most of the consumers fall in the right hand side of the vertical - axis and this means that, the acceptance values of these consumers go in the direction of the tomato samples treated with acetic acid, lemon juice and sodium metabisulphite associated with sweetness, aroma, color hue and texture attributes. The tomato treated with lemon juice was closely associated with color hue, texture, and the sample treated with acetic acid was closely associated with aroma, while the sample treated with sodium metabisulphite was closely associated with sweetness. The control tomato sample closely associated with whiteness was less preferred as it was found in the left hand side of the y - axis.

Therefore the attributes hue, sweetness, aroma and texture are the key attributes which drove the consumer to like the products, this goes in line with the statement that colour and appearance are the initial quality attributes that attract person to a food product and thus considered as an index of the inherent good quality of foods associated with the acceptability of food (Methakhup *et al*, 2005).

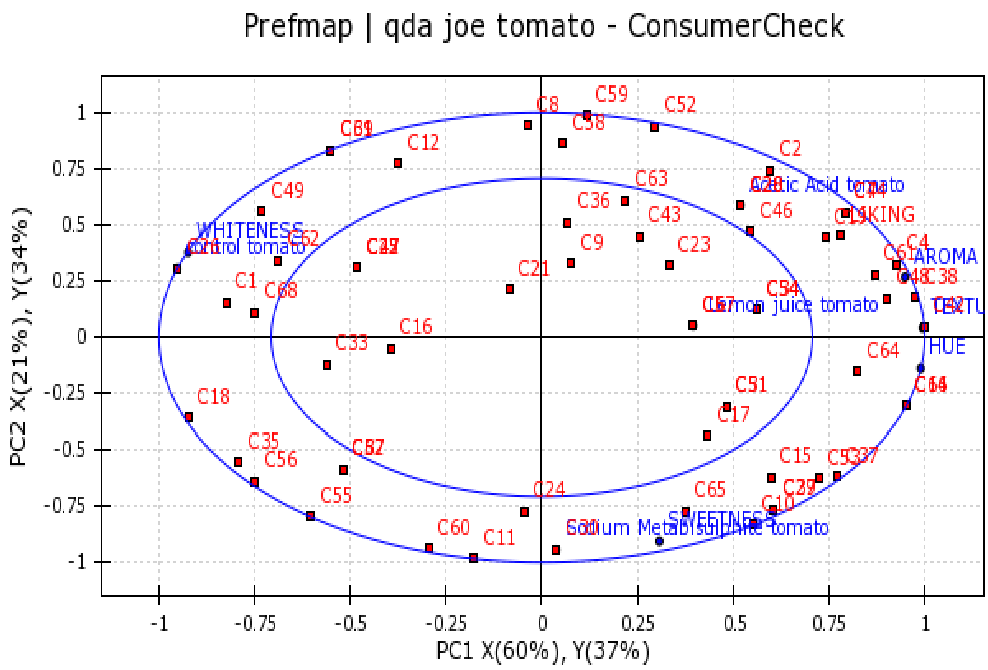

Figure 16: **Correlation loadings from a consumer check of tomato products with descriptive data as X variables and hedonic rating as Y variables**

Although many fruits and vegetable may be dried and stored without treating, but treating with preservatives normally improves quality and safety of the food. Treating can retain color and Nutrients, can stop decomposition by enzymes and extending shelf life.

According to Harrison and Andress (2000) it was found that treating fruits and vegetable can decrease the problem of color loss during processing and storage, reduce the losses of vitamins and flavor as well as destroying potentially hazardous micro organisms from products. Discoloration is one of the problem affecting fruits and vegetable during processing and storage (Maskan, 2001). It is normally caused by the oxidation and polymerization of phenolic compounds to brown pigments. Drying process normally increases the sweetness of fruits by the action of sugar concentration due to water removal. The findings imply that lemon juice, sodium metabisulphite and acetic acid treatments have significant effects on sensory attributes of both fruits and vegetables which were the color hue, aroma sweetness and texture. This means that treating fruits and vegetables with lemon juice, sodium metabisulphite and acetic acid generally improves the quality by decreasing the discoloration, retaining flavor compounds and reducing the vitamin losses.

The variation in consumer preferences brought attention into the sensory attributes that are drivers to individual acceptability of samples. Preference mapping in both fruits and vegetables showed that color hue, sweetness and aroma are the most important attributes for consumer liking of fruits and vegetables under the study. Color, aroma and sweetness correlated mainly to high consumer preferences for mango treated with lemon juice and sodium metabisulphite while for tomato color, aroma, sweetness and texture were mainly correlated to the samples treated with lemon juice, sodium metabisulphite and acetic acid. Colour and appearance are the initial quality attributes that attract person to a food product and thus considered as an index of the inherent good quality of foods associated with the acceptability of food (Methakhup *et al.*, 2005). Also the flavor may have an impact to consumer acceptability of the products.

Therefore the treatments which tend to preserve color and flavor of the dried products should be given considerations for the acceptability. Lemon juice and sodium metabisulphite treated samples have shown to retain both of the attributes in fruits and vegetables.

4.4 Microbial Analysis Results of Treated and Control Fruits and Vegetables Products

4.4.1 Microbial results for mango

Table 13 shows the results of microbial analysis of products treated with the preservatives and the control samples of fresh dried samples and one month period after drying. The results show that all the samples had less than $1x10^1$cfu/g microbial loads for fresh dried products and one month period of storage.

Table 13: Microbial results for treated and control mango samples for fresh dried and one month period of storage

Product/ sample	**First results (fresh dried sample) cfu/g**	**Second results (one moth storage time)**
Control sample	Less than $1x10^1$	Less than $1x10^1$
Sample treated with sodium metabisulphite	Less than $1x10^1$	Less than $1x10^1$
Sample treated with lemon juice	Less than $1x10^1$	Less than $1x10^1$
Sample treated with acetic acid	Less than $1x10^1$	Less than $1x10^1$

The results for microbial analysis shows that there were no significant difference at ($p<0.05$) as all the samples scored 0 count of microbial load.

The results go in line with the findings of Harrison and Andress, (2000) that fruits have long shelf life and this is enhanced by the high sugar and acid content they contain which allow to dry well and store for a long period of time without being deteriorated by micro-organisms.

4.4.2 Microbial results for tomato

Table 14 shows the results of microbial analysis of products treated with the preservatives and the control samples of fresh dried samples and after one month period of storage. The results show that all the samples had less than $1x10^1$cfu/g microbial loads for fresh dried products while the results after one month of storage time at room temperature were $1.8x10^1$cfu/g for the control tomato sample, $1.6x10^1$ cfu/g for the tomato treated with sodium metabisulphite and $2.2x10^1$ cfu/g for the tomato treated with acetic acid. However the remaining samples had the value less than $1x10^1$cfu/g values for microbial load. According to Harrison and Andress (2000) vegetables are less stable than fruits due to the low sugar and acid content they contain.

Table 14: Microbial results for treated and control tomato samples for fresh dried and one month period of storage

Product/ sample	First results (fresh dried sample) cfu/g	Second results (one moth storage time)
Control tomato sample	Less than $1x10^1$	$1.8x10^1$
Sample treated with sodium metabisulphite	Less than $1x10^1$	1.6x101
Sample treated with lemon juice	Less than $1x10^1$	Less than $1x10^1$
Sample treated with acetic acid	Less than $1x10^1$	2.2x101

Drying is one of the most widely used as methods of food preservation. The deterioration reactions are greatly minimized (Akpinar and Bicer, 2004). It also provides longer shelf-life, smaller space for storage and lighter weight for transportation (Ertekin and Yaldiz, 2004). In the results above tomato products were a bit not stable compared mango products however the observed number of micro-organisms in both mango and tomato lied within the standards of allowable maximum number of microbial loads set by the Tanzania

Bureau of Standards (Tanzania Bureau of Standards:2009) which is $1x10^5$cfu/g of total bacteria count.

The results reveal that drying produces the products which are microbiologically stable and safe for consumption. The microbial stability of the dried products is due to the removal of water availability which normally favors the deterioration enhanced by microbial growth and other biochemical reactions. Reduction of water activity in final product is very important mean to ensure the stability of the dried food. Final product with sufficient low water activity is safe from enzymatic spoilage in general because active water is not available for microbial growth. The favorable water activity for microbial growth and proliferations is considered to be above 0.8 however according to Jay, (1992) dried fruits and vegetable products with moisture content between 13 – 25% has water activity less than 0.8 thus making unfavorable for most of micro organisms to grow. In this study the results of the moisture content to all fruits and vegetable ranged between 17 – 22% which is safe for storage of the dried products and resulted to the amount of water activity of below 0.6 which is considered as safe water activity for the products. The survival, type and number of micro organisms during and after drying depends on the initial microbial quality of fresh produce, pre - treatments, moisture content of the finished products and hygienic practice during processing (Sagar and Suresh, 2010).

The findings have shown the significant effects of all preservatives on the microbial quality of the final dried products; however fruits have shown to be more stable than vegetables. In general all the treatments have shown the reasonably high effect in minimizing the contamination by micro organisms. Therefore all the types of preservatives used in the study are proper to use in dried foods for the sake of reduction of microbial load contamination, however further studies to investigate the microbial stability for a long period of time is required.

4.5. Shelf life Prediction of Mango Fruits

4.5.1 Initial absorbance of mango

The results in the Table 15 show the initial absorbance of mango. It was observed that mango treated with sodium metabisulphite and lemon juice had zero absorbance while the mango treated with acetic acid had the value of 0.002 absorbance and the control sample had 0.001 value of absorbance.

Table 15: Initial absorbance of mango

Sample name	Initial absorbance
Control mango	0.001
Mango treated with sodium metabisulphite	0
Mango treated with lemon juice	0
Mango treated with acetic acid	0.002

The results reveal that citric acid or sulphites are suitable means for brown control as observed in the initial absorbance of the samples. Citric acid acts as a chelating agent and acidulant, which functionally inhibits PPO activity (Santerre *et al*., 1988; Sapers, 1993). Sulphites, which act as PPO inhibitors, react with intermediates to prevent pigmentation (Sapers, 1993).

4.5.2 Absorbance of mango at 35°C and 45°C

The results in the Table 16 show the absorbance of mango at 35°C and 45°C measured after each seven days for 28 period of storage time. From the results the sample treated with sodium metabisulphite and lemon juice have the lower maximum value than the acetic acid and control samples.

Table 16: Absorbance of mango for 28 days at 35^{o}C and 45^{o}C

	Absorbance (35^{o}C)				Absorbance (45^{o}C)			
Product	**7**	**14**	**21**	**28**	**7**	**14**	**21**	**28**
Control mango	0.005	0.01	0.018	0.026	0.009	0.014	0.029	0.059
Mango treated with sodium metabisulphite	0.003	0.004	0.015	0.022	0.001	0.02	0.031	0.05
Mango treated with lemon juice	0.003	0.003	0.012	0.026	0.002	0.017	0.041	0.052
Mango treated with acetic acid	0.01	0.02	0.025	0.033	0.002	0.019	0.035	0.054

Acceptable value of absorbance ≤ 0.250 as for apricot (Christine, 1989)

The results of the absorbance go in line with other findings that citric acid or sulphites are suitable means for brown control as their value for absorbance are lower than their counterpart samples.

4.5.3 Predicted shelf life of mango at different storage conditions

The predicted shelf life involved the calculations from the linear model equations obtained by plotting the graphs of storage time in (days) versus the absorbance and storage temperature versus log of shelf life at 35^{o}C and 45^{o}C. The procedure was used to all the samples and the number of days which the sample can remain without deterioration was obtained.

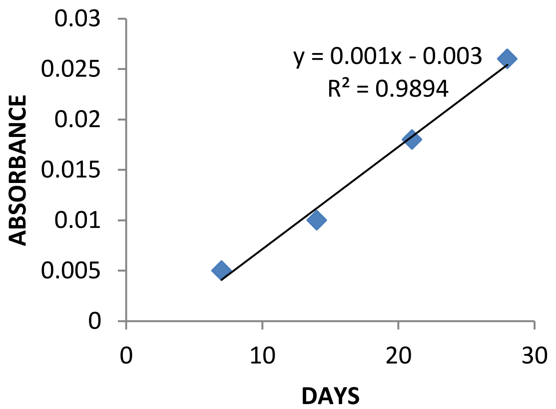

Figure 17: A plot of storage time (days) versus absorbance at 35^{o}C

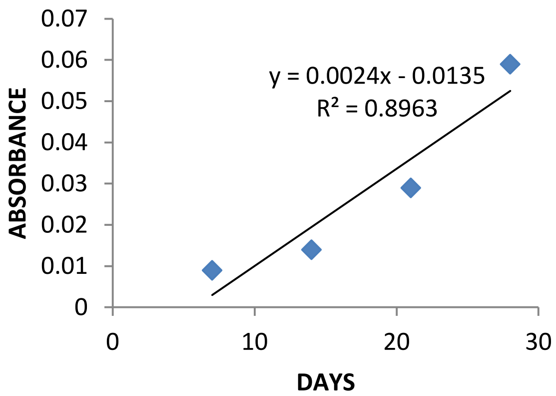

Figure 18: A plot of storage time (days) versus absorbance at 45°C

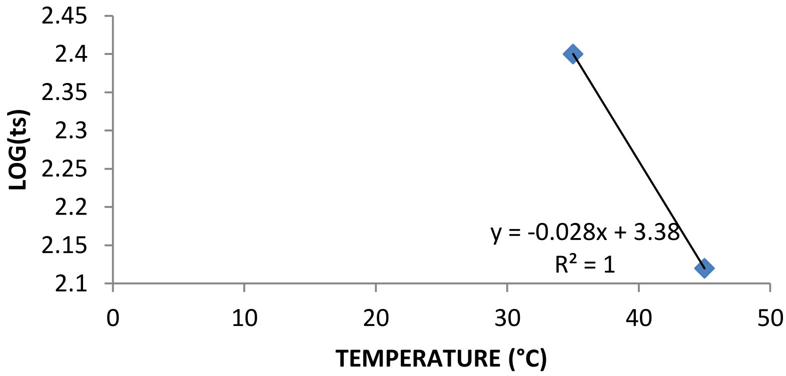

Figure 19: A plot of temperature (C) versus log of (ts)

Table 17: Linear model shelf life equation, R^2 and predicted shelf life (t_s) at 25°C and 28°C

Sample	Linear model equation	R^2	Predicted shelf life (days)	
			28°C	25°C
Control mango	y = -0.028x+3.38	1	394	478
Lemon juice treated mango	y = -0.029x + 3.425	1	410	501
Sodium metabisulphite treated mango	y = -0.003x + 3.45	1	407	501
Acetic treated mango	y = - 0.027x + 3.335	1	379	457

The results the of predicted shelf life reveal that the mango sample treated with lemon juice and sodium metabisulphite have longer shelf life than their counterparts' samples which are acetic acid treated sample and control. The results also go in line with many findings, according to Harrison and Andress (2000), the pre-treating of fruits and vegetable with ascorbic acid, citric acid, salt solution, blanching or sulphiting can reduce the effect of color loss which is caused by the browning reactions. These pre-treatments can also destroy the presence of hazardous micro- organisms during drying (Swanson, 2009), and hence extending the shelf life of the products.

4.5.4 Initial absorbance of tomato

The results in the Table 18 show the initial absorbance of tomato. It was observed that tomato treated with sodium metabisulphite and control sample had lower absorbance than the lemon juice and acetic acid treated samples.

Table 18: Initial absorbance of tomato

Sample name	Initial absorbance
Control tomato	0.074
Tomato treated with lemon juice	0.137
Tomato treated with sodium metabisulphite	0.072
Tomato treated with acetic acid	0.112

The results of the absorbance are supported with other findings that citric acid or sulphites are suitable means for brown control as the value for absorbance noted in sodium metabisulphite is lower than the counterpart samples, however the value for lemon juice sample was poor, this can be contributed by the initial quality of the sample used.

4.5.5 Absorbance of tomato at 35^oC and 45^oC

The results in the Table 19 show the absorbance of tomato at 35^oC and 45^oC measured after each seven days for 28 period of storage time. From the results the sample treated with sodium metabisulphite and lemon juice had the lower value than the acetic acid and control samples.

Table 19: Absorbance of tomato for 28 days at 35^{o}C and 45^{o}C

	Absorbance (35^{o}C)				Absorbance (45^{o}C)			
Product	**7**	**14**	**21**	**28**	**7**	**14**	**21**	**28**
Control tomato	0.137	0.214	0.294	0.403	0.315	0.554	0.713	0.863
Tomato treated with lemon juice	0.216	0.22	0.285	0.354	0.382	0.585	0.758	0.513
Tomato treated with sodium metabisulphite	0.115	0.152	0.264	0.254	0.199	0.407	0.465	0.516
Tomato treated with acetic acid	0.164	0.207	0.27	0.384	0.308	0.523	0.552	0.755

Acceptable level of absorbance ≤ 0.6(Serghei, 2010).

The results of the absorbance go in line with other findings that citric acid or sulphites are suitable means for brown control as their value for absorbance are lower than their counterpart samples which are acetic acid treated sample and control. Citric acid acts as a chelating agent and acidulant, which functionally inhibits PPO activity (Santerre *et al*., 1988; Sapers, 1993). Sulphites, which act as PPO inhibitors, react with intermediates to prevent pigmentation (Sapers, 1993).

4.5.6 Predicted shelf life of tomato at different storage condition

The predicted shelf life involved the calculations from the linear model equations obtained by plotting the graphs of storage time (days) versus the absorbance and the graph of storage temperature (^{o}C) versus the logarithm of shelf life at 35^{o}C and 45^{o}C. The same procedures of obtaining the shelf life have been used as for mango above. More details for the calculations have been attached to the appendices.

Table 20: Linear model shelf life equation, R^2 and predicted shelf life (t_s) at 25°C and 28°C

Sample	Linear model equation	R^2	Predicted shelf life (days)	
			28°C	**25°C**
Control tomato	y = -0.042x +3.14	1	92	123
Tomato treated with lemon juice	y= - 0.04x + 3.2	1	120	158
Tomato treated with sodium met	y= -0.038 + 3.21	1	140	182
Tomato treated with acetic acid	y= - 0.04 + 3.1	1	95	125

Shelf life of fruits (mango) and vegetable (tomato) under different storage conditions were predicted basing on the level of browning which was measured by the absorbance of the fruits and vegetable. The prediction was based on the acceptable limits of absorbance for both fruits and vegetables which were obtained from different literatures. Browning is associated to changes in color, flavor and softening (probably due to the action of pectic enzymes), with the exception of nutritional properties. Colour is one of the most important appearance attribute of food materials, since it influences the consumer acceptability. Abnormal colors, especially those associated with deterioration in eating quality or with spoilage, cause the product to be rejected by the consumer (Avila and Silva, 1999). Therefore approaches to improve the quality of dried fruits generally involve thermal, chemical and osmotic pre-treatments such as blanching, sulphitation and osmotic dehydration (Pott *et al*., 2005).

The results the of predicted shelf life reveal that the tomato sample treated with lemon juice and sodium metabisulphite have longer shelf life than their counterparts' samples which are acetic acid treated sample and control. The results are also in line with many research findings, according to Harrison and Andress (2000), the pre-treating of fruits and vegetable with ascorbic acid, citric acid, salt solution, blanching or sulphiting can reduce the effect of color loss which is caused by the browning reactions. These pre-treatments can also destroy the presence of hazardous micro- organisms during drying (Swanson, 2009), and hence extending the shelf life of the products. The results show that sodium metabisulphite and citric acid best maintains the color and general acceptance of minimally processed fruits and vegetables.

Sodium metabisulphite ($Na_2S_2O_5$) is used as a preservative in foods such as baked goods, jams, wines, dried fruit and many sauces. It is also used as an antibacterial agent and an antioxidant additive. Beside the suppression of microbial growth, all pre - treatments aim at thermal or chemical inactivation of detrimental enzymes, chiefly of polyphenols oxidase (PPO), and at inhibition of the Maillard reaction (Wedzicha *et al.,* 1994) by controlling pH, water activity, and reactive carbonyl compounds, respectively(Pott *et al.,* 2005).

The findings have shown the potential of drying process and addition of pre-treatments before drying in extending the shelf life of fruits and vegetables which lead to the reduction of food post-harvest losses. However the dried tomatoes have shown to have low shelf life compared to dried mangoes, according to the findings of Harrison and Andress (2000) on shelf life of fruits and vegetables, it was found that vegetables have about half the shelf life of fruits this difference is mainly contributed by the high content of natural sugar and acid which enhance better drying of fruits, better drying of fruits generally allow them to be stored for a long time and hence extending their shelf life. Therefore the results of shelf life prediction of mango and tomato obtained in this study go in line with the above findings because dried mango has shown longer shelf life than dried tomato.

In general, sodium metabisulphite and citric acid applications to products could be suggested for reducing surface browning, extending the shelf life of dried fruits and vegetables and minimizing the problem of post-harvest food losses.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The use of sodium metabisulphite and lemon juice in pre-treating fruits and vegetables before drying have shown to be very effective in retaining the colour, taste, aroma and texture attributes, reducing the microbial load and extending shelf life of fruits and vegetables. Sensory attributes mainly color and taste are the key drivers of consumer acceptability of any food, therefore pre- treating the fruits and vegetable with either sodium metabisulphite and or lemon juice can enhance the consumer acceptability towards these products. On the other hand acetic acid has shown to be not effective in retaining many of the quality attributes and extending shelf life as sodium metabisulphite and lemon juice. Although sodium metabisulphite is effective in preservation of dried fruits and vegetables but it is known to have many health problems to some people who are sulfite sensitive, it is also known to be the anti-nutritional compound by hindering some of the necessary vitamins from being absorbed by the body.

5.2 Recommendations

The use of lemon juice will be the best alternative in preservation of dried fruits and vegetables due to its ability to perform at the same level as does sodium metabisulphite. Lemon juice is readily available in developing countries so it can be easily and cheaply obtained and used by even small food processors who cannot afford to purchase sodium metabisulphite. Also the use of lemon juice will reduce the number of biotic health problems as noted when using sodium metabisulphite. The use of acetic acid as an alternative to sodium metabisulphite in preservation is not encouraged as its performance has shown to be not effective, however, further studies can be carried out using high concentration of acetic acid and comparison be made. It is also advised to carry out the studies using citric acid rich fruits and the comparison be made to lemon juice.

These findings will be very useful to food processors especially those involved in drying fruits and vegetables because they will maximize their profit by the use of cheap lemon juice and hence raising the economy of the country.

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APPENDICES

Appendix 1: Sensory evaluation Form

Consumer test for dried fruits/ vegetable samples

Panelist No…………………. ……………..   Sex………………………………

Age group (a) 10 - 20 (b) 20 – 30 (c) 30 – 40 (d) above 50

Time ………………………………   Date…………………………………….

Education level (a) Bachelor degree (b) Masters degree (c) Other specify…………

Please look and taste each of the (4) coded samples dried fruit/ vegetables. Indicate how much you like or dislike each sample by checking the appropriate sample attribute and indicate your reference (1 – 9) in the column against each attribute. Put the appropriate number against each attribute.

9 – Like extremely

8 – Like very much

7 – Like moderately

6 – Like

5 – Neither like nor dislike

4 – Dislike

3- Dislike moderately

2 – Dislike very much

1 – Dislike extremely

Attribute				
Appearance/ color				
Taste				
Aroma				
Texture				
Overall acceptability				
Would you prefer to buy a product				

Are you the frequent user of this product? (a) Yes   (b) No

Comments

……………………………………………………………………………………………………

……………………………………………………..

Appendix 2: Quantitative descriptive test

Name

……………………………………….Sex………………………………Time……………

Please evaluate each coded sample in the order they are listed. Choose appropriate number in the scale from 1 to 9, where 1 is low intensity and 9 is high intensity. How do you find the characteristics of fruits and vegetable?. Put the appropriate number against each characteristic.

Sample code……………………………………

Hue

Faint 1 2 3 4 5 6 7 8 9 very concentrated

Sweetness

Not sweet 1 2 3 4 5 6 7 8 9 very sweet

Texture

Not hard 1 2 3 4 5 6 7 8 9 very hard

Whiteness

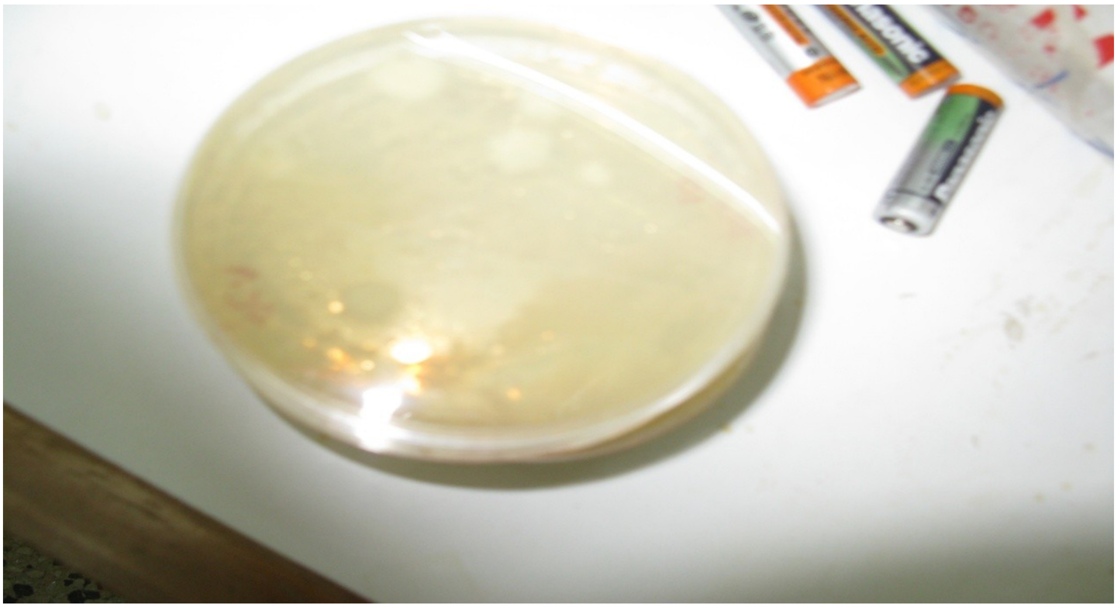
Grey 1 2 3 4 5 6 7 8 9 very white

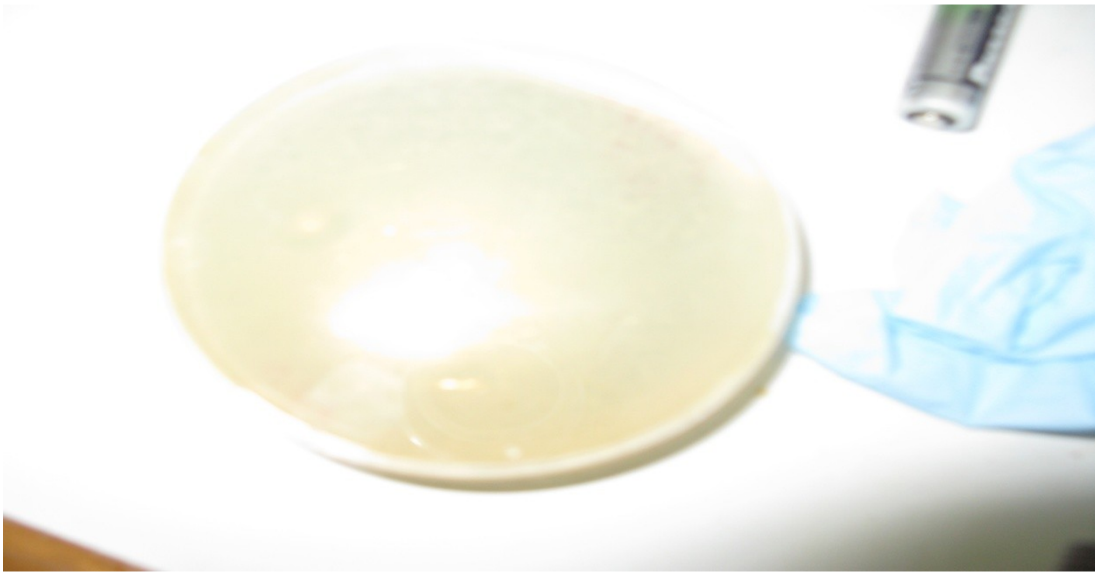
Appendix 3: Dying of fruits and vegetables

Mango drying

Vegetable drying

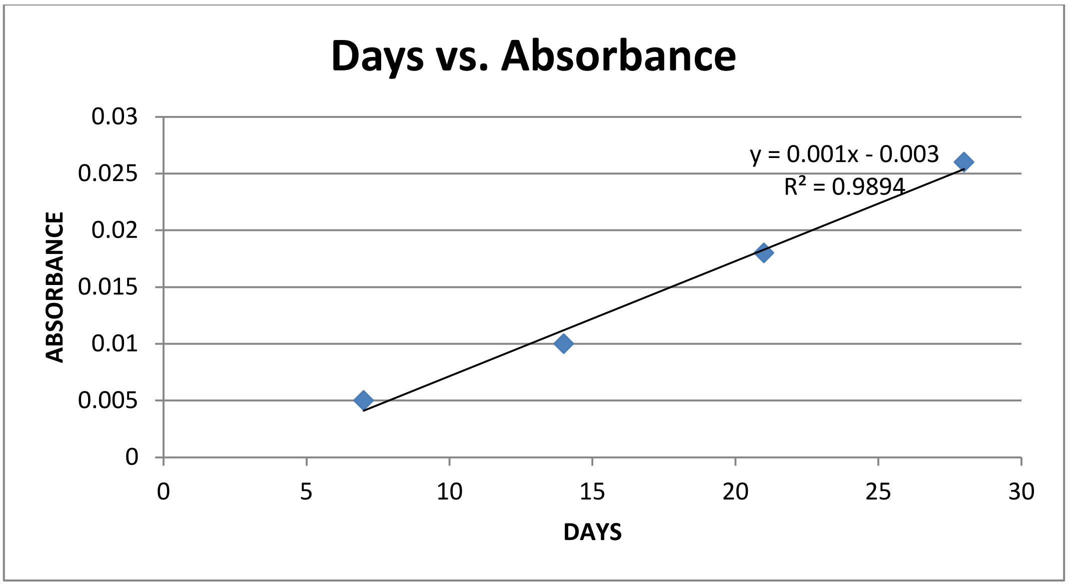
Appendix 4: Microbiological analysis





Appendix 5: Shelf life prediction linear model graphs

Control mango at 35°C



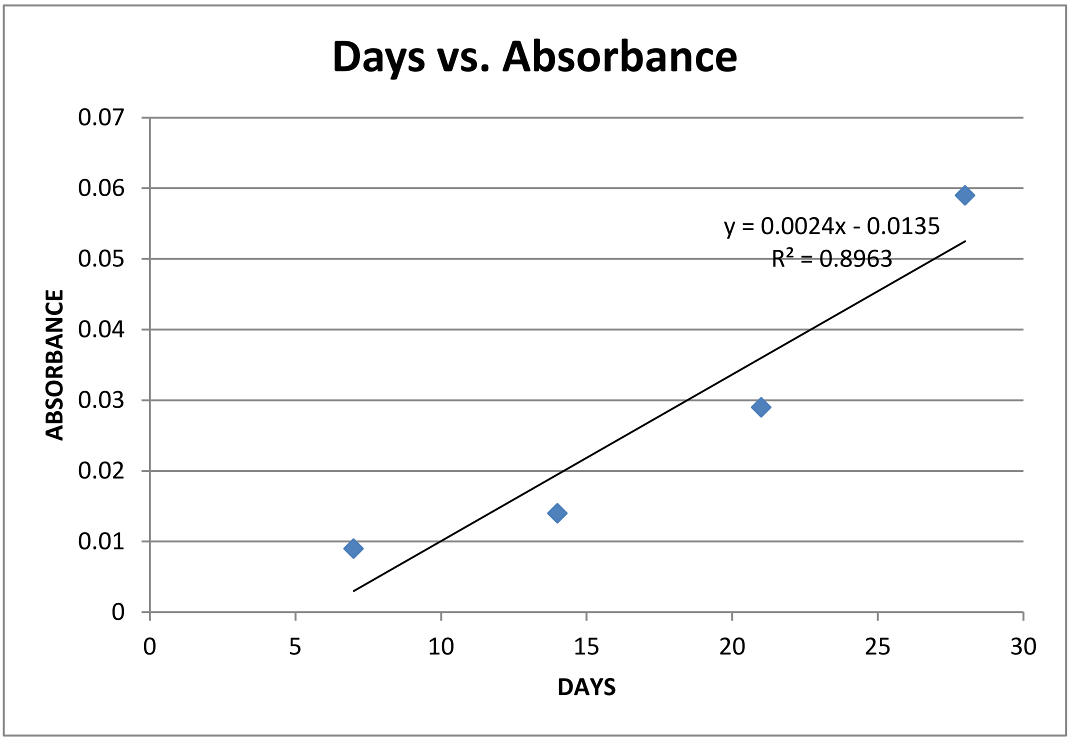
y = 0.001x - 0.003

0.250 = 0.001x - 0.003

0.250 + 0.003 =0.001x

x (ts) = 253 days at 35°C

Control mango at 45°C



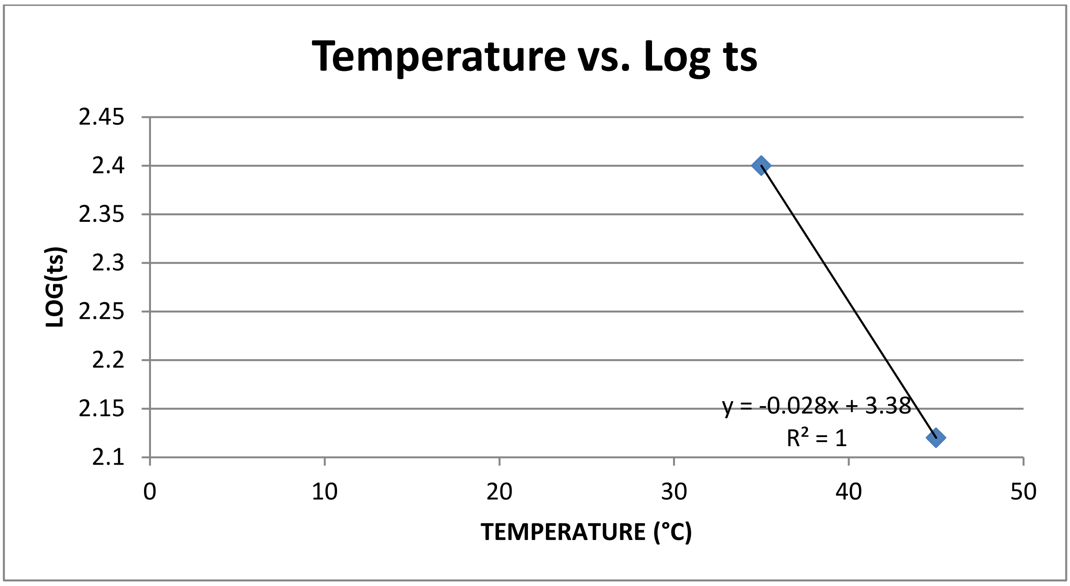
y = 0.002x - 0. 013

0.250 = 0 .002x -0.013

0.25+ 0.013 = 0.002x

x (ts) = 132 days at 45°C

Temperature versus log of shelf life at 35°C and 44°C



Y = - 0.028X +3.38

Y =(-0.028 X 28) +3.38

Y = 2.596

From log(ts) = y

(ts) = 394 at 28°C

(ts) = 478 at 25°C