EFFECT OF HOT WATER AND CALCIUM CHLORIDE TREATMENT ON THE SHELF-LIFE OF 'KEITT' MANGOES AND 'CAVENDISH' BANANAS FROM MOZAMBIQUE

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A thesis submitted to Graduate School in fulfillment of the requirements for the degree of Doctor of Philosophy in Food Science of Egerton University

EGERTON UNIVERSITY

November, 2018

DECLARATION AND RECOMMENDATION

Declaration

This thesis is my own original work and has not been published elsewhere in part or whole or presented for the award of a degree in this University or any other University.

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Recommendation

This thesis is the candidate`s original work and has been prepared with our guidance and assistance. It has been submitted with our approval as University Supervisors.

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DEDICATION

With honour, I dedicate this thesis to my father, Mr. Branquinho Ernesto, my mother (*in memoriam*) Mrs. Rosa Paulino and to my brothers Francisco, Felisberto and Justino. I want to give special dedication to my wife Mrs. Maria Penicela, the love of my life. This work is also, dedicated to my daughters Rosa Marry, Rinalda Paula, Drielle Victória and Dagny Eugénia.

ACKNOWLEDGEMENT

I feel greatly indebted to all people who have supported and assisted me morally, materially, spiritually and intellectually in the course of this research. My sincere thanks go to Egerton University for offering me an opportunity to further my studies in the Faculty of Agriculture, Department of Dairy & Food Science & Technology. My special gratitude goes to my very supportive and encouraging supervisors; Prof. Symon M. Mahungu, Prof. Abdul K. Faraj and Dr. Mary Omwamba for believing in me.

My sincere thanks go to Instituto Superior Politécnico de Manica (ISPM) for allowing me to further my studies in Egerton University. Similarly, I wish to appreciate Prof. Rafael Massinga for his overwhelming support for continuing with my studies.

I wish to thank Mr. Bernard Oloo (Assistant Lecturer in the Department & Dairy, Food Science & Technology) and also my classmate. His reception, expertise and intellectual support was very valuable. I wish to thank Olivier Kashongwe for statistical design and data tabulations.

For admiration of solid character, I wish to thank my dear wife Maria Penicela for long hours spent reading through this work and more importantly for taking care for our children. My lovely daughters Rosa, Rinalda, Drielle and Dagny I thank you so much for the long hours spent waiting for me.

My colleague in the Thorton Hostel António Manhique you are a wonderful cheering squad during this academic journey; thank you for all the support. Finally I have attained my goal and to all of you I say a BIG THANK YOU.

ABSTRACT

Mango (*Mangifera indica* L.) and Banana (*Musa acuminata* L.) are important tropical fruits ripen quickly and have a short postharvest life and commercialization window. In Mozambique, about 40 % of these fruits have been lost. In order to recommend small and medium enterprises in post-harvest fruit preservation, there is a need to develop appropriate alternative techniques for the post-harvest handling of fruits. In this work, the extension of the shelf-life of fresh mango and banana fruits by delaying ripening using hot water dipping and calcium treatment was studied. Although hot water and calcium chloride as post-harvest losses reduction treatments and shelf-life prolong were already studied, reports on the effects of optimized hot water dipping and calcium chloride on the ripening and other physiological aspects in mangoes and bananas from Mozambique are scarce or totally missing. For representation of whole country, the fruits were collected from Gaza, Manica and Nampula provinces of south, central and north parts of Mozambique, respectively. The banana (variety Cavendish) and mango (variety Keitt) samples were collected Mid-August 2016 and in January 2017, respectively. Three hundred and six fruits collected were at three different maturity stages (green, green-yellowish and yellow) and transported to the Instituto Superior Politécnico de Manica (ISPM). The raw material was characterised according to their proximate composition, size, weight, firmness and colour. Analyses of soluble solids and ascorbic acid were also performed. Sensory attributes of flavour, sweetness, astringency and overall acceptance and visible chilling injury were assessed. The optimal hot water dipping temperature and calcium chloride concentration was determined using Rotational Composite Design (RCD). The bananas and mangoes ripening and shelf-life after the postharvest treatment were determined using Randomized Complete Block Design (RCBD). The results of fruit characterization showed that mango fruits with low moisture (green with 83.62%), and fibers (0.44%), high ash (2.05%) crude lipids (0.29%), protein (0.85%) and carbohydrate (13.81%), high total soluble solids (24.60%), and high vitamin C content (14.83mg/100g) were collected in Nampula. However, banana fruits with low moisture (73.18%) and fibers (0.27%), high crude proteins (3.44%), ash (0.58%), and crude lipids content (4.92%), high total soluble solids (24.50%) and vitamin C content (2.40mg/100g) were collected in Manica. The results showed that the optimal conditions of the process stabilized with the desirable function was obtained at 55ºC of hot water temperature dipping and 3% of calcium chloride concentration. The results indicated that, as the chilling injury scores increased, fruit firmness was maintained, total solid soluble increased, vitamin C content decreased and high shelf-life in samples treated with calcium chloride and kept on refrigerator storage conditions. These qualities were reported in green-yellow bananas from Manica and green-yellow mangoes from Nampula where the shelf-life time reached 25 and 27 days, respectively. The researcher concluded that calcium chloride treatment and refrigerator storage conditions better fit. This is the first time that Mozambique mangoes and bananas fruits were characterized and assessed in the postharvest treatment and storage conditions providing valuable information to extend shelf-life of bananas and mangoes. The researcher recommends that stakeholders working in the postharvest treatment area should take advantage of the calcium chloride treatment and refrigeration storage conditions initiatives to improve the fruit shelf-life. Mozambique policy formulation process should embrace an all inclusive formulation to achieve a positive and sustainable policy impact on the fruit post-harvest sector. Stakeholders should promote use of calcium chloride to improve fruit post-harvest productivity in the target area sustainably.

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ACRONYMS AND ABBREVIATIONS

1-MCP	1-Methylcyclopropene
ANOVA	Analysis of variance
AOAC	Association of official analytical chemists
AOX	Alternative oxidase
CA	Controlled atmosphere
df	Degrees of freedom
DNA	Deoxyribonucleic acid
FAO	Food and Agriculture Organization of the United Nations
HDA	Hot dry air
HSP	Heat shock proteins
HWD	Hot water dip
HWR	Hot water rinse
ISPM	Instituto Superior Politécnico de Manica
MAP	Modified atmosphere packaging
N.N.E.	Non-nitrogen extract
PE	Enzyme pectinesterase
pH	Potential hydrogen ion
PR	Pathogenesis-related
RCBD	Randomized complete block design
SMEs	Small and medium enterprises
SMS	Stable Micro Systems
SPSS	Statistical package for social sciences
SSC	Soluble solids content
TA	Titratable acidity
TSS	Total soluble solids
USD	United state dollar
UV	Ultra violet
WVH	Saturated water vapour heat
A_w	Water activity

CHAPTER ONE
INTRODUCTION

The small-scale food processing sector has a great agro-economic potential in Mozambique. The government of Mozambique has recognized this aspect and hence, has developed an integrated program to enhance the competitiveness and sustainability of agro-processing industries especially the small and medium enterprises (SMEs). In Mozambique, fruits and vegetables are predominantly produced by small-holder farmers (owning less than 4 hectares) (Benfica, 1998; TechnoServe, 2002; Hamela & Manhicane, 2013). The incomes of the small-holder farmers will greatly improve if they adopted value addition technology at farm level or in cooperatives and community-based organizations.

Mangoes and banana are major fruits grown in Mozambique mostly by the small-holder farmers. Hamela and Manhicane (2013) and MINAG (2014) report that, for an annual average, Mozambique produces 800 tons of various fruit, where 30% are bananas, followed by citrus (25%), mango (20%) and litchi. However, Mozambique exports, for an annual average, only 200 tons of fruits where 65 % of those exports are bananas, followed by citrus and mango.

A main challenge for Mozambique fruit sector, research, development, and policy is how to feed over 30 million people with safe fruit by the year 2020 (PEDSA, 2011). While considerable attention is directed toward increasing fruit production by 50–70% to meet this target, one important and complementary factor that is often forgotten is reducing fruit loss and fruit waste (Affognon *et al*., 2015). It is suggested that about one third of the fruit produced in Mozambique is lost or wasted (MINAG, 2014), representing a loss of 300 tons of fruit per year correspondent of 60 and 90 tons of mango and banana fruits, respectively.

In general, the storage life of produce is inversely related to the respiration rate (Klein & Lurie, 1990). The respiration rate can be reduced, and storage period extended using appropriate techniques. In recent years there has been growing interest in heat-treatments as a method of reducing chilling injury in fruits, and other horticultural crops, thus permitting extended storage times (Wang, 2010). Heat treatment has been shown to be generally effective as a postharvest treatment on maintaining quality parameters in mango (Aml *et al.*, 2012) and grapefruit (Porat *et al.*, 2000) and reducing chilling injury in tomato fruit (McDonald *et al.*, 1999) during cold storage.

Tolerance to low temperature in ‘Hass’ avocado can be increased by pretreatment with high temperature such as 38°C hot air and hot water treatments (Biggs *et al.*, 1988).

Heat treatment could protect the ultra-structure of the pericarp cells in the heat-pretreated grape berries under chilling stress (Mohammed & Brecht, 2002). Heat pretreatment was also effective for decrease in the fruit decay rate during low temperature storage. Apart from heat treatment, other techniques such as calcium salts have also been used in the delay of climacteric fruits ripening process.

Calcium chloride has shown promise in quality retention of fruits and vegetables. Pre- and post-harvest application of calcium may help to reduce senescence during commercial and retail storage of fruit, with no detrimental effect on consumer acceptance (Lester & Grusak, 2000). Calcium dips have been employed to improve firmness and extend the postharvest shelf life of a wide range of fruits and vegetables (Joyce *et al.*, 2001). Increasing the calcium content can help to delay softening and decrease the incidence of physiological disorders. Calcium chloride has been reported to reduce the onset of ripening in Atemoya (Torres *et al*., 2009), avocado (Yuen *et al.*, 1994) and strawberry, (Hernández-Muñoz, 2006) but not in banana (Perera & Karunaratne, 2002) or mango (Lester & Grusak, 2000).

Reports on the ripening delay processes in order to extend the shelf life of mangoes and bananas using hot water and calcium salt treatments in Mozambique are scarce or missing. Thus, the aim of the current work was to investigate the impact of hot water and calcium dip treatment on the onset of ripening of mango and banana cultivars that are grown in Mozambique. The raw materials were characterized, the hot water temperature and calcium salt concentration were optimized and the physico-chemical and sensory parameters of the preserved ripe fruits were evaluated. The knowledge derived from this work can be disseminated to the relevant institutions in order to be used by the small and medium enterprises (SMEs) community-based organizations (CBDs) and cooperatives in rural areas.

1.1 Statement of the problem

Mangoes and bananas are the raw materials readily available in large quantities. From MINAG (2014) report, Mozambique produces, annually, 240 tons of bananas and 160 tons of mangos. The value-added products have high demand both within and out of Mozambique. They offer good opportunities for small and medium enterprises (SMEs).

Mangoes and bananas, climacteric type of fruits, cannot be preserved for long period after harvest at room temperature. When stored at ambient temperatures, they ripen within 2–10 days after harvest (Huber, 2008; Tripathi *et al.*, 2016), depending on the cultivars and stage of maturity. Thus, there is need to delay the onset of ripening of these fruits in order to increase their shelf-life. Generally, the storage period of fresh fruit can be extended by low temperature, which reduces the rate of respiration of the fruit. However, chilling injury is often induced during low temperature storage of mangoes (Kim *et al.*, 2009) and bananas (Mirshekari *et al.*, 2012). This results in huge quality losses and finally, loss of the fruits altogether.

There is often a significant delay between harvesting and the arrival of the fruit at the point of consumption, during which time fruit may ripen. Fruit for domestic markets may also be stored during times of over-production. Postharvest treatments used by small and medium enterprises in Mozambique are scarce. Fruit bulk storage and/or (straw or wooden) barn has been mostly recommended by extension agents for Mozambique small and medium enterprises without fruit pretreatment (GAFSP, 2016) leading to an increase in post-harvest losses of fruits.

Thus, there was a need to develop an appropriate pre-storage technique to delay ripening of fruits and provide quality produce for both location and export markets. Hot water dipping and calcium chloride treatment are two of such postharvest treatments. However, their optimum level of utilization and their synergistic effect if any on post-harvested fruits has not been evaluated. Therefore, the purpose of this study was to optimize the hot water dipping temperature and the calcium chloride concentration in delaying the ripening of mangoes and bananas. The impact of this treatment on the physico-chemical parameters and sensory attributes of the ripe fruits as well the actual change in shelf-life were determined.

1.2 General objective

To improve food and nutrition security in Mozambique through prolonging the shelf-life of fresh Keitt mango and Cavendish banana fruits via optimized hot water dipping and calcium chloride treatment.

1.3 Specific objectives

1. To characterize Keitt mango and Cavendish banana fruits from Mozambique by means of physico-chemical parameters.
2. To optimize hot water temperature dipping and calcium chloride concentration treatment to the selected physico-chemical parameters of Keitt mango and Cavendish banana fruits from Mozambique.
3. To determine the effect of optimized hot water dipping and calcium chloride treatment on the ripening stage of Keitt mango and Cavendish banana fruits from Mozambique, based on selected physico-chemical parameters and sensory attributes.

4. To determine the effect of optimized hot water dipping and calcium treatment on the shelf-life of Keitt mango and Cavendish banana fruits from Mozambique to the chilling injury.

1.4 The hypotheses

The study aims at testing the following null hypothesis at $p < 0.05$ level of significance.

1. H_o: There are no significant differences between Keitt mango and Cavendish banana characteristics of these fruits from Mozambique.
2. H_o: There is no optimized point of hot water temperature dipping and calcium chloride concentration treatment in order to delay ripening of climacteric Keitt mango and Cavendish banana fruits from Mozambique.
3. H_o: There are no significant differences between physico-chemical parameters and sensory attributes on the ripening of Keitt mango and Cavendish banana fruits from Mozambique treated with optimized hot water and calcium chloride.
4. H_o: There are no significant differences between physico-chemical parameters and sensory attributes on the shelf-life of Keitt mango and Cavendish banana fruits from Mozambique treated with optimized hot water and calcium chloride.

1.5 Justification

Postharvest treatments that have been applied to fruit have targeted mainly improvement of post-processing quality in order to extend shelf life. Heat treatments are another postharvest treatment that has been used to control postharvest decay and/or improve the storage quality of fruits. Mirshekari *et al.* (2015) studied the enzymatic activity and microstructural changes of hot water treatment on banana during ripening at 50 ºC for 0 (control), 10, and 20 min. The bananas were then kept at room temperature (25±2ºC) to observe the ripening progress. The firmness and activity of cell wall degradation enzymes such as polygalacturonase (PG), pectin methylesterase (PME), and pectate lyase (PL) were determined. It was noted that treated fruit was firmer than the control fruit during the ripening process. Polygalacturonase (PG), PME, and PL activities were reduced in the treated bananas when compared with the control treatment.

Hot water treatment disturbed cell wall degrading enzymes activity and delayed the disassembling of pectin fraction of Berangan banana. The beneficial effects obtained with heat treatments have generally been explained in terms of pectin esterase (PE) activation, which is known to occur in the temperature range of 55–70 °C (Singh, 2007). Pectin esterase (PE) is the enzyme responsible for cleaving the methoxyl groups from methylated galacturonic acid residues in pectin, generating free pectic acids (Hussain *et al.*, 2012) which contain newly available carboxyl groups.

Calcium dips have been used as firming agents to extend postharvest shelf life in apples (Maxin *et al*., 2012) strwaberries (Hernández-Muñoz, 2006) and to improve post processing quality in tomatoes (Senevirathna & Daundasekera, 2010). Firming and resistance to softening resulting from addition of Ca^{2+} have been attributed to the stabilization of membrane systems and the formation of Ca-pectates. The Ca-pectates increase rigidity of the middle lamella and cell wall due to increased resistance to polygalacturonase attack (or inhibition of degradation) on the pectic substances of the middle lamella and cell wall (Hussain *et al.*, 2012) and to improve turgor pressure (Lester & Grusak, 2000).

Reports of combination of hot water treatment followed by calcium dip are scarce, therefore, the synergy between hot water dipping and calcium chloride treatment in this study were determined on the physico-chemical and sensory parameters of the climacteric fruits - bananas and mangoes. Post-harvesting treatment tolerance of the product varies depending on species, cultivars, maturity, size, environmental and/or pre-harvest factors, and method of application, this study, therefore, focused on mangoes (*Mangifera indica* L.) variety Keitt and bananas (*Musa acuminata* L.) variety Cavendish, what are the most common varieties of these crops produced in Mozambique.

This work contributes on bringing the knowledge of the ripening process and senescence of fruits growing in Mozambique. The study plays an important role in producing information regarding to the changes produced or that appear during ripening on fruit quality after pre-treatment and storage. The results are relevant to solve problems related to operations and equipment for the processes of treatment, handling and preservation of fruits focused on Keitt mango and Cavendish banana fruits.

1.6 Scope and limitation

This study was limited by the following factor:

Because the family practices affect the fruit production and management, the researcher only concentrated on the fruit;

The view on fruit management was limited to the fruit ripeness, not the fruit production;

Fruit postharvest treatment protocols such as, hot water dipping and calcium treatment was the two of the methods of postharvest fruit management assessed and the findings were not generalized to other postharvest fruit methods;

Other mango and banana varieties out there are becoming available to consumers in Mozambique and this work focused on Keitt mango and Cavendish banana fruits.

1.7 Assumptions

This study was based on the following assumptions:

i. The small-holder farmers and fruit producers in Mozambique are not utilizing fruit postharvest treatment in fruit management.
ii. The physico-chemical and sensory parameters' responses are going to reflect their real perception of the effectiveness of climacteric fruit nutritional qualities.
iii. The sample of bananas and mangoes selected was physico-chemical and sensory readily to give the information as stipulated in the literature.

CHAPTER TWO
LITERATURE REVIEW

This chapter examines various scholarly tworks related to the topic of this study. A selection of the literature reviewed was guided by the research objectives, and the theoretical framework which gave information about the study.

2.1 Role of fruits and vegetables

Fresh fruit and vegetables are a major source of essential nutrients needed for human wellbeing. They are, however, perishable living products that require coordinated activity by growers, storage operators, processors, and retailers to maintain quality and reduce food loss and waste. Food and Agriculture Organization (FAO) estimated that 32 % (weight basis) of all food produced in the world was lost or wasted in 2009 (Lipinski *et al*, 2013). Reducing the loss and waste of fresh fruit and vegetables is important since these foods provide essential nutrients and represent sources of domestic and international revenue.

Specifically, fruits play a vital role in nutrition and they are a rich source of vitamins, minerals, dietary fibers, carotenoids (lycopene, beta-carotene and xanthophyll), flavonoids, phenolic and other phytochemicals (Liu, 2003; Schreiner & Huyskens-Keil, 2006). Apart from regular consumption, different types of fruits have varying processing approaches for different applications. Fleshy fruits like apple, peach, pear, pineapple, watermelon and mango are commercially valuable as human food, eaten both fresh and as jams and marmalade. Fruits are also used in manufactured foods like cookies, muffins, yogurt, ketchup, puree, sauces, soup, salad, ice cream and cakes.

2.2 Fruit production and consumption in Mozambique

Mozambique is a tropical country with plenty of fruit varieties all year around. Unfortunately, consumption of fruits is not as high as it is supposed to be because of unavailability during off season and lack of proper post-harvest preservation. Food and Agriculture Organization (FAO) of the United Nations recommend annually per capita consumption of fruits is a total of 146 kg for a healthy person (FAO, 2009), however in Mozambique, the annually per capita consumption is a low of 61 kg (Hamela & Manhicane, 2013; MINAG, 2014).

Fruits are generally expensive in Mozambique because of the post-harvest spoilage of fruits in supply cycle and costly preservation procedure. People pertinent to the fruit business are not familiar with effective methods or techniques of food preservation that can contribute towards better post-harvest management and less spoilage. Approximately 3360 thousand Metric tons of fruits are produced annually in Mozambique and post-harvest losses of fruits and vegetables ranges from 18-40% in different levels of supply cycle (César, 2014).

Current Scenario in Mozambique is predominantly an agricultural country. The climate and soil is suitable for a wide range of horti-fruitcultural cultivation. High and medium high lands are mostly suitable for fruits and vegetables. More than 100 vegetables, 70 fruits and 60 spices types are produced every year (MINAG, 2014). Some major vegetables are cucurbits, yard long bean, okra, radish, cauliflower, cabbage, tomato, beans, aroids, carrot and leafy vegetables. Major fruits are, namely, various kinds of citrus, jackfruit, mango, pineapple, papaya, guava, banana, melon, water melon and litchi. Spices like onion, garlic, ginger, green chili and coriander are cultivated.

About 10 types of fruits and vegetables are exported from Mozambique to more than 15 different countries in the world (PEDSA, 2011). Export of fresh fruits and vegetables from Mozambique also increased significantly from 20 million USD in 2008-09 to 60 million USD in 2012-13 (César, 2014). However, it is still insignificant compared to other countries of the world.

2.3 Fruits ripening mechanisms

Ethylene production is closely associated with ripening of many fruits. Typically, fruit will generate barely detectable amounts until ripening when there is a burst of production. Fruit fall more or less into two classes of behaviour with respect to ethylene physiology (Tripathi *et al.*, 2016).

Climacteric fruits, such as mango, banana, avocado, apple, tomato, papaya, fig, passionfruit, pear, and melon are characterized by a ripening-associated increase in respiration and in ethylene production, the phytohormone ethylene being the major trigger and coordinator of the ripening process. In this class, as fruit progress towards edibility, respiratory rate increases followed by a decline as fruit senesce (Mahajan *et al*., 20114).

Ethylene production also increases sharply to a maximum at this time, and then declines before fruit rots intervene and lead to a renewed output. The major rise in ethylene production may take place before, just after or close to the respiratory peak. Climacteric fruit ripen after harvest, and need not remain on the tree or vine. These fruit in fully ripeness state are too delicate to withstand transportation over long distances and should preferably be ripened near the consumption area (Tripathi *et al*., 2016).

By contrast, non-climacteric fruits, such as grape, orange blueberry, strawberry, cherry, citrus, litchi, cucumber, and pineapple, are characterized by the lack of ethylene-associated respiratory peak and the signaling pathways that drive the ripening process remain elusive. Respiration rate either remains unchanged or shows a steady decline until senescence intervenes, with no increase in ethylene production. Paradoxically, both unripe climacteric and non-climacteric fruit do increase their respiration rate when exposed to exogenous ethylene. For example, in order to improve external skin colour and market acceptance, citrus like orange, lemon, mousambi and kinnow can be treated with ethylene, as a de-greening agent. Ethylene treatment breaks down the green chlorophyll pigment in the exterior part of the peel and allows the yellow or orange carotenoid pigments to be expressed.

All fruits were once classified under this either/or nomenclature but many variations between the two types became apparent, so the original classification is better seen as two extremes of a continuum. For example, kiwifruit progress through most of the ripening changes in the absence of any rise in ethylene and CO_2 production; this occurs only towards the end of ripening and softening as fruit undergoes middle lamella dissolution. Ripening is no longer perceived as always being driven by ethylene production or by a rise in respiration.

2.3.1 Mango

Mango (*Mangifera indica*) is one of the delicious seasonal fruits grown in the tropics. Botanically, this exotic fruit belongs within the family of Anacardiaceae, a family that also includes numerous species of tropical-fruiting trees in the flowering plants such as cashew (Lo'ay *et al*., 2005). Each mango fruit measures 5 to 15 cm in length and about 4 to 10 cm in width, and has typical “mango” shape, or sometimes oval or round. Its weight ranges from 150 gm to around 750 gm. Outer skin (pericarp) is smooth and is green in un-ripe mangoes but turns in ripe fruits into golden yellow, crimson red, yellow or orange-red depending upon the cultivar type. Internally, its flesh (mesocarp) is juicy, orange-yellow in colour with numerous soft fibrils radiating from its centrally placed flat, oval-shaped stone (enveloping a single large kidney-shaped seed). Mango seed (stone) may have a single embryo or maybe polyembryonic.

Mango fruit (USDA, 2010) is rich in pre-biotic dietary fiber, vitamins, minerals, and poly-phenolic flavonoid antioxidant compounds. Mango fruit is an excellent source of Vitamin-A and flavonoids like beta-carotene, alpha-carotene, and beta-cryptoxanthin. About 100 g of fresh fruit provides 25% of recommended daily levels of vitamin-A (Berardini *et al*., 2005; Gouado *et al*., 2007). Together; these compounds have been known to have antioxidant properties and are essential for vision.

Vitamin A is also required for maintaining healthy mucous and skin. Consumption of natural fruits rich in carotenes is known to protect from lung and oral cavity cancers. Fresh mango is a good source of potassium. About 100 g of fruit provides 156 mg of potassium while just 2 mg of sodium (Galli *et al*., 2011). 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 foods rich in vitamin C helps the body develop resistance against infectious agents and scavenge harmful oxygen-free radicals (Costa *et al*., 2017).

2.3.2 Keitt mango variety

Keitt mangoes are oblong in shape with a pale to dark green skin, though they occasionally have a yellow blush. Keitt mangoes are fiber-free unlike most mangoes, and with a thin seed it allows for a greater amount of its orange-yellow flesh. Keitt mangoes have a tangy sweet flavour with a hint of honey (Berardini *et al*., 2005).

Keitt mangoes are available for a short time during the late summer and early fall. Keitt mangoes are the largest cultivar of *Mangifera indica* seen in the Mozambique market (César, 2014). They also are said to be some of the most flavourful and tangy mangoes available (Costa *et al*., 2017).

Figure 1. Mango (*Mangifera indica* L.) of Keitt variety

2.3.3 Banana

Bananas (*Musa acuminata* L.) are the most popular fruit in the world. The banana is, in fact, not a tree but a high herb that undergrows by rhizome up to 15 metres. Botanically, it belongs to the family of Musaceae, commercially; it is one of the widely cultivated crops in the tropical and subtropical zones (Sharrock, 2001).

The banana whole plant is a false stem (pseudostem) consisting of broad leaves, together with their long petioles, overlapping each other in a disc-like fashion. At maturity, the rhizome gives rise to a flower (inflorescence) which is carried up along true core stem (smooth un-branched stem) which pass through the centre of pseudostem. The flower finally emerges out at the top in-between leaf clusters.

The inflorescence subsequently develops in to a huge hanging bunch, consisting of 3 to 20 hands (tiers), with each hand carrying about 5-10 fingers (fruits). There are several cultivars of banana that comes in different size, colour (yellow to brown), weight (70-150 g) and taste. Structurally, it has a protective outer skin layer and delicious, sweet and tart, creamy-white edible flesh inside.

Banana is one of the high calorie, tropical fruits. About 100 grams of fruit carry 90 calories. Besides, it contains health benefiting anti-oxidants, minerals, and vitamins. Banana fruit is composed of soft, easily digestible flesh made up of simple sugars like fructose and sucrose that upon consumption instantly replenishes energy and revitalizes the body (Ahmad *et al.*, 2010).

The fruit holds soluble dietary fiber (7 % of daily-recommended allowance per 100 g) that helps normal bowel movements; thereby reducing constipation problems. Banana is good source of vitamin-B6 (pyridoxine); provides about 28% of daily-recommended allowance. Pyridoxine is an important B-complex vitamin that has beneficial role for the treatment of neuritis, and anemia. Further (Ding *et al.*, 2007), it helps decrease homocystine (one of the triggering factors in coronary artery disease and stroke episodes) levels within the human body. The fruit is also a moderate source of vitamin-C (about 8.7 mg per 100 g) (Auta & Kumurya, 2015).

2.3.4 Cavendish banana variety

The Cavendish banana is the most widely-grown banana cultivar in Mozambique (MINAG, 2014). These fruits are ubiquitous and cheaply available year-round in fresh form. Cavendish bananas accounted for 47% of global banana production between 1998 and 2000, and the vast majority of bananas entering international trade (Anyasi *et al.*, 2015).

The fruits of the Cavendish bananas are eaten raw, used in baking, fruit salads, fruit compotes, and to complement foods. The outer skin is partially green when sold in food markets, and turns yellow when it ripens (Tapre & Jain, 2012). As it ripens the starches turn to sugar making a sweeter fruit. When overripe, the skin turns black and the flesh becomes mushy. Bananas ripen naturally until they are picked (Soltani *et al*., 2011).

Figure 2: Banana (*Musa acuminata* L.) fruit of Cavendish variety

2.4 Postharvest treatments

Fresh fruits are living tissues subject to continuous change after harvest. Some changes are desirable from consumer point of view but most are not. Postharvest changes in fresh fruit cannot be stopped, but these can be slowed down within certain limits to enhance the shelf life of fruits. The post-harvest treatments play an important role in extending the storage and marketable life of horticultural perishables.

The most important postharvest treatments include: thermal treatments such as, hot water dip (HWD), saturated water vapour heat (WVH), hot dry air (HDA) and hot water rinse (HWR) with brushing (Schirra *et al.*, 2000) and chemical treatments (Mahajan *et al.*, 2014) such as, calcium treatment, anti-microbial and anti-browning agents, nitric oxide (NO), sulfur dioxide (SO_2), ethylene and 1-Methylcyclopropene (1-MCP). Other postharvest treatments are: controlled atmosphere (CA) storage, modified atmosphere packaging (MAP), edible coating and irradiation.

2.4.1 Heat treatment

Heat treatment has been studied as an alternative to chemical treatments for harvested fresh fruits and vegetables. Treatment include hot water dip (HWD), saturated water vapour heat (WVH), hot dry air (HDA) and hot water rinse (HWR) with brushing (Schirra *et al.*, 2000).

Beneficial effects of these heat treatments are linked: (i) through changes in physiological processes such as a reduction of chilling injury and delay of ripening processes by heat inactivation of degradative enzymes (Lurie, 1998), (ii) by killing of critical insect contaminations, (iii) by controlling the onset of fungal decay (Schirra *et al.*, 2000) and (iv) by controlling the impedance of outer and inner mesocarp of fruits (Nyanjage *et al.*, 2001).

Heat treatments can be short-term duration (up to 1 h) or long-term duration (up to 4 h). Heat treatments have been applied to firm potatoes, tomatoes, carrots, and strwaberries; to preserve the colour of asparagus, broccoli, green beans, kiwi fruits, celery, and lettuce; to prevent development of overripe flavours in cantaloupe and other melons; and to generally add to the longevity of grapes, plums, bean sprouts and peaches, among others (Lurie, 1998; Schirra *et al.*, 2000; Fallik, 2004).

It has been demonstrated that heat shock by using hot water washing at temperature ranging from 37 – 55°C for duration of 30 sec to 3 minutes can improve the postharvest quality of spinach, rocket leaves, apples and mandarin fruit (Mahajan *et al.*, 2014). A clear mode of action of any water treatment is to wash-off the spores from the fruit surface. Hot water is a better vector of energy than air and has provided comparable reductions in fungal decay. Blue mould of grapefruit caused by *Penicillium sp*. has been controlled by dipping fruit in hot water for 2 min at 50°C (Schirra *et al.*, 2000).

Phased hot-water treatment of 'Keitt' and 'Tommy Atkins' mangoes and 1 day of intermittent warming resulted in a significantly low incidence and severity of internal and external injury and diseases and low off-flavours compared with control and hot water at 46.5°C for 90 min (Nyanjage *et al.*, 1998). Improvements in the quality of bell pepper, apples, melons, sweet corn, kumquat, and grapefruit have been reported with cold water cleaning in combination with brushing and a short hot water rinse (Fallik, 2004).

In thermal treatments included hot water treatment, fruits may be dipped in hot water before marketing or storage to control various post-harvest diseases and improving peel color of the fruit. Also, vapor heat treatment proved very effective in controlling infection of fruit flies in fruits after harvest. The boxes are stacked in a room, which are heated and humidified by injection of steam. The temperature and exposure time are adjusted to kill all stages of insects (egg, larva, pupa and adult), but fruit should not be damaged. A recommended treatment for citrus, mangoes, papaya and pineapple is 43 ºC in saturated air for 8 h and then holding the temperature for further 6 h.

To date, commercial applications of heat treatments are limited. Heat treatment provide alternative to fungicide applications and in Germany, HWD has been used in storage of organic apples. Treatment of fruit after a few days of cold-storage or immediately after the opening of a long-term CA storage room provides new options for prolonging their subsequent storage life (Maxin *et al*., 2012), although acceptance of this technology by fruit growers has been hampered by high energy costs and also the need for added labour at the peak work period during harvest time.

The effects of postharvest heat-treatments on fruits are varied. Elevated temperatures alter the firmness of fruit such as plums, tomatoes and avocados (Biggs *et al.*, 1988), their chemical composition and colour (Klein & Lurie, 1990), as well as both respiration (Kerbel *et al*., 1987; Klein & Lurie, 1990) and ethylene production (Biggs *et al.*, 1988). Amongst the changes caused by heat-treatments is the induction of heat shock proteins (HSP), which are implicated in protecting plants from heat injury.

2.4.2 Calcium treatment

It is well known that calcium is involved in maintaining the textural quality of produce. Calcium ions form cross-links, or bridges between free carboxyl groups of the pectin chains, resulting in strengthening of the cell wall. A common treatment used to improve tissue firmness is to dip fruit or vegetable pieces in calcium solutions, as described for strawberries (Hernández-Muñoz, 2006), pears and strwaberries (Rosen & Kader, 1989), and shredded carrots (Izumi & Watada, 1994), among others.

In contrast, calcium treatment was not effective in carrot slices and sticks, a fact attributed to insufficient calcium absorption by the tissue, since the levels of calcium were two and three times higher in shredded carrots than in sticks and slices, respectively. In addition, increasing the concentration of calcium chmoride in the dip solution (0.5 % or 1 %) brought an increase in the tissue calcium content of treated samples, without a subsequent correlation with product texture (Izumi & Watada, 1994).

A combined treatment associating low temperature blanching to activate the enzyme pectinesterase (PE) prior to the calcium dip is helpful in preserving fruit texture. The PE brings about the de-esterification of pectin, thus increasing the number of calcium binding sites. To such mechanism has been attributed the firming effect observed in apple slices kept at 38 ºC for 6 days immediately after harvest, and sliced and dipped in calcium solution after 6 months of cold storage (Hussain *et al*., 2012). In fresh-cut melon cylinders dipped in calcium chloride solutions at different temperatures (Lester & Grusak, 2000), texture was firmer in samples treated at 60 ºC (77 % improvement in firmness), than at 40ºC (58 % improvement) and 20 ºC (45 % improvement).

Frequently, calcium chloride has been used as a firming agent, however, it may confer undesirable bitterness to the product. Fresh-cut cantaloupe cylinders dipped in calcium lactate solutions resulted in a textural improvement similar to calcium chloride treated fruit cylinders. Sensory evaluation indicated that results were better in terms of bitterness and a more detectable melon flavour was perceived. Fresh-cut cantaloupe cylinders treated by a combination of heat treatment (60 ºC) and calcium lactate dip were not significantly different either in bitterness or firmness, in relation to fruit treated at 25 ºC (Luna-Guzman *et al.*, 1999).

2.4.3 Other postharvest treatments

Controlled atmosphere (CA) storage refers to the monitoring and adjustment of the CO_2 and O_2 levels within gas tight stores at optimum storage temperature. In most cases, the concentrations of CO_2 are higher and those of O_2 are lower, optimum concentrations depending on the specific product and the purpose of the CA storage conditions.

Modified atmosphere packaging (MAP) involves the packaging of a whole or fresh cut product in plastic film bags. Correct equilibrium atmosphere can delay respiration, senescence, and slow down rate of deterioration, thereby extending product storage life (Caleb *et al*., 2013).

Edible coating are thin layers of external coatings applied to the surface of fresh produce to enhance the waxy cuticle or as replacements for natural barriers where the produce cuticle has been removed. Several edible coatings including chitosan, *Aloe vera*, polyvinyl acetate, mineral oils, cellulose and protein based have shown desirable attributes on fresh produce with good barrier properties, without residual odour or taste and efficient antimicrobial activity (Dhall, 2013).

Irradiation can be applied to fresh fruits and vegetables to control micro-organisms and inhibit or prevent cell reproduction and some chemical changes. It can be applied by exposing the crop to radiations from radioisotopes (normally in the form of gamma-ray) that penetrates objects and break molecular bonds including the DNA of living organisms (Hussain *et al*., 2012).

However, the fruit post-harvest sector is weak and needs an intervention to meet the demand of the fruits in the moments of peak production. Either hot water or calcium chloride is easy-to-handle technique and their cost may be insignificant by looking at the availabilities of the resources involved comparing to the others postharvest treatments above mentioned.

2.5 Overview of fruit loose and postharvest treatment in Mozambique

Total fruit production in the world has been estimated 392 million tons and 30-40 % of total production in developing countries is spoiled due to lack of postharvest handling up to consumption (FAO, 2009). Mozambique the is second largest producer of fruits in the Southern Africa Development Community (SADC) (PEDSA, 2011). But in the case of developing country like Mozambique, the postharvest losses noticed close to 40 % of the total fruits production (César, 2014) which badly affects the availability of fruits to the consumers.

Mango and banana are perishable fruits that facilitate the easy attack of the micro-organism due to high water activity and spoiled rapidly. Improper handling, packaging, transporting, storage and preservation techniques increase the postharvest losses in fruits up to 50% (Lipinski *et al*., 2013).

Still Lipinski *et al*. (2013) comment that practices of postharvest technologies can reduce the quantitative and qualitative losses of fresh fruits maintain the product quality up to final consumption. Postharvest produce requires appropriate handling and transporting facilities. In Mozambique, government programs are challenging postharvest losses and no significant declination has been observed within past two decades according to the resources (educational programs, training programs and research programs) utilized (MINAG, 2014).

Postharvest quality and shelf life of the fruits is related with the cultivation practices, varieties of the cultivar and environmental aspects. The soil and climatic characteristics and integrated management practices also affect the postharvest losses and postharvest storage duration (Falah *et al.,* 2015). Several environmental factors like temperature, humidity and gaseous atmosphere are responsible for postharvest losses. Availability of perishable produces up to long time after harvesting is possible only with skilled and scientific postharvest and processing approaches to preserve the products with least deterioration, on which, this work was focused.

2.5.1 Postharvest handling

Fruits should be harvested very carefully after observing the appropriate maturity level and quality because lower or upper maturity level of produces reduces the storage life and enhanced the spoilage (Liu, 2003). Mozambique government through extension services is working on good methods of harvesting, handling, transportation and storage in order to enlarge the shelf life and maintain the qualitative characteristics of the harvested produces (MINAG, 2014).

Sterilized or properly clean packaging also has been recommended by the extension services for enhance the quality and prevent the excess respiration of packed fruits. Several preservation technologies like cold storage and modified atmosphere packaging as been recommended for keeping the fruits safe and hygiene, but this approach is lacking on scientific base for fruits from Mozambique.

2.5.2 Cooling of the harvested fruits

Good quality of the fruits depends upon temperature because storage at optimum temperature retards over ripening, softening, respiration rate and spoilage (Wang, 2010). McDonald *et al.* (1999) stated that higher storage temperature increased the respiration rate results rapid spoilage and fast degradation in shelf life of the fruits and vegetables.

Therefore, refrigeration is one of the most recommended by Mozambique agricultural extension agents and used by small and medium enterprises as the cooling methods and cold chain (supply chain of fruits with controlled temperature) also practiced for minimizing the losses throughout the entire storage and distribution system (César, 2014).

Cooling and freezing of fruits are necessary at different stages like after harvesting (pre-cooling), during storage (cold storage) and during transportation (vehicles with freezer) for controlling the wastage and degradation in the quality aspects of the produces (Baloch & Bibi, 2012)**.** The numbers and capacity of cold storage increased in Mozambique during last few years but still not sufficient for handling the production and the existed cold storage also need to be improvement, especially for small and medium enterprises that have no enough economic conditions.

2.5.3 Postharvest storage

Storage facilities affect the physiochemical quality of fruits and proper care of maturity level of the fruits in the storage minimized the decay, percentage and total sugar level. Changes on the postharvest characteristics of fruits like colour, physical firmness, moisture content and sensory parameters can be delayed by using proper storage and transportation facilities and increase the fruit shelf-life (Amin & Hossan, 2013). And this is important issue to be put on Mozambique small and medium enterprise aware.

Raffia sacks, super grain bags (SGB), plastic silo tanks (PST), farmer's raffia sacks treated with acetyllic, metal silo treated with acetyllic and metal silo alone (without insecticide) have been recommended and used for cereal postharvest storage but not for fruits. Therefore, fruit bulk storage or (straw or wooden) barn have been used by Mozambique small and medium enterprises. These facilities have been used without fruit pretreatment leading to an increase in post-harvest losses of fruits.

2.5.4 Packing

Fruits require good packaging, which can prevent the physical and chemical damage. Proper packaging and handling have been considered for preventing the mechanical damages of fruits because more compact as well as loose packaging (TechnoServe, 2012). Improper handling during loading and unloading can cause the mechanical damages which affect the market value of the produces.

Mozambique government through extension services has been recommending the use of perforated films, wood boxes and cardboard boxes but straw baskets are the most used by small farmers for fruit preservation and transportation.

CHAPTER THREE

MATERIALS AND METHODS

This chapter presents the site for samples collection, characterization and physico-chemical analysis carried out. The statistic design to achieve each objective detail is also presented.

3.1 Site for the collection of the mangoes and bananas

The Keitt mango and Cavendish banana fruits for this research work were collected from Xai-xai district (Gaza Province in the southern part of Mozambique), Macate district (Manica Province in the central part of Mozambique) and Ribwae district (Nampula Province in the northern part of Mozambique). The Map accessed from SETSAN (2014) in the Figure 3 shows the location of fruits collection sites in Mozambique. The geographical coordinates of the collection sites were 23° 44' 60'' South, 32° 45' 00'' East; 18° 56' 04'' South, 32° 52' 00'' East and 15° 06' 59'' South, 39° 15' 59'' East, respectively.

The location of fruits collection in Mozambique

Figure 3. Map of Mozambique showing the site where the mangoes and bananas were collected from

3.2 Environmental conditions of the regions

3.2.1 Nampula province

According to MAE (2014), the climate of Nampula Province is influenced by the hot air of the Mozambique Channel and the easterly sea winds. The annual balancing of this planetary system of centers of low pressures and sea winds from the eastern quadrant causes a climatic regime with two distinct seasons, which are described below:

i) Hot and humid season that comprises the months of October to March. The highest values of precipitation and temperature are recorded in January that are 1600 mm and 33 °C, respectively. This is the period that the temperature, humidity and evapotranspiration reach their maximum values. Under these conditions, the water balance is positive and corresponds to the most intense vegetative period of the year.

ii) Dry and fresh season that goes from April to September. This season coincides with the coldest month of the year (July with an average of 20ºC and also the least rainy month in August).

The relief of the Province is constituted by three altimetric zones, namely areas of mountains, plateaus and plains. The mountains lie essentially in the extreme west, with more than 1000 m of altitude, near the border with Niassa Province (GAFSP, 2016).

3.2.2 Manica province

Manica Province is located in the Center-West of the Country, along the border with Zimbabwe. The total area of the Province is 61,661 Km^2, about 7.7 % of the total area of Mozambique (SETSAN, 2014).

Manica Province is characterized by a tropical climate altered by altitude, with a tendency to hot and humid, with two distinct seasons: a rainy season, from September to March, and a dry one, from April to August. The average temperatures in the summer are of 25 ºC. However, the hottest temperatures (28 °C) occur in the Save and Zambezi Valleys. The coolest temperatures (15 to 20 ºC) occur in the districts of Gondola, Manica, Mossurize, Báruè and in the mountainous areas over the West part of the Province. (MAE, 2004).

The average annual precipitation reaches 1400 mm. In dry regions, this does not exceed 700 mm and in the upper zones of the interior can reach 1800 mm. In the dry period, morning fogs appear, characteristic of the transition periods between the wet and dry season, occurring mainly in the highlands, and may be accompanied by heavy rains (GAFSP, 2016).

The plateaus, with altitudes varying between 200 and 1000 m, are located in the Central and Eastern regions, occupy about 70% of the area of the Province. The plains, with altitudes varying from 100 to 200m are located in the Southeast of the Province.

3.2.3 Gaza province

According to MAE (2005), it can be stated that the climate of Gaza Province is dry semi-arid type, characterized by large pluviometric variations throughout the year and between the years, therefore with a dryland agriculture high risk. The average annual precipitation is around 620 mm, occurring essentially from November to March and the average annual reference evapotranspiration is 1500 mm.

The pluviometric regime only allows a period of crop growth with an estimated duration of about 90 days, presenting regions with a high risk of crop loss for rainfed crops. The probability of occurrence of droughts in this province is superior to 30%. The probability of crop losses in the region is 50%. The annual average temperature is 23.6 °C (GAFSP, 2016).

3.3 Collection of mangoes and bananas

Three hundred and six Cavendish banana fruits were harvested in mid-august 2016 while same amount of Keitt mangoes were harvested in January 2017. The fruits collected were of uniform size, and at the three different maturity stage (green, green-yellowish and yellow) based on length, diameter, colour and firmness. They were transported to the laboratory of "Technology and Food Analyses", Agriculture Division of Instituto Superior Politécnico de Manica (ISPM). Upon arrival at the laboratory, the pedicels were cut back and further selection carried out based on uniformity of shape, colour and size, absence of visible wounds, blemish and or disease. The selected mangoes and bananas were washed in chlorinated water (100 ppm free chloride) for 2 min, dried and randomly distributed in different groups for each trial.

3.4 Analyses

3.4.1 Proximate composition determination

The Keitt mango and Cavendish banana fruits were characterised according to its proximate composition in relation to water content (moisture), ash, lipids, proteins, fibre (AOAC, 2005) and carbohydrates. Moisture content was determined in a vacuum oven at 105 °C according to official method 925.19.

Protein content was analyzed by the Kjeldahl method using a conversion factor of 6.25 according to official method 984.13. Lipid content was determined by the Soxhlet method based on ether extraction according to official method 942.05.

The ash content (fixed mineral residue) was measured gravimetrically after calcination of the samples in the muffle furnace (Nabertherm, L5/11/B410 Model, Maximum Temperature of 1200 ºC, Bremen, Germany) at 550 °C according to official method 942.05. The fiber was determined by acid hydrolysis according to official method 991.43. The sugar fraction, also called carbohydrate or the non-nitrogen extract (NNE), was determined by the difference between 100 and the total sum of all other constituents.

3.4.2 Length and diameter measurement

The fruits were selected on the basis of their appearance and the absence of injuries, rot and characteristic rotting odour. All fruits were first washed to remove surface impurities and sanitized. Some of the sanitized fruits were then separated for characterization. The length and diameter in centimeters of the fruits were determined using a digital caliper ruler. The length was measured from the bottom (pointed end) to the top while the diameter was determined from the centre of the mango and banana fruit or equator.

3.4.3 Firmness measurements

The mango and banana fruits firmness measurements were determined using a food penetrometer (0.2 kg/cm^2 scale indicator, 10 mm indenter penetration depth and 3.5 mm probe size, ELCOMP (PTY) LTD Midrand, South Africa). The peel firmness (expressed in $x10^5$ Pa) is defined as the mean of the pressure applied on the peel for one second to break the peel. Each fruit was compressed 3.5 mm at different locations of the skin around the fruit centre according to Vijayanand *et al*. (2015).

3.4.4 Colour measurements

According to the method established by Pathare *et al.* (2013), skin colour of the fruit was measured using a colour differential meter (ZE–2000, Nippon Denshoku, Japan) to determine Hunter Lab's L* value (lightness or brightness), a* value (redness or greenness), and b* value (yellowness or blueness) of the fruit at the center. The colorimeter was calibrated with a white standard tile.

3.4.5 Brix degree measurement

Total soluble solids were determined as °Brix using a refractometer ATAGO hand held type (ELCOMP (PTY) LTD Midrand, South Africa), which was calibrated with distilled water and maintained at a constant temperature of 25ºC.

3.4.6 Ascorbic acid determination

An oxidation-reduction titration was performed according to the method established by Davies *et al.* (1991). An iodine solution of known concentration was prepared and its concentration verified by titrating a solution of ascorbic acid. The iodine solution thus prepared was, then, used to titrate the respective fruit extracts. The ascorbic acid was expressed as g ascorbic acid per 1000 mL of fruit extract.

3.4.7 Water activity measurement

The water activity (A_w) was determined at 25 ºC with the use of the Aqualab model CX-2T (Decagon Devices Inc., Pullman, WA, USA).

3.4.8 pH measurement

The pH was measured by using a pH tester (APEX lab equipment, Hebi City, Qibin District, China), with an electrode for liquids previously calibrated with standard buffer solutions at different pH values (pH = 4.0 and pH = 7.0) according to official method 970.21 (AOAC, 2005). The mangoes or bananas were washed, peeled and liquefied using fruit pressing machine (ELCOMP (PTY) LTD Midrand, South Africa) to obtain juice. Fifty ml of mango or banana juice were taken and the pH was measured by direct immersion of the electrode in juice.

3.4.9 Tritratable acidity measurement

Titratable acidity (TA), expressed as percentage of citric acid for mango and malic acid for banana, was determined by titrating with 0.1N NaOH. The fruits were washed, peeled and liquefied to obtain the juice. Ten ml of the mango or banana juice were accurately measured and transferred into a conical flask. Into each of the flasks, 3 drops of phenolphthalein (1%) were added as an indicator according to AOAC (2005) official method 925.53.

3.4.10 Sensory analysis

Tests involving individual assessment in isolated tasting conditions under a standard light source were done using affective method, and no trained panelists according to ISO 13302 method. For the six samples submitted to post harvest treatment at different maturity stage, the judges were asked to assess pulp flavour, sweetness, astringency and overall acceptance. The nine samples submitted to post harvest treatment and storage conditions the sweetness attribute was removed. A total of 52 non-trained participants (33 females and 19 males, ages 19 to 55) were recruited from the campus of Instituto Superior Politécnico de Manica.

The consumers were asked to complete a questionnaire about their liking using a 5-point hedonic scale (1 = "very low" and 5 = "very high"). A randomized block design was used for sample presentation sequences and samples were labeled with random 3-digit numbers within each set. Panelists were given a cup of water or unsalted saltine crackers as palate cleansers.

3.4.11 Chilling injury

There were, sample A (calcium chloride on frozen), B (calcium chloride on refrigerated), C (calcium chloride on room temperature), D (hot water in frozen), E (hot water on refrigerated), F (hot water on room temperature), G (control on frozen), H (control on refrigerated or), I (control on room temperature). A randomized block design was used for sample presentation sequences and samples were labeled with random 3-digit numbers within each set.

Visible chilling injury, expressed as pitting on the fruit surfaces, was observed daily according to the statistical design samples collection, therefore, after sample treatment. Observations by 52 untrained participants (33 females and 19 males, ages 19 to 55) were made on the first visible symptom and on the rate of development of chilling injury using the following score: 0 = none; 1 = slight injury; 2 = moderate injury; 3 = moderate to severe injury 4 = severe injury 5 = spoiled (damaged) fruit. The nine samples were prepared according to the postharvest treatment and storage conditions undergone.

3.4.12 Shelf-life

Shelf life (days) of Keitt mango and Cavendish banana fruits of each treatment was recorded during the period of storage. It was observed from the date of harvesting to the last edible stage. Therefore, fruit shelf life was visually assessed daily. A fruit was considered unsalable and discarded from the experiment when the sample showed visible symptom and was scored at 4 or 5 on the rate of development of chilling injury (as performed on 3.4.11). Thus, the criteria for damage were mouldy, soft texture, wrinkled and skin discoloration.

3.5 Statistical design for the experiment

3.5.1 Characterization of banana and mango fruits from Mozambique

The fruit was brought from Gaza, Manica and Nampula representing the three main geographical regions of Mozambique. At the laboratory of "Technology and Food Analyses", Agriculture Division of Instituto Superior Politécnico de Manica (ISPM) the twenty-seven (27) Keitt mango and twenty-seven (27) Cavendish banana fruits in the three maturity stage were characterised according to its proximate composition in relation to water content (moisture), ash, lipids, proteins, fibre and carbohydrates. Analyses of size, weight, firmness, colour, soluble solids and ascorbic acid were, also, performed.

The statistical significance study of the different effects was conducted through One Way Analysis of Variance (ANOVA) using the LSD (least significant differences) method as the method for multiple comparisons, with a confidence level of 95% (= 0.05). The variance analysis was performed with the Statistical Package Stat-graphics System (SPSS) procedure (Version 8.0) to detect the differences between mango or banana fruits from different regions of Mozambique and maturity stage. When significant differences ($p < 0.05$) detected, test of means (Tukey test) data was done to understand which treatments differ.

3.5.2 Optimization of the hot water temperature dipping and calcium chloride for the banana and mango fruits

3.5.2.1 Dip treatment with hot water and calcium chloride

The optimization of the postharvest treatments for the mango and bananas fruits experiments was conducted in two stainless steel equipment (pan). For this experiment, thirty-six (36) Keitt mango and thirty-six (36) Cavendish banana fruits were used for assessment. The temperature of the solutions was measured by a thermocouple. During the experiments, the stainless-steel equipment was sealed in order to maintain the internal pressure. Arranged in a single layer, simulating the real situation of fruit handling the whole mango or banana samples were placed in small plastic perforated hammock, closed and then immersed in the solution and each having 3 replicate fruits. These plastic perforated hammocks allow the contact between fruit and solution and the identification of each sample, by their position inside them.

All dip assays with the postharvest treatments were held for a total of 10 minutes (5 min in each treatment). Since the water temperature varies, the calcium chloride solution temperature was kept constant at 40 ºC. The samples were removed from the solution and immediately immersed in a cold bath composed of ice and cold distilled water.

The samples were allowed to cool in the ice water for 20 seconds. This procedure is commonly applied to stop the mass transfer and remove the solution from the food surface (Corrêa *et al*., 2010; Arballo *et al*., 2012; Corrêa *et al*., 2014). Due to the short contact between the food and the liquid, there is no significant rehydration. They were allowed to drain and thereafter held under ambient conditions. The fruits were carefully dried with paper towels to remove the bath water or solution. They were placed in hermetic containers and kept under refrigeration (7 °C) for further analysis within 48 hours after the procedure. The samples were analyzed for the proximate composition, firmness, colour, ºBrix, WA, pH, titratable acidity and vitamin C.

3.5.2.2 Central composite statistical design

Two sets of treatment were performed namely, hot water[1] temperature and calcium chloride concentration. An experimental central composite design with twelve experiments according to a 2^2 factorial design, with 4 axial points and 4 replicates at central point was employed. The experiments were conducted with hot water (X_1) and calcium chloride (X_2) separately for mango and banana fruits, according to the matrix design (Table 1).

[1] For purposes of creating a logical argument, in this work, will be considered 45-65 ºC temperature range as hot water.

Table 1. Matrix design with coded and decoded variables' values

Assay	variables			
	Coded		Decoded	
	Hot water (ºC)	Calcium chloride (%)	X_1 (ºC)	X_2 (%)
1	-1	-1	50	2
2	1	-1	60	2
3	-1	1	50	4
4	1	1	60	4
5	-1.41	0	47.95	3
6	1.41	0	62.05	3
7	0	-1.41	55	0.88
8	0	1.41	55	5.12
9	0	0	55	3
10	0	0	55	3
11	0	0	55	3
12	0	0	55	3

By means of a regression analysis, each answer (Y) statistically significant was adjusted to a second-order polynomial with the explanatory variables (X_n). The general expression used to predict the behaviour of each response assessed is described as follows:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{12} X_1 X_2 + \varepsilon \quad (1)$$

where Yi is the predicted response and X_1 and X_2 are the independent variables (hot water temperature and calcium chloride concentration, respectively); β_0 is the coefficient for the intercept of the plane with the axis response; β_1 and β_2 are the linear coefficients by the method of least squares; β_{11} and β_{22} are the variable quadratic coefficients; β_{12} is the coefficients of interaction between independent variables; ε is the experimental error.

The model was adjusted through the technique of ‘backward elimination procedure’ that allows one to examine the best regression, thus eliminating insignificant terms ($p < 0.05$ and $R^2 \geq 0.80$). This includes the statistical significance of each terms of the adjustable model (p-value), the estimated effects in each term (βi), the determination coefficient of the model (R^2), in order to establish the accuracy of the model using the software Statistic 8.0 (StatSoft, Inc., Tulsa, OK, EUA) (Rodrigues & Iemma, 2012). The three-dimensional response surface graphics, as well as their respective boundary curves, were also obtained.

3.5.2.3 Optimization and validation of the process conditions

The resulting models were optimized to determine the levels of the variables that gave the optimum values of the responses and complete models were adopted for prediction of the optimum condition of hot water and calcium chloride treatment for the Keitt mango and

Cavendish banana fruits. In this optimization, the multiple responses were also performed to develop an optimum for each experimental design, according to desirability or each dependent variable, combined into an overall composite function, called the desirability function.

For optimization, the predicted response that was not statistically affected with the independent variables ($p < 0.05$) was not considered. Simultaneous optimization of responses was carried out according to the methodology proposed by Derringer. & Suich. (1980). The method is based on converting each response variable (Y_i) in an individual desirability function (d_i) with restricted range values [0,1], where zero is assigned to an undesirable response and the 1 is assigned to a desirable response. Once the individual desirability functions for the predicted values of each variable response is specified, they are combined into a global desirability (D) through the geometric mean of n individual desirability (equation 2) which was maximized (D values close to 1) and reduces the simultaneous optimization to a single value.

$$D = \left(d_1 x\, d_2 x\, d_3 .....x\, d_n\right)^{\frac{1}{n}} \qquad (2)$$

Therefore, with the aid of the desirability function the set of optimized conditions of the process of combined hot water temperature dipping and calcium chloride concentration treatment to the selected physico-chemical parameters of the mango and banana fruits was obtained. This took into account the maximization of firmness, fiber and tritratable acidity, minimization moisture, water activity and pH as well as the maintenance of the colour, ash, lipids and vitamin C.

To achieve the validation of the predicted process conditions an experiment was conducted by using the conditions established by the optimization as well as comparing the values predicted by the models to experimentally obtained values.

3.5.3 Determination of the effect of hot water dipping and calcium treatment on the ripening of banana and mango fruits

First of all, the mangoes and bananas were washed in tap water and immersed in a solution of sodium hypochlorite, 0.2 kg per kg solution for 15 minutes for sanitation. On this experiment, eighty-one (81) Keitt mango and eighty-one (81) Cavendish banana fruits were used for ripening assessment. Solution of sodium hypochlorite was chosen because it is the most used disinfectant in the fresh-cut industry (Caleb *et al.*, 2013). After, the fruits were rinsed and their surface carefully dried with towel paper to remove the bath water or solution.

The dip treatment was conducted, separately, in two stainless steel equipment (pan). Arranged in a single layer, the samples consisting of whole mango or banana were placed in small plastic perforated hammock, closed and then immersed, neither in hot water nor in the calcium solution and each having 8 replicate fruits. All dip essays with the postharvest treatments were held for 5 minutes. Hot water temperature of 55 ºC and 3 % of calcium chloride concentration were used. The calcium chloride solution temperature was kept constant at 40 ºC

Concluded the heat postharvest process, the samples were removed from the solution and immediately, and briefly, immersed in a cold bath composed of ice and cold distilled water. The samples were weighed and placed in hermetic containers and kept under refrigeration (7 °C) for further analysis, in up to 48 hours after the procedure. The material was further analyzed for water activity, soluble solids, pH, titratable acidity, vitamin C content and sensory attributes.

3.5.3.1 Statistical analyses

The design for this experiment was a Randomized Complete Block Design (RCBD). Experiments with sampling had at least two sources of degree of freedoms (df) namely, fruit region native, ripening stage and postharvest treatments. Each answer (Y) statistically significant from the regression analysis was adjusted to a polynomial equation with the explanatory variables (X_n). The general expression, below, was used to predict the behaviour of each response assessed:

$$Y_i = B + T + R + \varepsilon \qquad (3)$$

where Yi is the predicted response and B, T and R are the independent variables, namely, B (block) as fruit region native, T (treatment) as postharvest treatment and R (replication) as ripening stage; ε is the experimental error.

Data was analyzed with the analysis of variance (ANOVA) procedure of SPSS 8.0 program. When significant differences ($P < 0.05$) detected, test of means (Tukey test) data was done to understand which treatments differ.

3.5.4 Determination of hot water dipping and calcium treatment on the shelf life of banana and mango fruits

The respective fruit was initially treated as described in section 3.5.3. For this experiment, one hundred and sixty-two (162) Keitt mango and same fruit amount of Cavendish banana fruits were used for shelf life assessment.

After concluding the heat postharvest process, the samples were removed from the solution and immediately, and briefly, immersed in a cold bath composed of ice and cold distilled water. The samples were weighed and placed in hermetic containers and kept under either refrigeration conditions (8.0 ±0.2 ºC), freezing (-1.0 ± 0.3 ºC) or room temperature (in non-controlled temperature, which was reported to be within 24 to 26 ºC) for further analysis. On the first day (called "day zero") and on the 4^{th}, 8^{th}, 12^{nd}, 16^{th} and 20^{th} days, fruits from each treatment were analyzed by physico-chemical, sensory and visual methods. Fruit moisture, firmness, soluble solids concentrations, titratable acidity, ascorbic acid content, chilling injury, sensory characteristics and overall shelf-life of Keitt mango and Cavendish banana fruits were perfomed.

3.5.4.1 Statistical analyses

Four sources of variation were relevant to the comparison of treatment means, namely, (i) variation among the regions of Mozambique, (ii) postharvest treatments, (iii) storage conditions and (iv) shelf life time. The control group, without any treatment, was stored at room temperature (24 – 26°C; RH 70%). Data were collected in triplicate and the means were analyzed with the analysis of variance (ANOVA) procedure of SPSS 8.0 program (IBM Corporation). When significant differences ($p < 0.05$) were detected, test of means (Tukey test) of the data was done to understand which treatments differ.

CHAPTER FOUR
RESULTS AND DISCUSSION

This chapter presents the results and discussion of the raw material characterization, post-harvest treatment (hot water dipping and calcium chloride) optimization and the effect of these post-harvest treatments on the ripening and shelf life of banana and mango fruits carried out.

4.1 Characterization of banana and mango fruits from Mozambique

4.1.1 Fruit proximate composition

The proximate of Cavendish banana and Keitt mango fruits composition, in *wet weight basis,* collected in different regions of Mozambique is presented in Tables 2a and 2b, respectively. Banana fruits moisture content was reported in significance differences between fruits from different regions at different maturity. Green-yellow Cavendish bananas from Nampula had highest moisture content (81.21 %) and the lowest value was found in green bananas from the same region (70.98 %). The green banana fruits presented lowest moisture content for all regions compared to the bananas in other stages of maturity (Table 2a).

The moisture content of different mango fruits from different regions at different maturity stage showed significance difference at $p < 0.05$. Yellow Keitt mangoes from Manica had highest moisture content (90.02 %) and the lowest value (83.62 %) was found in green mangoes from Nampula (Table 2b).

The increase in pulp moisture content during ripening may be due to carbohydrate breakdown and osmotic transfer from the peel to pulp (Bezerra & Dias, 2009; Appiah *et al*., 2011). In these studies, it was reported that moisture content of the fruits increased from 79.75 to 83.11 % for mango and 73.68 to 75.91 % for banana fruits during ripening. However, the results were lower than those reported in the current work due to differences of the fruit cultivars. But, the reported results corroborate those obtained by Girma *et al*. (2016) for mango and Reis *et al*. (2016) for banana fruits. These researchers observed moisture content varying from 80.80 % to 87.33 % and 69.41 % to 77.28 %, respectively. The researchers reported that, besides pulp yield, the water content of bananas influences the yield of concentrated and dehydrated products. Thus, varieties with lower moisture levels are more attractive for making different banana fruit products.

The ash content was found to be highest in green mango fruits from Nampula (2.05 %) followed by green mangoes from Manica (1.93 %). The lowest ash content value was found in green-yellow mangoes from Gaza (0.28 %). The ash content of mangoes from the three regions was significantly different at $p < 0.05$. Similarly, the amounts of fibers were significantly different at $p < 0.05$ ranging from 0.44 to 6.15 %. However, the lipid, protein and carbohydrate contents were not significantly different at $p < 0.05$. This observation was maintained even between regions of sample collection or fruit maturity stage, which ranged from 0.08 – 0.29 %, 0.44 – 0.85 % and 3.49 – 13.81 %, respectively (Table 2b).

For the Cavendish bananas, the ash content was found to be highest in green banana fruits from Manica (0.58%) followed by those from Nampula (0.46 %). The lowest ash value was found in green-yellow bananas from Nampula (0.31 %). The ash content of bananas from the three regions was significantly different at $p < 0.05$. Similarly, the amounts of lipids, fiber and carbohydrate were significantly different at $p < 0.05$. The amounts ranged from 1.88 – 4.92 %, 0.29-4.10 % and 9.75-15.67 % for lipids, fiber and carbohydrates, respectively (Table 2a). However, the protein content which ranged from 2.21% - 3.44 % was similar for the bananas from all the regions regardless of the stage of maturity.

Marques *et al.* (2010) assessing mango rind and pulp proximate composition and mineral contents reported similar proximate mango composition as obtained in the current work. Wasala *et al*. (2012) assessing the physical and mechanical properties of three commercially grown Banana (*Musa acuminata* Colla) Cultivars in Sri Lanka reported that the average proximate composition of *Embul*, *Seeni* and *Kolikuttu* cultivars of banana at the harvest maturity indicated that the moisture, protein and fiber contents of three banana cultivars are not significantly different ($p < 0.05$).

Therefore, Mozambique mango and banana fruits present high moisture than reported in some literatures depending on location fruit production and the moisture increases from green to the ripe fruits for all regions. The moisture content of agricultural produce influences their bulk density including other proximate parameters as reported in this work. Therefore, the mangoes with low moisture content were collected in Nampula while low moisture content banana fruits were obtained from Manica.

Table 2a. Proximate composition of Cavendish banana fruits from different regions at different maturity stage

Origin	Maturity stage	Moisture (%)	Ash (%)	Lipids (%)	Protein (%)	Fiber (%)	Carbohydrate (%)
Gaza	green	76.99±0.04C*a*	0.45±0.02A*a*	1.94±0.11A*a*	3.21±1.05A*a*	3.10±0.28A*a*	14.3±1.09B*a*
	g-yellow	80.34±0.02C*b*	0.39±0.01A*a*	1.94±0.11A*a*	2.80±1.16A*a*	1.71±0.46A*a*	12.18±1.50B*a*
	yellow	79.54±0.03C*b*	0.36±0.02A*b*	2.79±1.10A*a*	2.39±0.20A*a*	1.91±0.40A*b*	13.02±1.17B*b*
Manica	green	73.18±0.09A*a*	0.58±0.01B*a*	4.82±1.59B*a*	3.44±0.35A*a*	3.21±0.51A*a*	15.57±1.74B*a*
	g-yellow	76.64±0.01A*b*	0.43±0.01B*a*	4.92±1.00B*a*	2.74±1.03A*a*	0.89±0.45A*a*	14.22±1.25B*a*
	yellow	78.87±0.05A*b*	0.42±0.03B*b*	4.27±0.27B*a*	2.21±0.90A*a*	0.27±0.19A*b*	13.93±1.31B*b*
Nampula	green	70.98±0.02B*a*	0.46±0.01A*a*	1.88±1.11A*a*	2.97±0.63A*a*	4.10±0.10B*a*	19.61±1.12A*a*
	g-yellow	81.21±1.00B*b*	0.31±0.02A*a*	2.27±0.47A*a*	3.15±0.76A*a*	3.31±0.29B*a*	9.75±0.47A*a*
	yellow	81.20±0.06B*b*	0.33±0.01A*b*	2.26±0.48A*a*	3.32±0.92A*a*	2.98±0.26B*b*	9.89±1.59A*b*

It is shown the mean values and standard deviation (σ) for each proximate parameter. Each column, means followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same lower case is not significantly different between maturity stages.

Table 2b. Proximate composition of Keitt mango fruits from different regions at different maturity stage

Origin	Maturity stage	Moisture (%)	Ash (%)	Lipids (%)	Protein (%)	Fiber (%)	Carbohydrate (%)
Gaza	green	84.31±0.03D*de*	1.55±0.00D*d*	0.19±0.05D*d*	0.80±0.19D*d*	4.65±0.28DE*d*	8.45±0.14D*d*
	g-yellow	86.35±0.06D*d*	0.28±0.01D*d*	0.16±0.07D*d*	0.69±0.23D*d*	2.57±0.46DE*e*	9.38±1.13D*d*
	yellow	87.01±0.04D*e*	1.35±0.01D*e*	0.09±0.02D*d*	0.48±0.04D*d*	4.04±0.16DE*e*	6.64±0.41D*d*
Manica	green	86.72±0.08E*de*	1.93±0.01D*d*	0.08±0.04D*d*	0.56±0.07D*d*	6.15±0.01E*d*	4.44±0.52D*d*
	g-yellow	88.42±0.07E*d*	1.66±0.02D*d*	0.10±0.05D*d*	0.55±0.21D*d*	4.97±0.29E*e*	5.32±0.77D*d*
	yellow	90.02±0.05E*e*	1.49±0.00D*e*	0.12±0.03D*d*	0.44±0.22D*d*	4.47±0.16E*e*	3.49±0.38D*d*
Nampula	green	83.62±0.03F*d*	2.05±0.01E*d*	0.16±0.14D*d*	0.63±0.15D*d*	1.34±0.35D*e*	13.81±0.65D*d*
	g-yellow	84.90±0.03F*e*	0.85±0.01E*e*	0.11±0.03D*d*	0.85±0.19D*d*	0.44±0.19D*e*	13.76±1.08D*d*
	yellow	89.12±0.02F*de*	1.21±0.01E*d*	0.29±0.05D*d*	0.59±0.13D*d*	3.63±0.35D*d*	7.16±0.09D*d*

It is shown the mean values and standard deviation (σ) for each proximate parameter. Each column, means followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same lower case is not significantly different between maturity stages.

4.1.2 Size, weight and firmness attributes of Keitt mangoes and Cavendish bananas from Mozambique

The size attributes of the Cavendish banana and Keitt mango fruits are presented in the Tables 3a and 3b. In the Table 3b, green Keitt mangoes from Nampula had highest length (10.61 cm) and the lowest value was found in green-yellow mangoes from Manica (9.22 cm).

Although, the mango fruits length from different regions at different maturity stage showed no significance difference ($p < 0.05$), the mangoes from Nampula were found to be longer, thicker and heavy but presented the lowest firmness. For green mangoes, the mean peel hardness assessed as fruit firmness was 10.11 Pa though not statistically different from the green mango samples from Manica and Gaza. Though the peel of green mangoes harvested in Gaza was not significantly different in hardness from those from Nampula and Manica ($p < 0.05$); the hardness of the green-yellow and yellow maturity stages was significantly different from the Nampula and Manica samples. Vijayanand *et al*. (2015) assessing the physico-chemical characterization and the effect of processing on the quality characteristics of Sindura, Mallika and Totapuri mango cultivars reported similar size attributes for the various regions of production.

In the Table 3a, the characteristics of length and circumference of Cavendish banana fruits were found to be significantly different ($p < 0.05$) in the three regions of production. The bananas from Manica were found to be significantly longer and stout compared to those from Nampula and Gaza.

Mattos *et al*. (2010) characterizing agronomically, physically and chemically banana fruits reported similar length and diameter values in 26 banana accessions of the active genebank of Embrapa. Average fruit lengths of *Embul*, *Seeni* and *Kolikuttu* cultivars are 10.5 ± 0.86, 10.5 ± 0.86 and 14.3 ± 1.66 cm, respectively according to Wasala *et al*. (2012) report. The length values reported were significantly lower than those observed in the current work. But the diameter at the middle of the fruit was similar as reported in this work.

In green bananas (Table 3a), the mean peel hardness assessed as fruit firmness were 15 Pa. The peel hardness was not significantly different at $p < 0.05$ for the three regions that is Nampula, Manica and Gaza. However, the green-yellow banana fruits showed that Manica's banana fruits are firmer (14 Pa) followed by Nampula's banana fruits (10 Pa). In ripe bananas, the lowest mean peel fruit firmness was 6.67 Pa and the highest was 8.27 Pa without significant differences at $p < 0.05$ for the three regions. The observed results of firmness for the ripe bananas corresponded to a peel fruit firmness loss of more than 50 % relative to the green banana frimness.

Table 3a. Size, weight and firmness attributes of Cavendish bananas from different regions at different maturity stage

Fruit Origin	Maturity stage	Fruit size Length (cm)	Diameter (cm)	Fruit Weight (g)	Fruit Firmness (x10^5 Pa)
Gaza	green	13.00±0.10A*a*	2.97±0.12A*a*	167.03±2.76A*a*	15.00±0.02A*a*
	g-yellow	14.07±0.12A*a*	3.10±0.00A*a*	157.06±4.26A*b*	7.20±1.31A*b*
	yellow	13.27±0.12A*b*	3.27±0.29A*a*	148.03±2.46A*c*	7.33±1.40A*c*
Manica	green	17.20±0.17B*a*	3.90±0.00B*a*	173.36±2.85A*a*	14.99±0.78A*a*
	g-yellow	15.83±0.12B*a*	3.37±0.06B*a*	162.07±1.44A*b*	14.70+0.30A*b*
	yellow	15.87±0.12B*b*	3.57±0.06B*a*	154.20±2.20A*c*	6.67±1.53A*c*
Nampula	green	14.77±0.15AB*a*	3.20±0.26B*a*	162.80±1.71A*a*	15.00±0.00A*a*
	g-yellow	15.30±0.20AB*a*	3.17±0.15A*a*	149.03±2.40A*b*	10.33±1.53A*b*
	yellow	13.83±0.12AB*b*	3.00±0.10A*a*	147.46±3.26A*c*	8.27±0.64A*c*

It is shown the mean values and standard deviation (σ). Each column, means followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same lower case is not significantly different between maturity stages.

Table 3b. Size, weight and firmness attributes of Keitt mangoes from different regions at different maturity stage

Fruit Origin	Maturity stage	Fruit size Length (cm)	Diameter (cm)	Fruit Weight (g)	Fruit Firmness (x10^5 Pa)
Gaza	green	10.03±0.22D*d*	7.88±0.97D*d*	576±1.20D*d*	10.00±0.04D*d*
	g-yellow	9.51±1.09D*d*	8.44±0.54D*e*	676±1.30D*d*	8.21±1.33D*e*
	yellow	11.02±0.61D*d*	7.54±0.52D*f*	640±2.33D*d*	8.45±1.52D*f*
Manica	green	9.57±0.53D*d*	6.45±0.63D*d*	512±0.52D*d*	12.00±0.20D*d*
	g-yellow	9.22±0.90D*d*	7.94±0.14D*e*	667±1.91D*d*	11.70±0.25D*e*
	yellow	9.27±0.81D*d*	7.33±0.57D*f*	526±2.20D*d*	8.67±1.32D*f*
Nampula	green	10.61±0.91D*d*	8.87±0.07E*d*	617±0.81D*d*	8.33±0.18D*d*
	g-yellow	11.08±0.20D*d*	8.13±0.97E*e*	677±2.51D*d*	7.00±1.33D*e*
	yellow	10.22±1.22D*d*	8.07±0.27E*f*	767±0.34D*d*	5.27±0.58D*f*

It is shown the mean values and standard deviation (σ). Each column, means followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same lower case is not significantly different between maturity stages.

Soltani *et al.* (2011) and Bugaud *et al.* (2007) reported that the firmness, rupture energy and hardness decreased as banana fruit ripened. Similar firmness trends were found in this work for both mango and banana fruits. The similar trends were also reported by Vijayanand *et al*. (2015) for mangoes and Singh & Reddy (2006) for oranges. According to Reis *et al.* (2016), peel firmness is a quality considered relevant by most consumers of raw bananas. Decreases in firmness as the fruit ripens were as a result of alteration in the composition of cell wall, solubilization of pectins, and hydration of cell walls.

Fruits and vegetables softening are due to alteration in cell wall structure by degrading enzymes, for example, polygalacturonase. The other reported cause of softness was due to the degradation of starch (Singh, 2007) as observed in this work. It can be explained because of the existence of a high degree of turgidity in live fruit and vegetables or whether a relative state of flabbiness develops from loss of osmotic pressure as well as final texture depends on several cell constituents. It is this cell turgidity that is high in yellow banana fruits leading for low peel firmness. Therefore, Mozambique mango higher growth presented as fruit weight, diameter and length was obtained in Nampula but banana fruits higher growth (weight, diameter and length), was collected in Manica.

4.1.3 Colour of Keitt mangoes and Cavendish bananas from Mozambique

The respective Hunter Lab values for bananas and mangoes from the three regions of Mozambique are shown in the Tables 4a and 4b, respectively. Lightness intensity analysis (L*) on the fruit’s epidermis showed no significant statistical differences between mangoes and bananas from different regions even fruits at different maturity stage. For all fruits, a luminosity increasing tendency indicates an increase in reflectance, making the colour saturation less pure and therefore more luminous.

The component a* presents a typical change. There is a significant change in the a* value at negative trending to positive over the fruit maturity stage, as a consequence of chlorophyll degradation and the increase in concentration of carotenoid pigments due to an increase in the ethylene concentration. Besides, the carotenoid pigments concentration together with anthocyanin presence generates the fruit epidermis natural colour. The a* negative values shown in Tables 4a and 4b, reveals a change in the epidermis toward less intense green hues, with an increase until maturation, showing more greenness for banana fruits (Table 4a) and more redness for mangoes (Table 4b), indicating the loss of green colour and tendency to yellow hues at the end of the organoleptic maturation.

Table 4a L, a*, b* average values of Cavendish banana fruits from different regions at different maturity stage

Fruit Origin	Maturity stage	Colour attributes		
		L	a*	b*
Gaza	green	43.22±2.03A*a*	-35.87±0.78A*a*	24.98±2.81A*a*
	g-yellow	44.77±0.95A*a*	-32.51±1.06A*a*	37.01±0.68A*b*
	yellow	42.43±1.21A*a*	-11.46±0.67A*b*	47.46±0.95A*c*
Manica	green	44.66±1.12A*a*	-38.65±0.50A*a*	30.38±0.05A*a*
	g-yellow	42.69±1.45A*a*	-36.66±0.84A*a*	40.97±1.21A*b*
	yellow	45.16±1.10A*a*	-14.64±0.32A*b*	48.75±1.09A*c*
Nampula	green	42.87±1.68A*a*	-33.26±0.63A*a*	28.47±1.12A*a*
	g-yellow	43.18±0.15A*a*	-37.25±0.70A*a*	41.59±1.01A*b*
	yellow	41.33±1.06A*a*	-11.89±1.56A*b*	53.43±0.94A*c*

It is shown the mean values and standard deviation (σ), lightness intensity (L*), redness or greenness (a*) and yellowness or blueness (b*). Each column, means followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same lower case is not significantly different between maturity stages.

Table 4b. L, a*, b* average values of mango fruits from different regions at different maturity stage

Fruit Origin	Maturity stage	Colour attributes		
		L	a*	b*
Gaza	green	42.16±1.68D*d*	-5.87±0.78D*d*	21.32±0.48D*d*
	g-yellow	42.99±2.10D*d*	-2.51±1.06D*e*	17.53±0.54D*d*
	yellow	42.87±0.88D*d*	1.46±0.40D*f*	19.13±0.11D*d*
Manica	green	43.22±2.03D*d*	-8.65±0.50D*d*	20.05±0.56D*d*
	g-yellow	42.44±1.12D*d*	-6.66±0.84D*e*	19.31±0.39D*d*
	yellow	42.85±1.45D*d*	1.06±0.26D*f*	18.75±1.09D*d*
Nampula	green	42.02±1.33D*d*	-7.25±0.76D*d*	19.47±0.96D*d*
	g-yellow	43.19±2.06D*d*	-3.26±0.63D*e*	21.59±1.01D*d*
	yellow	44.05±1.35D*d*	2.00±0.45D*f*	21.76±2.45D*d*

It is shown the mean values and standard deviation (σ), lightness intensity (L*), redness or greenness (a*) and yellowness or blueness (b*). Each column, means followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same lower case is not significantly different between maturity stages.

The value of b*, increase in the most advanced maturation stages, as shown by the colour change in the epidermis from yellow to orange. For this reason, b* is considered the main responsible of the external appearance in fruit ripening. In effect for mango fruits, the statistical results for b* are not also significant like those for a*, but for banana fruits they are statically significant ($p < 0.05$).

The luminosity parameter behaviour can be explained by the increase in the concentration of ethylene. Ethylene breakdown the chlorophyll and starch in the different fruit maturity stages. During this process, a physiologically mature tissue change to one more visually attractive. Furthermore, a decrease in luminosity is observed in green banana fruits, possibly due to the beginning of degradation of chlorophyll pigments by oxidation, which leads to colour darkening and is confirmed by the a* and b* values increase.

These results are similar to those reported for Tommy Atkins mangoes by Costa *et al*. (2017) and Cavendish bananas (Grande Naine cultivar) by Bugaud *et al.* (2007) who attributed this change to the increase in chlorophyll degradation, having a rapid transition from a greenish yellow to yellow leading to carotenoids compounds production. Therefore, Mozambique mango and banana fruits present no lightness intensity differences but the redness or greenness and yellowness or blueness was high as the fruit ripe mainly for fruits from Gaza Province.

4.1.4 Total soluble solids of Keitt mango and Cavendish banana fruits from Mozambique

The total soluble solids (TSS) of Keitt mango and Cavendish banana fruits obtained in different regions of Mozambique is presented in Figure 4. Total soluble solids increased during the ripening stage for both crops, ranging from 10.67 % (green mango) to 24.60 % (yellow mango) and 10.00 % (green banana) to 2.50 % (yellow banana), that can be associated to the hydrolysis of stored starch in vacuoles and intercellular spaces during the fruit growth.

Significant statistical difference between different maturity stages was reported showing high TSS values of yellow mangoes from Nampula (TSS = 24.60 %) and yellow banana fruits from Manica (TSS = 24.50 %) and low values of green mangoes from Manica (TSS = 10.67 %) and green bananas from Gaza and Nampula (TSS = 10.00 %). Therefore, green and green-yellow banana fruits total soluble solids were not statistically different. Mango samples from Nampula presented high TSS followed by Gaza and Manica contrasting to the banana samples that presented high TSS of Manica followed by Gaza and Nampula.

The average TSS of green-yellow mango and banana fruits was slightly lower than that of yellow fruits, thus indicating higher sugar content in the latter. In principle, this could cause less sweetness to be perceived in green-yellow fruits which in turn could influence consumer acceptance. This suggestion however, needs further testing since the difference mango and banana is marginal.

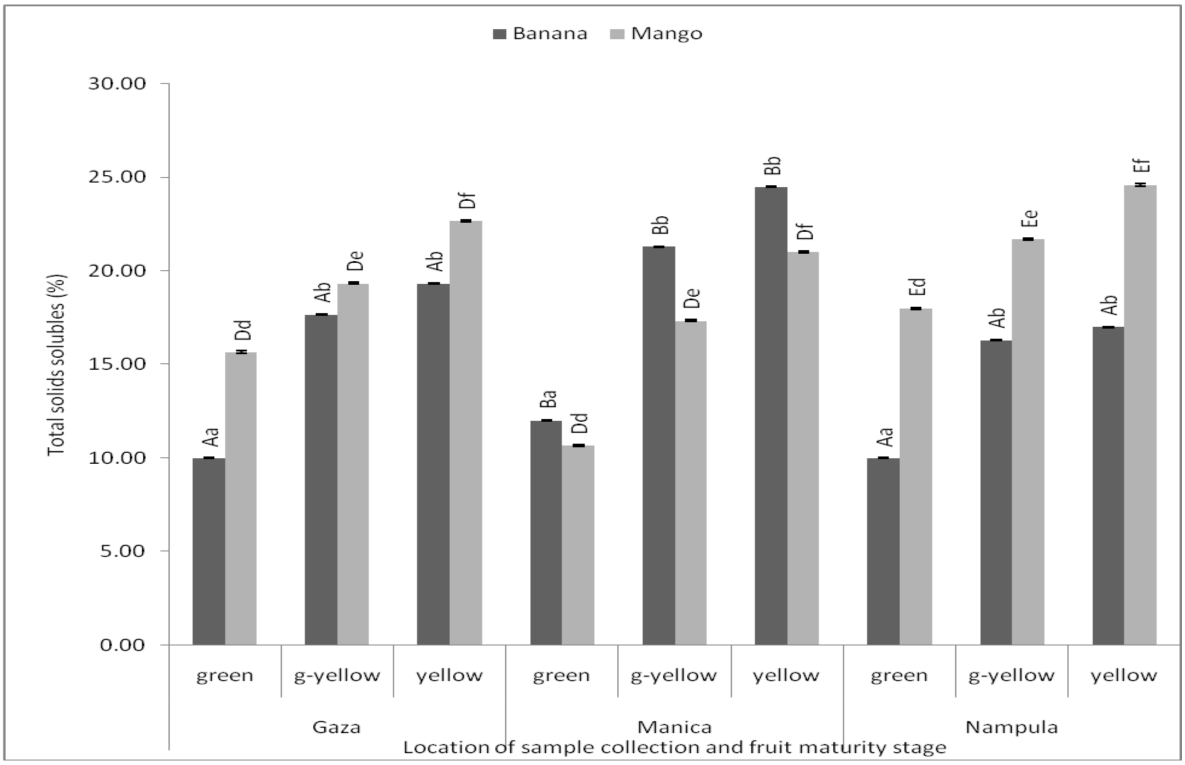

Figure 4. Total soluble solids of Keitt mangoes and Cavendish banana fruits from different regions at different maturity stage

Bars followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same lower case is not significantly different between fruit maturity stages. Where *a*, *b* and *c* for banana and *d*, *e* and *f* for mango fruits.

High TSS has been associated with high sucrose content in banana pulp (Akhter *et al*., 2012). It has been reported that the average starch content drops from 70 to 80 % in the pre-climacteric period to less than 1% at the end of the climacteric period (Huber, 2008), while sugars, mainly sucrose, accumulate to more than 10 % of the fresh weight of the fruit (Ahmad *et al.*, 2010).

Starch hydrolysis occurs due to the increase in the activity of enzymes α-amylase, β-amylase and starch phosphorylase which transform starch into reducing sugars (Lester &

Grusak, 2000; Hussain *et al.*, 2012). Besides, there is a direct increase with the maturation stage in which the fruits were harvested. The data obtained in this investigation are similar to those reported by Appiah *et al*. (2011) and Akhter *et al*. (2012) where a higher concentration of total soluble solids in the samples harvested in later maturation stages than in those fruits that were collected in an early maturation stage. Therefore, Nampula mango fruits presented high TSS than fruits from other regions of Mozambique showing starch solubility, sugar availability and physiology maturity (above 10% according to Galli *et al*., 2012) of these samples but banana with high TSS were collected in Manica.

4.1.5 Vitamin C of Keitt mango and Cavendish banana fruits from Mozambique

The vitamin C content expressed as ascorbic acid of Keitt mangoes and Cavendish bananas obtained in different regions of Mozambique is presented in Figure 5. In this Figure 5, the values of vitamin C content increase during the ripening stage for both crops, ranging from 8.53 mg/100g (green mango from Manica) to 14.83 mg/100g (yellow mango from Nampula) and 1.13 mg/100g (green banana from Nampula) to 2.40 mg/100g (yellow banana from Manica). Significant statistical difference between different maturity stages was reported showing high vitamin C content when the fruit was ripe. With statistical difference at $p < 0.05$, mango samples from Nampula presented high vitamin C content followed by Gaza and Manica. However, for the banana samples, high vitamin C content was reported in Manica followed by Gaza.

The ascorbic acid amounts found for Keitt mango fruits were lower than those reported by Ellong *et al.* (2015) who presented vitamin C content ranging from 16 mg/100g to 34 mg/100g. But Cavendish banana fruits in this study were similar to those found by Hernández *et al*. (2008) for banana fruits unripe, half-ripe and ripe, respectively using liquid chromatographic determination of vitamin C and 0.1% oxalic acid extraction. However, in this current study, the green bananas contained less vitamin C than the yellow bananas. Leong & Shui (2002) described vitamin C content of 2.1 ± 0.8 mg/100 g for ripe banana, although in this study the banana cultivar was not specified.

These differences between Keitt mango and Cavendish banana fruits reported in this work comparing with the literature could be attributed to the variation in vitamin C content among cultivars and the pre-harvest factors (Lee & Kader, 2000). Therefore, Keitt mango fruits with high vitamin C content were collected in Nampula but Cavendish banana fruits with high vitamin C content were collected in Manica showing good adaptability of these crops in the respective regions of Mozambique.

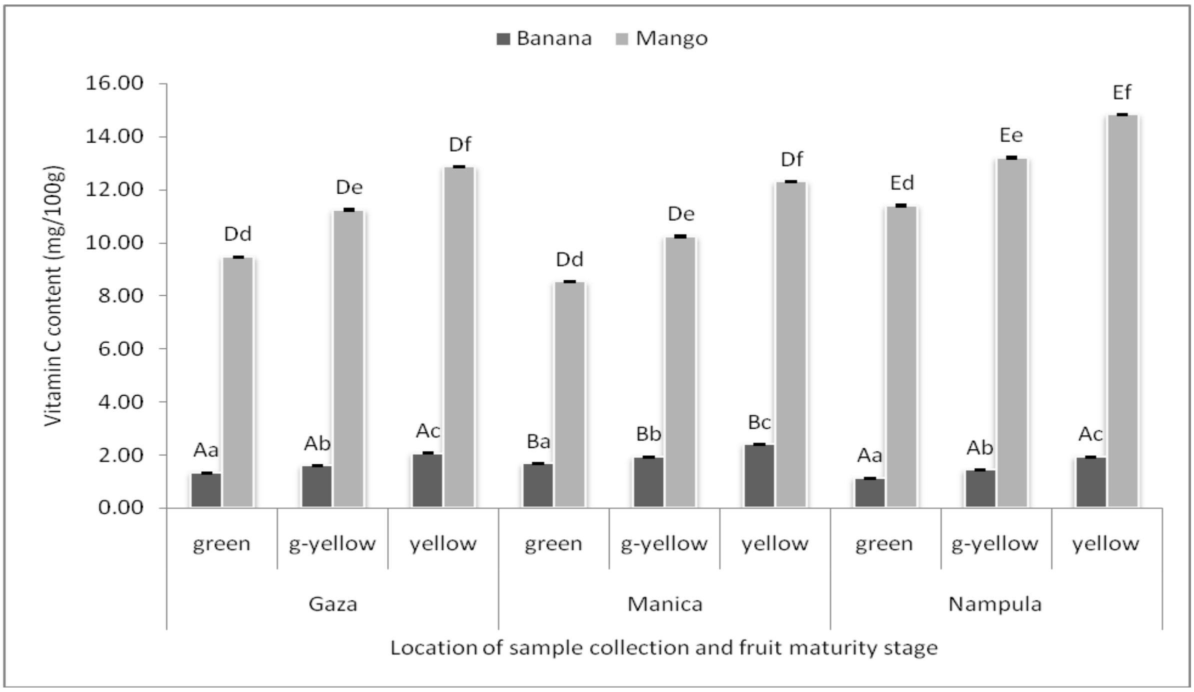

Figure 5. Vitamin C content of Keitt mangoes and Cavendish banana fruits from different regions at different maturity stage

Bars followed by the same capital letter are not significantly different (ρ≤0.05) by Tukey test between the location of sample collection. In a similar way, the same lower case is not significantly different between fruit maturity stages. Where *a*, *b* and *c* for banana and *d*, *e* and *f* for mango fruits.

4.2 Optimization of the hot water temperature dipping and calcium chloride for the banana and mango fruits

4.2.1 Effect of hot water and calcium chloride on the proximate fruit composition

Based on the central composite design (CCD) carried out with two variables, the results on the Cavendish banana and Keitt mango fruits proximate composition are presented in Table 5aa and 5ab while the effects of the variables are shown in Table 5ba and 5bb (on appendices), respectively. From the results on the Table 5ab, it is observed that for mango fruits, high values are obtained in assays 6 and 10 for moisture (85.74 %), 1 and 7 for ash (0.18 %), 8 for lipids (0.40 %), 7 for protein (0.80 %), 4 for fiber (3.75 %) and 1 for carbohydrates. It is also observed that low values were obtained in assay 7 (82.38 %) for moisture, 5 and 8 (0.11 %) for ash, 5 (0.16 %) for lipids, 11 (0.31 %) for protein, 2 (0.59 %) for fiber and (10.01 %) for carbohydrates.

For banana fruits (Table 5aa), it is observed that high values are obtained in assays 10 for moisture (82.59 %), 3 for ash and lipids (0.70 % and 3.02 %, respectively), 7 for proteins

(4.02 %), 4 for fiber (3.75 %) and 2 for carbohydrates (22.94 %). It is also observed that low values were obtained in assay 2 for moisture and fiber (70.90 % and 0.59 % respectively), 5 for ash (0.52 %), 4 for lipids (0.79 %), 11 for proteins (1.57 %) and 10 for carbohydrates (9.88 %). Other reports suggest that combining hot water and calcium chloride prevents the destruction of cell compartments and also the contact of PolyPhenolOxidase with polyphenols in the vacuole (Lamikanra & Watson, 2007) without degrading the proximate attributes. This observation may be due to the optimization of specified set of parameters in the current study. When optimizing a process, the goal is to maximize one or more of the process specifications, while keeping all others within their constraints (Rodrigues & Iemma, 2012).

It can be observed that, hot water temperature dipping was not statistically significant on proximate mango fruits composition but the linear term of calcium chloride was significant on the lipids and the quadratic terms of calcium chloride concentration was statistically significant on the moisture content with confidence level of 95 %. The interaction between hot water dipping and calcium chloride treatment was statistically significant ($p < 0.05$) for fibers content.

For banana fruits, it can be observed that, quadratic terms of calcium chloride concentration and hot water temperature was statistically significant on the moisture and ash content with confidence level of 95%. The interaction between hot water dipping and calcium chloride treatment was statistically significant ($p < 0.05$) for ash, lipids and fibers content.

Reports on hot water and calcium chloride on the Keitt mango and Cavendish banana fruits proximate composition are scarce. Maureen *et al.* (2016) studying the effects of induced ripening on the proximate, biochemical and mineral compositions of *Musa sapientum* (Banana) reported that there are significant differences in the percentage of proximate composition. In this report, the moisture content, dry matter, ash, crude fibre, ether extract, crude protein and carbohydrate of the plantain were compared.

The hot water dipping was reported as the method that did not induce ripening as the respective values were lowest. Similar results were reported by Iroka *et al.* (2016) on the proximate, biochemical and mineral compositions of *Carica papaya* (Pawpaw Fruit). Auta & Kumurya (2005) were comparing proximate analysis, mineral elements and anti-nutrients composition between *Musa sapientum* (Banana) and *Musa paradisiaca* (Plantain) pulp flour and reported that no significant difference was observed when the moisture, ash, crude fibre, crude fat, crude protein and total carbohydrate contents of the two *Musa* species were compared to each other at $p < 0.05$.

Table 5aa. Central composite design assay on the proximate composition of Cavendish banana fruits

	Variable		Moisture	Ash	Lipid	Protein	Fiber	Carbohyd
Assay	X_1	X_2	(%)	(%)	(%)	(%)	(%)	(%)
1	50	2	76.57^{Ed}	0.58^{Ed}	2.37^{Dd}	2.74^{Dd}	2.57^{Dd}	15.16^{Dd}
2	60	2	70.90^{Dd}	0.68^{Ee}	2.68^{Dd}	2.21^{Dd}	0.59^{Dd}	22.94^{Dd}
3	50	4	78.62^{Ee}	0.70^{Ee}	3.02^{Dd}	2.68^{Dd}	1.63^{Dd}	13.35^{Dd}
4	60	4	73.27^{Dd}	0.62^{Ee}	0.79^{Dd}	3.61^{Dd}	3.75^{Dd}	17.96^{Dd}
5	47.95	3	74.25^{Ed}	0.52^{Dd}	2.01^{Dd}	2.62^{Dd}	2.78^{Dd}	17.81^{Dd}
6	62.05	3	73.76^{Dd}	0.54^{Dd}	2.26^{Dd}	3.26^{Dd}	3.07^{Dd}	17.10^{Dd}
7	55	0.88	73.97^{Dd}	0.69^{Ee}	2.27^{Dd}	4.02^{Dd}	3.10^{Dd}	15.95^{Dd}
8	55	5.12	75.19^{Ed}	0.70^{Ee}	1.94^{Dd}	2.33^{Dd}	1.71^{Dd}	18.12^{Dd}
9	55	3	77.00^{Ed}	0.62^{Ee}	1.95^{Dd}	2.62^{Dd}	1.89^{Dd}	15.92^{Dd}
10	55	3	82.59^{Fe}	0.63^{Ee}	1.93^{Dd}	3.26^{Dd}	1.71^{Dd}	9.88^{Dd}
11	55	3	82.18^{Fe}	0.63^{Ee}	1.93^{Dd}	1.57^{Dd}	1.91^{Dd}	11.78^{Dd}
12	55	3	78.65^{Fe}	0.64^{Ee}	1.96^{Dd}	2.91^{Dd}	1.91^{Dd}	13.93^{Dd}

X_1 and X_2 correspond to the independent variable. X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration (%); Ma – mango fruits; Ba – Banana fruits. Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) by Tukey test between hot water temperature and, the same lower case is not significantly different between calcium chloride concentration.

Table 5ab. Central composite design assay on the proximate composition of Keitt mango fruits

	Variable		Moisture	Ash	Lipid	Protein	Fiber	Carbohyd
Assay	X_1	X_2	(%)	(%)	(%)	(%)	(%)	(%)
1	50	2	80.78^{Ab}	0.18^{Aa}	0.29^{Ab}	0.55^{Aa}	2.57^{Aa}	15.64^{Aa}
2	60	2	83.06^{Aa}	0.15^{Aa}	0.23^{Aa}	0.44^{Aa}	0.59^{Aa}	15.49^{Aa}
3	50	4	84.59^{Ab}	0.14^{Aa}	0.29^{Ab}	0.54^{Aa}	1.63^{Aa}	12.84^{Aa}
4	60	4	84.86^{Ab}	0.17^{Aa}	0.36^{Ac}	0.72^{Aa}	3.75^{Aa}	10.15^{Aa}
5	47.95	3	85.18^{Ab}	0.11^{Aa}	0.16^{Aa}	0.52^{Aa}	2.78^{Aa}	11.19^{Aa}
6	62.05	3	85.74^{Ab}	0.17^{Aa}	0.36^{Ab}	0.65^{Aa}	3.07^{Aa}	10.01^{Aa}
7	55	0.88	82.38^{Aa}	0.18^{Aa}	0.25^{Ab}	0.80^{Aa}	3.10^{Aa}	13.30^{Aa}
8	55	5.12	83.28^{Aa}	0.11^{Aa}	0.40^{Ac}	0.47^{Aa}	1.71^{Aa}	14.15^{Aa}
9	55	3	84.25^{Ab}	0.16^{Aa}	0.31^{Ac}	0.52^{Aa}	1.89^{Aa}	13.02^{Aa}
10	55	3	85.74^{Ab}	0.17^{Aa}	0.23^{Aa}	0.65^{Aa}	1.71^{Aa}	11.66^{Aa}
11	55	3	85.58^{Ab}	0.16^{Aa}	0.29^{Ab}	0.31^{Aa}	1.91^{Aa}	11.91^{Aa}
12	55	3	84.25^{Ab}	0.16^{Aa}	0.27^{Ab}	0.58^{Aa}	1.91^{Aa}	12.99^{Aa}

X_1 and X_2 correspond to the independent variable. X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration (%); Ma – mango fruits; Ba – Banana fruits. Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) by Tukey test between hot water temperature and, the same lower case is not significantly different between calcium chloride concentration.

4.2.2 Effect of hot water and calcium chloride on the firmness and colour attributes

The central composite design (CCD) matrix with the codified variables and the results on the firmness and colour attributes of Cavendish banana and Keitt mango fruits are presented in Table 6aa and 6ab and the effect of the variables are summarized in Table 6ba and 6bb (on appendices), respectively.

For banana fruits, in Table 6aa, it is seen that assay 5, where the lowest hot water temperature was used and medium calcium chloride value, presented higher firmness value (10.00×10^5 Pa) and the assay 8, where medium hot water temperature was used and high calcium chloride concentration obtained the lower value (7.33×10^5 Pa). It can be observed, in Table 6b, that with exception of calcium chloride concentration, hot water temperature significantly ($p < 0.05$) influenced the banana fruits peel firmness.

Table 6aa. Central composite design assay on the firmness and colour attributes of Cavendish banana fruits

Essay	X_1 (ºC)	X_2 (%)	Firmness ($x10^5$Pa)	L	a*	b*
1	50	2	8.67^{Dd}	44.66^{Dd}	-37.25^{Dd}	41.60^{Dd}
2	60	2	7.67^{Dd}	44.77^{Dd}	-32.51^{Ee}	37.01^{Dd}
3	50	4	8.67^{Dd}	42.88^{Dd}	-36.66^{De}	40.97^{Ed}
4	60	4	7.33^{Dd}	43.19^{Dd}	-35.78^{Ee}	39.39^{Dd}
5	47.95	3	10.00^{Ed}	43.51^{Dd}	-36.87^{De}	40.63^{Ed}
6	62.05	3	7.67^{Dd}	43.82^{Dd}	-35.79^{Ee}	39.24^{Dd}
7	55	0.88	8.00^{Dd}	43.22^{Dd}	-35.02^{Ee}	39.72^{Dd}
8	55	5.12	7.33^{Dd}	43.82^{Dd}	-37.29^{Dd}	40.75^{Ed}
9	55	3	7.67^{Dd}	43.53^{Dd}	-35.44^{Ee}	39.84^{Dd}
10	55	3	7.67^{Dd}	44.80^{Dd}	-35.47^{Ee}	39.99^{Dd}
11	55	3	8.00^{Dd}	43.22^{Dd}	-36.52^{De}	41.23^{Ed}
12	55	3	7.67^{Dd}	43.82^{Dd}	-35.79^{Ee}	39.24^{Dd}

X_1 and X_2 correspond to the independent variable. X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration (%); L, a^* and b^* are the colour attributes. Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between hot water temperature and, the same lower case between calcium chloride concentration by Tukey test.

It can be seen, in Table 6ab, that assay 5, where the high hot water temperature and calcium chloride were used, presented higher firmness value (12.00 x 10^5 Pa) and the assay 6, where highest hot water temperature was used and medium calcium chloride concentration obtained the lower value (3.67 x 10^5 Pa). It can be observed, in Table 6b, that the interaction between hot water dipping and calcium chloride treatment statistically ($p < 0.05$) influenced the mango fruits peel firmness with confidence level of 95 %.

Table 6ab. Central composite design assay on the firmness and colour attributes of Keitt mango fruits

Essay	X_1 (ºC)	X_2 (%)	Firmness (x10^5Pa)	L	a*	b*
1	50	2	10.00^{Aa}	42.88^{Ba}	-5.87^{Aa}	21.32^{Bb}
2	60	2	4.20^{Aa}	43.00^{Ba}	-2.51^{Aa}	17.53^{Aa}
3	50	4	4.33^{Aa}	42.88^{Ba}	1.46^{Aa}	19.13^{Bb}
4	60	4	12.00^{Aa}	42.88^{Ba}	-7.46^{Aa}	19.96^{Bb}
5	47.95	3	11.70^{Aa}	42.23^{Aa}	-7.94^{Aa}	20.54^{Bb}
6	62.05	3	3.67^{Aa}	42.33^{Aa}	-4.89^{Aa}	18.77^{Ab}
7	55	0.88	11.00^{Aa}	42.77^{Ba}	0.06^{Aa}	18.15^{Ab}
8	55	5.12	7.33^{Aa}	42.66^{Ba}	-2.66^{Aa}	19.11^{Bb}
9	55	3	11.00^{Aa}	44.32^{Ba}	-1.00^{Aa}	20.85^{Bb}
10	55	3	12.00^{Aa}	43.92^{Ba}	-5.03^{Aa}	18.93^{Bb}
11	55	3	11.70^{Aa}	42.77^{Ba}	-2.42^{Aa}	20.18^{Bb}
12	55	3	11.00^{Aa}	43.31^{Ba}	0.72^{Aa}	20.30^{Bb}

X_1 and X_2 correspond to the independent variable. X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration (%); L, a^* and b^* are the colour attributes. Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between hot water temperature and, the same lower case between calcium chloride concentration by Tukey test.

Ngamchuachit *et al.* (2014) reported opposite behaviour when were assessing the effectiveness of calcium chloride and calcium lactate on maintenance of textural and sensory qualities of fresh-cut mangoes where they noted that fresh-cut mango firmness was increasing when the calcium content used increased. In this work with mango and banana fruits, the high codified variable values reduced the mango and banana fruits peel firmness.

Similar fruit peel firmness behaviour was reported by the Lum & Norazira (2011). These researchers assessed the effect of hot water and reported the submergence time and storage duration on quality of dragon fruit (*Hylocereus polyrhizus).* They observed that increasing of hot water temperature decreased the dragon fruit firmness significantly. Therefore, disturbance in cell structure and membrane damaged on fruit which was soaked in high water temperature was the source of decrease in fruit firmness.

The cell walls are more stable to different treatments, therefore, calcium dips have been employed to improve firmness and extend the postharvest shelf life of a wide range of fruits and vegetables (Joyce *et al*., 2001). Ioannou & Ghoul (2013) reported that calcium salts are better in the strengthening of cell walls. The current results are also similar with those reported by Kazemi *et al.* (2013) on pomegranate. They associated the retention of firmness in calcium ions treated fruits to their accumulation in the cell walls leading to facilitation in the cross linking of the pectic polymers. The cross linking increases wall strength and cell cohesion.

Banana fruits (Table 6aa) colour attributes showed that, the hot water temperature and calcium chloride concentration acted in order to obtain high values in assay 10, 2 and 1 (44.80, -32.51 and 41.60) and low values in assay 3, 8 and 2 (42.88, -37.29 and 37.01), respectively for L, a^* and b^* attributes. Moreover, it was observed from the difference between the highest and lowest values obtained (L = 1.92, a^* = 4.78 and b^* = 4.59) that the treatments did not cause high change on the banana fruits peel colour. From Table 6ba, the hot water temperature and calcium chloride concentration were statistically influential only in linear term of each one for a^* values (redness or greenness) and linear term of hot water temperature for b^* (yellowness or blueness), but were not statistically significant for L (lightness or brightness) values.

With respect to Keitt mango fruits (Table 6ab) colour attributes, the hot water temperature and calcium chloride concentration acted in order to obtain high values in assay 9, 3 and 1 (44.32, 1.46 and 21.32) and low values in assay 5, 5 and 2 (42.23, -7.94 and 17.53), respectively for L, a^* and b^* attributes. Moreover, it was observed from the difference between the highest and lowest values obtained (L = 2.09 and a^* = 6.48) that the treatments did not cause high change on the mango fruits peel colour. From the Table 6bb, the hot water temperature and calcium chloride concentration were statistically significant in the quadratic term of hot water temperature on L values (lighteness intensity), linear term hot water and quadratic term of calcium chloride on b* (yellowness or blueness). The interaction between hot water dipping and calcium chloride treatment was statistically significant ($p < 0.05$) for a* and b* colour attributes.

It is desirable that the treatment carries to the smaller colour changes. Similar observations were reported by Ngamchuachit *et al.* (2014) for Atkins and Kent mangoes when they applied calcium chloride. In a heat treatment, the colour variation is a very complex aspect. It is related to the moisture content, solids incorporated and pigment concentration. This is attributed to the hot water treatment which protect the ultra-structure of the pericarp cells in the heat-pretreated fruits and calcium treatment which decrease the incidence of physiological disorders. Greater variation on colour is obtained with the higher temperature and high concentrations of calcium chloride (Corrêa *et al*., 2014). However, the hot water temperature and calcium chloride solution concentrations used in the present work were significantly lower than those reported by (Corrêa *et al*., 2014).

4.2.3 Effect of hot water and calcium chloride on the ºBrix, A_w, pH, TA and Vitamin C

The ºBrix, WA, pH, TA and vitamin C values for Cavendish banana and Keitt mango fruits obtained after hot water and calcium chloride treatment are presented in Table 7aa and 7abb while the effect of central composite design variables are presented in Table 7ba and 7bb (on appendices), respectively.

It can be observed, in Table 7aa, that low Cavendish bananas values were obtained in assays 2 for ºBrix (11.30 %), 1 and 8 for A_w (0.87), 10 for pH (4.51), 5 for TA (0.11 %) and 4 for vitamin C (1.20 %). High values were obtained in assay 3 for ºBrix (21.00), 3 and 6 for A_w (0.94), 2 for pH (5.88), 2, 3, 11 and 12 for TA (0.18 %) and 2 for vitamin C (2.07 %).

It can be observed, in Table 7ab, that low Keitt mangoes values were obtained in assays 10 for ºBrix (11.33 %), 8 and 9 for A_w (0.96), 11 and 12 for pH (4.01), 6 and 7 for TA (0.06 %) and 9 for vitamin C (9.13 %). High values were obtained in assay 1 for ºBrix (16.00 %), 2, 3, 5, 7 and 10 for A_w (0.98), 4 for pH (5.02), 1, 3, 5 and 8 for TA (0.10 %) and 8 for vitamin C (14.83 %).

These results indicated that the hot water (X_1) and calcium chloride (X_2) were the most influential variables over the two responses studied. Therefore, in the present study, mangoes total soluble solids, water activity and vitamin C were not statistically affected ($p < 0.05$) by hot water dipping and calcium chloride treatment (Table 7ba and 7bb). Quadratic effect related to X_1 showed that the higher the temperature of hot water, the higher is the pH. In a similar way, quadratic effect related to X_2 showed that the higher the calcium chloride treatment, the higher is the pH. Linear effect related to X_1 showed that the higher the temperature of hot water, the smaller is the titratable acidity.

Table 7aa. Central composite design assay on the ºBrix, A_w, pH, TA and vitamin C of Cavendish banana fruits

Assay	Variable		TSS	A_w	pH	TA	Vit. C
	X_1 (ºC)	X_2 (%)	(%)			(%)	(%)
1	50	2	12.00^{Ed}	0.87^{Dd}	5.36^{Dd}	0.17^{Ed}	1.77^{Dd}
2	60	2	11.30^{Dd}	0.88^{Dd}	5.88^{Dd}	0.18^{Ed}	2.07^{Ed}
3	50	4	21.00^{Ef}	0.94^{Dd}	5.85^{Dd}	0.18^{Ed}	2.03^{Ed}
4	60	4	19.00^{Ef}	0.90^{Dd}	5.19^{Dd}	0.12^{Dd}	1.20^{Dd}
5	47.95	3	13.30^{De}	0.89^{Dd}	5.02^{Dd}	0.11^{Dd}	1.40^{Dd}
6	62.05	3	17.67^{Ee}	0.94^{Dd}	5.63^{Dd}	0.14^{Dd}	1.47^{Dd}
7	55	0.88	19.33^{Ef}	0.89^{Dd}	5.38^{Dd}	0.16^{Ed}	1.93^{Ed}
8	55	5.12	13.10^{Ed}	0.87^{Dd}	5.21^{Dd}	0.17^{Ed}	1.93^{Ed}
9	55	3	16.33^{Ee}	0.92^{Dd}	5.45^{Dd}	0.16^{Ed}	1.80^{Dd}
10	55	3	16.67^{Ee}	0.92^{Dd}	4.51^{Dd}	0.17^{Ed}	1.73^{Dd}
11	55	3	16.00^{Ee}	0.92^{Dd}	4.70^{Dd}	0.18^{Ed}	1.70^{Dd}
12	55	3	17.00^{Ee}	0.93^{Dd}	4.70^{Dd}	0.18^{Ed}	1.69^{Dd}

X_1 and X_2 correspond to the independent variable. X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration (%); ºBrix is the total soluble solids; A_w is the water activity; pH is the potential hydrogenionic; TA is the titratable acidity (%) and Vit. C is the vitamin C content (mg/100g). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between hot water temperature and, the same lower case between calcium chloride concentration by Tukey test.

In the present study, bananas total soluble solids, water activity and pH were not statistically affected ($p < 0.05$) by hot water dipping and calcium chloride treatment (Table 7ba). Quadratic effect related to X_1 showed that the higher the temperature of hot water, the smaller is the titratable acidity. In the present study, the interaction between hot water dipping and calcium chloride treatment influenced negatively ($p < 0.05$) the vitamin C content (Table 7ba).

These results are not in agreement with those by Torres *et al.* (2009) report who evaluated the effects of heat treatment and calcium on postharvest storage of atemoya fruits. The total soluble solids (3.5 ± 0.11 ºBrix), titratable acidity (0.11 ± 0.03 %), pH (5.40 ± 0.01) and ascorbic acid (19.29 ± 0.09 mg/100g) were not different between treated and untreated fruits. Izundu *et al.* (2016) assessing the effects of ripening acceleration methods on the proximate, biochemical and mineral compositions of *Musa paradisiaca* (Plantain) noted that there is significant difference in the composition of the TA, pH, reducing sugar, and vitamin C of the plantain between treatment ($p < 0.05$) where hot water and also, calcium carbide presented low values of TA, high values of vitamin C and similar values of pH as reported in the present study. Similar results were reported by the Maureen *et al.* (2016).

Considering the high levels of vitamin C in hot water and calcium chloride treated Cavendish bananas in the current study, it is concluded that the Cavendish banana fruits preserved its characteristics and are a good source of vitamin C and malic acid. Various studies have shown that changes in cell pH by altered physical conditions affect the mineral, biochemical and proximate contents of plant since the vacuolar acidity influences the formation of the various chemical forms. For instance, in fruits, the acid pH range of anthocyanins are predominantly present as red flavylium cation, and with rising pH mainly the colourless carbinol and the blue quinonoidal bases are synthesized leading to a scarlet colour.

Table 7ab. Central composite design assay on the ºBrix, A_w, pH, TA and vitamin C of Keitt mango fruits

Assay	Variable		TSS	A_w	pH	TA	Vit. C
	X_1 (ºC)	X_2 (%)	(%)			(%)	(%)
1	50	2	16.00^{Aa}	0.97^{Aa}	4.94^{Ba}	0.10^{Ba}	12.87^{Aa}
2	60	2	14.17^{Aa}	0.98^{Aa}	4.99^{Ba}	0.08^{ABa}	12.00^{Aa}
3	50	4	13.50^{Aa}	0.98^{Aa}	5.00^{Bb}	0.10^{Ba}	10.10^{Aa}
4	60	4	14.33^{Aa}	0.97^{Aa}	5.02^{Bb}	0.07^{Aa}	10.90^{Aa}
5	47.95	3	14.33^{Aa}	0.98^{Aa}	4.97^{Ba}	0.10^{Ba}	12.70^{Aa}
6	62.05	3	15.33^{Aa}	0.97^{Aa}	5.00^{Bb}	0.06^{Aa}	12.37^{Aa}
7	55	0.88	15.33^{Aa}	0.98^{Aa}	5.00^{Bb}	0.06^{Aa}	12.63^{Aa}
8	55	5.12	13.67^{Aa}	0.96^{Aa}	4.00^{Aa}	0.10^{Ba}	14.83^{Aa}
9	55	3	13.67^{Aa}	0.96^{Aa}	4.15^{Aa}	0.07^{Aa}	9.13^{Aa}
10	55	3	11.33^{Aa}	0.98^{Aa}	4.03^{Aa}	0.07^{Aa}	11.60^{Aa}
11	55	3	15.50^{Aa}	0.97^{Aa}	4.01^{Aa}	0.07^{Aa}	12.87^{Aa}
12	55	3	15.17^{Aa}	0.97^{Aa}	4.01^{Aa}	0.07^{Aa}	12.00^{Aa}

X_1 and X_2 correspond to the independent variable. X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration (%); ºBrix is the total soluble solids; A_w is the water activity; pH is the potential hydrogenionic; TA is the titratable acidity (%) and Vit. C is the vitamin C content (mg/100g). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between hot water temperature and, the same lower case between calcium chloride concentration by Tukey test.

Similar effects were documented for kiwi-fruit (Shahkoomahally & Ramezanian, 2013). In pomegranate, Kazemi *et al.* (2013) also found TA increased significantly during the experiment, while the TSS content decreased gradually with addition of sodium and calcium treatment. These researchers also reported that the concentrations of $CaCl_2$ delayed the rapid oxidation of ascorbic acid.

4.2.4 Models and surface predicted responses

It can be seen from Table 6bb and Table 7bb (on appendices) that the statistical models for b*, pH and titratable acidity were suitable for describing the Keitt mangoes experimental data. These responses were statistically affected by the independent variables ($p < 0.05$). The model presented high values of determination coefficient for a statistical model ($R^2 \geq 0.80$). With respect to other predicted responses, the statistical models showed lack of adjustment because $R^2 < 0.80$. Thus, only the models for b*, pH and titratable acidity are presented “(4, 5 and 6)”:

$$Y_{b*} = 20.07 - 1.37X_1 - 0.18X_1^2 + 0.40X_2 - 1.27X_2^2 + 2.31X_1X_2 \quad (4)$$

$$Y_{pH} = 4.05 + 0.03X_1 + 1.06X_1^2 - 0.33X_2 + 0.57X_2^2 - 0.02X_1X_2 \quad (5)$$

$$Y_{TA} = 0.07 - 0.03X_1 + 0.01X_1^2 + 0.01X_2 + 0.02X_2^2 - 0.01_1X_2 \quad (6)$$

where X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration in the solution (%).

In a similar way for banana fruits, it can be seen from Table 5ba, Table 6ba and Table 7ba (on appendices) that the statistical models for ash, firmness and vitamin C content were suitable for describing the Cavendish banana fruits experimental data where the responses were statistically affected by the independent variables ($p < 0.05$). The model presented high values of determination coefficient for a statistical model ($R^2 \geq 0.80$) and predicted responses with $R^2 < 0.80$ showed statistical models lack of adjustment. Thus, only the models for ash, firmness and vitamin C are presented “(7, 8 and 9)”:

$$Y_{ash} = 0.63 + 0.01X_1 - 0.08X_1^2 + 0.02X_2 + 0.08X_2^2 - 0.09X_1X_2 \quad (7)$$

$$Y_{firmness} = 7.75 - 1.41X_1 + X_1^2 - 0.32X_2 - 0.17X_2^2 - 0.17X_1X_2 \quad (8)$$

$$Y_{vit\,C} = 1.68 - 0.11X_1 - 0.21X_1^2 - 0.15X_2 + 0.29X_2^2 - 0.57X_1X_2 \quad (9)$$

where X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration in the solution (%).

The surface responses from the predicted models of Keitt mangoes b*, pH and titratable acidity are presented in Figure 6, Figure 7 and Figure 8, respectively. These graphics reflect the influences of two independent variables, namely, hot water temperature (ºC) and calcium chloride concentration in the solution (%). The increase in b^* (yellowness or blueness) was observed with low or high values of hot water and calcium chloride concentration where optimal ranged from 55 to 65ºC and 0.88 to 2.5 % or 45 to 50ºC and 4 to 5.12 % (Figure 6).

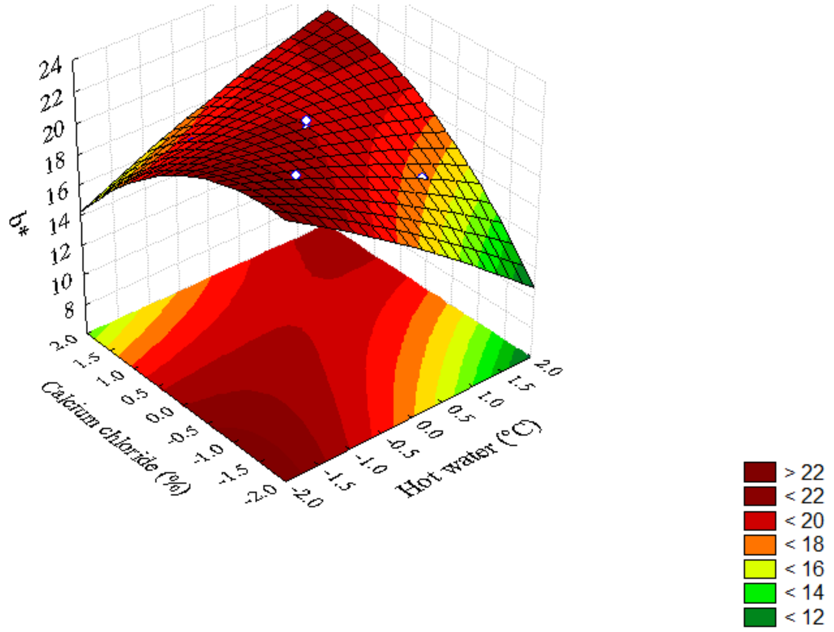

Figure 6. Surface responses from the predicted model of b* colour attribute of mango fruits Hot water codes correspond: -2.0 (45 ºC), -1.5 (47.5 ºC), -1.0 (50 ºC), -0.5 (52.5 ºC), 0.0 (55 ºC), 0.5 (57.5 ºC), 1.0 (60 ºC), 1.5 (62.5 ºC) and 2.0 (65 ºC). Calcium chloride codes correspond: -2.0 (1.0 %), -1.5 (1.5 %), -1.0 (2.0 %), -0.5 (2.5 %), 0.0 (3.0 %), 0.5 (3.5 %), 1.0 (4.0 %), 1.5 (4.5 %) and 2.0 (5.0 %).

Therefore, mango fruits which were subjected to high or low hot water dipping and calcium chloride treatment (40 to 50 ºC and 0.88 to 2.5 % or 60 to 65ºC and 4 to 5.12 %) produced significantly higher peel colour score showing more yellowness than blueness which might be due to creation of a physical barrier against gas exchange from fruit surface, that may have reduced oxygen intake which is necessary for the biodegradation of chlorophyll (Anwar & Malik, 2007).

The influences of hot water temperature (ºC) and calcium chloride concentration in the solution (%) on mango fruits showed increased pH values with X_1 and X_2 extreme combination where optimal was found at central coded variables' value ranged from 52 to 57 ºC and 2.5 to 3.5 % (Figure 7).

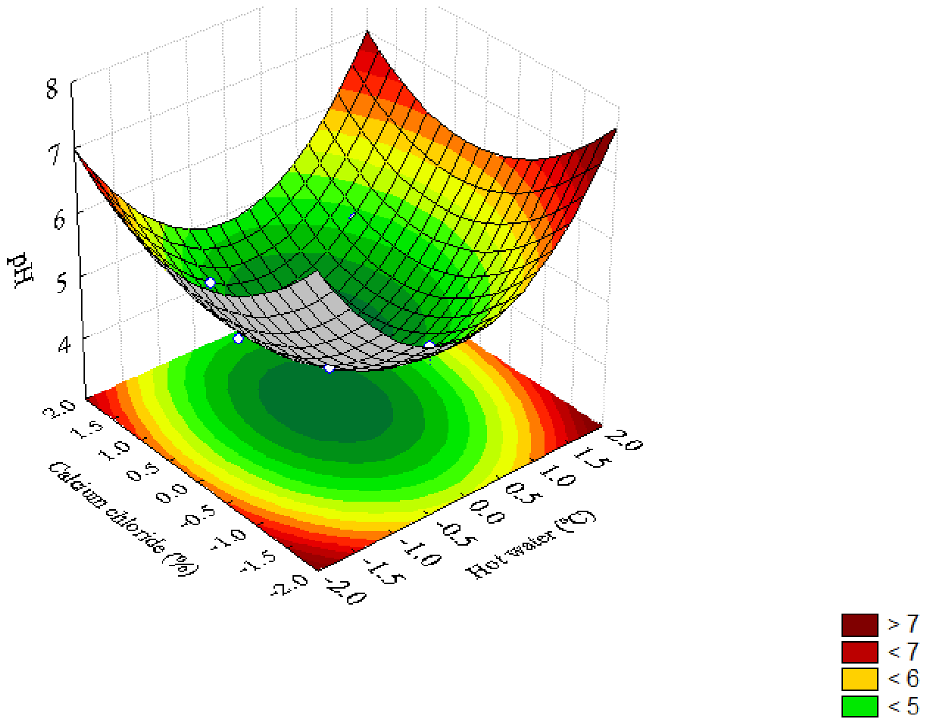

Figure 7. Surface responses from the predicted model of mango fruits pH

Hot water codes correspond: -2.0 (45 ºC), -1.5 (47.5 ºC), -1.0 (50 ºC), -0.5 (52.5 ºC), 0.0 (55 ºC), 0.5 (57.5 ºC), 1.0 (60 ºC), 1.5 (62.5 ºC) and 2.0 (65 ºC). Calcium chloride codes correspond: -2.0 (1.0 %), -1.5 (1.5 %), -1.0 (2.0 %), -0.5 (2.5 %), 0.0 (3.0 %), 0.5 (3.5 %), 1.0 (4.0 %), 1.5 (4.5 %) and 2.0 (5.0 %).

Reports on both hot water and calcium chloride on the Keitt mango fruits pH are scarce but Kumah *et al.* (2011) assessing the effect of hot water treatment on quality and shelf-life of Keitt mango reported increasing trend in the pH values while the hot water temperature and the processing time were increasing, contrasting with this work where the optimum point is know.

High mango fruits titratable acidity values were found combining low hot water temperature (ºC) with high calcium chloride concentration in the solution (%) and the optimal ranged from 45 to 50 ºC and 4.5 to 5.5 % (Figure 8).

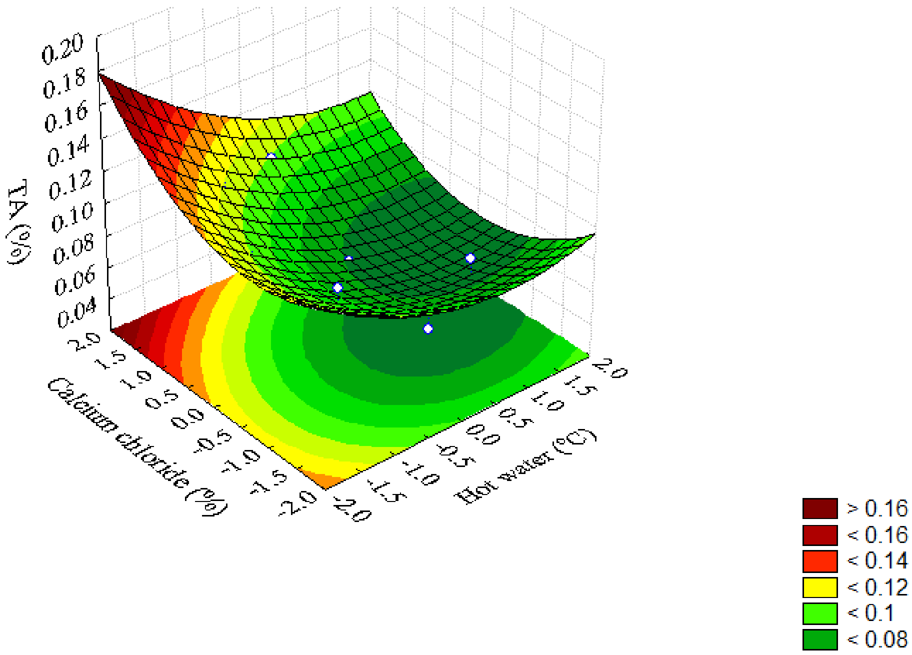

Figure 8. Surface responses from the predicted model of mango titratable acidity
Hot water codes correspond: -2.0 (45 ºC), -1.5 (47.5 ºC), -1.0 (50 ºC), -0.5 (52.5 ºC), 0.0 (55 ºC), 0.5 (57.5 ºC), 1.0 (60 ºC), 1.5 (62.5 ºC) and 2.0 (65 ºC). Calcium chloride codes correspond: -2.0 (1.0 %), -1.5 (1.5 %), -1.0 (2.0 %), -0.5 (2.5 %), 0.0 (3.0 %), 0.5 (3.5 %), 1.0 (4.0 %), 1.5 (4.5 %) and 2.0 (5.0 %).

Islam *et al.* (2013) assessing the changes in Acidity, TSS, and sugar content at different storage periods of the postharvest mango (*Mangifera indica* L.) reported high titratable acidity values (2.47 % for Khirshapat and 3.77 % for Langra varieties) of raw material but after treating with Bavistin DF the acidity was similar as reported in this work, and also, high Bavistin level presented high titratable acidity showing that regardless of variety or chemical used, mangoes fruits acidity improve with high treatment level. The results of this work are, also, in concordance with Kumah *et al.* (2011) where low hot water temperature showed high titratable acidity.

The surface responses from the predicted models of banana fruits ash, firmness and vitamin C content are presented in Figure 9, Figure 10 and Figure 11, respectively. These graphs reflect the influences of two independent variables, namely, hot water temperature (ºC) and calcium chloride concentration in the solution (%).

Figure 9 shows the increase in the ash content with high hot water temperature and low calcium chloride concentration or low hot water temperature and high calcium chloride concentration. The optimal conditions for banana treatment ranged from 50 ºC to 55 ºC of hot water temperature and 2 % to 3 % of calcium chloride concentration. Ash is considered among the chemical characteristics that define quality of a food (Osagie & Eka, 1998) but certain treatments may be proposed to accelerate the degradation process, to prevent overall losses of minerals, or to improve the retention of critical components in food.

Maureen *et al.* (2016) used calcium carbide treatment, hot water treatment, dried plantain leaves treatment, smoked treatment and then polythene bag treatment as induced ripening methods and reported that hot water presented the lowest ash content followed by the control and calcium carbide treatment, meaning that those three treatments were not acting as ripening inductor but qualities maintainers treatments. Ash of foods is mineral contents having sodium, calcium, phosphorus and potassium, iron, and magnesium that make it valuable not only as a raw material for indigenous soap industries but also in the treatment of soils for acidity (Auta & Kumurya, 2015; Iroka *et al*., 2016; Izundu *et al*., 2016).

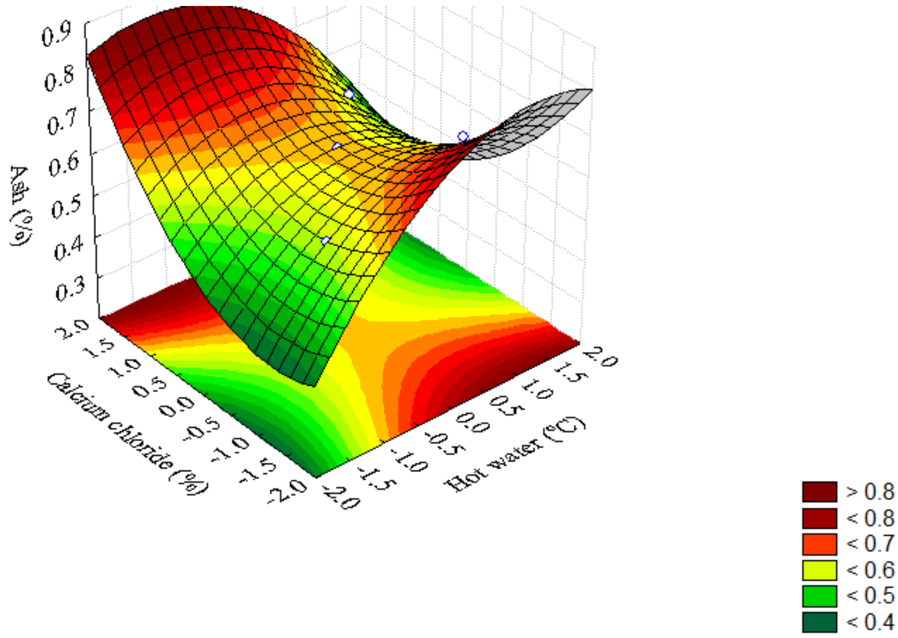

Figure 9. Surface responses from the predicted model of banana ash

Hot water codes correspond: -2.0 (45 ºC), -1.5 (47.5 ºC), -1.0 (50 ºC), -0.5 (52.5 ºC), 0.0 (55 ºC), 0.5 (57.5 ºC), 1.0 (60 ºC), 1.5 (62.5 ºC) and 2.0 (65 ºC). Calcium chloride codes correspond: -2.0 (1.0 %), -1.5 (1.5 %), -1.0 (2.0 %), -0.5 (2.5 %), 0.0 (3.0 %), 0.5 (3.5 %), 1.0 (4.0 %), 1.5 (4.5 %) and 2.0 (5.0 %).

The increase in firmness was observed with any values of calcium chloride concentration and hot water optimal ranged from 40 to 50 ºC (Figure 10). Amin & Hossain (2013) reported that temperatures higher than 57 °C for 7-9 min caused defects on the banana peel. However, during this current study, no banana fruit peel was damaged.

Mahmud *et al.* (2008) assessing the effects of different concentration and applications of calcium on storage life and physicochemical characteristics of papaya (*Carica papaya* L.) observed that calcium infiltration treatment at 2.5 % significantly affected firmness followed by calcium infiltration treatments at 3.5 and 1.5 %, respectively compared with control treatment after storage (without calcium treatment).

In this Mahmud *et al.* (2008) report, the infiltration treatment at 2.5 % demonstrated the best effect on maintaining fruit firmness compared with other treatments. Differently with the results obtained in this work where calcium dip treatments at 0.88 % to 5.12 % significantly improved maintenance of fruit firmness but maintenance of firmness tended to be higher in 3 % treated samples. The desired effect of calcium infiltration at 3 % on maintaining fruit firmness may be due to the calcium binding to free carboxyl groups of polygalacturonate polymer, stabilizing and strengthening the cell walls.

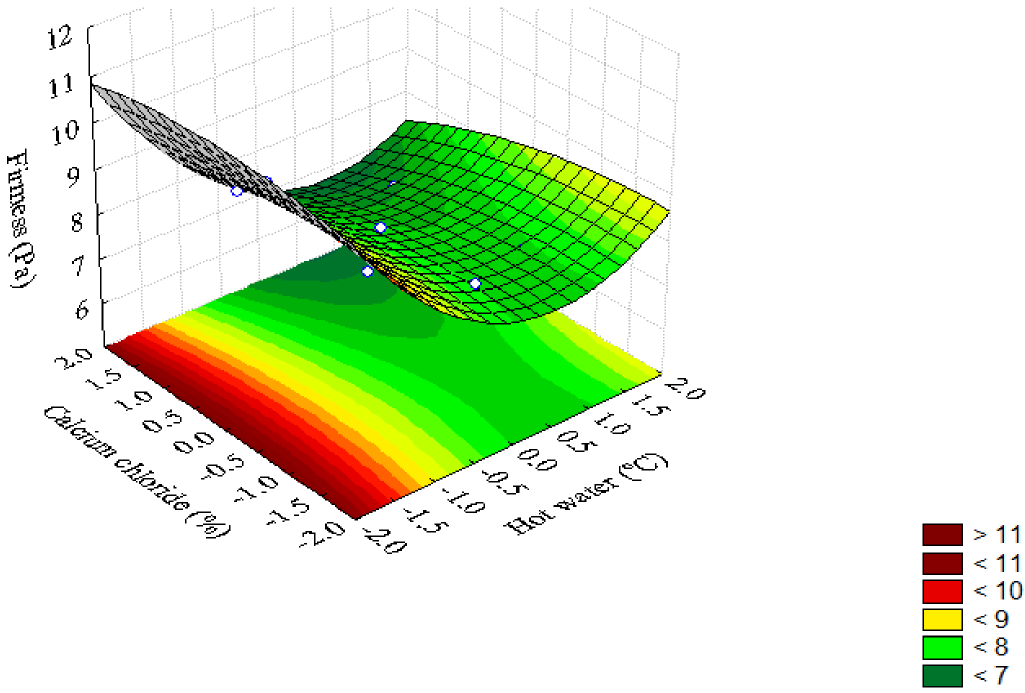

Figure 10. Surface responses from the predicted model of banana firmness

Hot water codes correspond: -2.0 (45 ºC), -1.5 (47.5 ºC), -1.0 (50 ºC), -0.5 (52.5 ºC), 0.0 (55 ºC), 0.5 (57.5 ºC), 1.0 (60 ºC), 1.5 (62.5 ºC) and 2.0 (65 ºC). Calcium chloride codes correspond: -2.0 (1.0 %), -1.5 (1.5 %), -1.0 (2.0 %), -0.5 (2.5 %), 0.0 (3.0 %), 0.5 (3.5 %), 1.0 (4.0 %), 1.5 (4.5 %) and 2.0 (5.0 %).

A firming effect by a combination of calcium chloride dip and heat treatment has also been shown in fresh cut melons by Luna-Guzman *et al.* (1999). These results may indicate that the firming effect is accompanied by improved water holding capacity due to a more cross-linked pectin network. Additionally, higher water holding capacity could be related to increased firmness due to higher turgor pressure which is supported by higher moisture content and hardness attributes obtained with infiltration treatment at 3 %.

Figure 11 shows the increase in the vitamin C content with high hot water temperature and low calcium chloride concentration or low hot water temperature and high calcium chloride concentration. The optimal preservation conditions ranged from 50 ºC to 55 ºC of hot water temperature and 2 % to 3 % of calcium chloride. Amin & Hossain (2013) treated two different varieties of banana, ‘Bari Kola’ and ‘Sabri Cola’, with six different combinations of hot water temperatures and times. The bananas treated with combinations of 53 °C for 9 min or 55 °C for 7 min exhibited reduced vitamin C content, however, in the current work, the observations were different.

Laufinan & Sams (1989) treated apple with 0 to 4 % $CaCl_2$ and stored the fruit at 2 °C and found that ascorbic acid content ranged between 200-400 % in calcium treated fruit as compared to the control (untreated). They found that $CaC1_2$ treated fruit were firmer and had more ascorbic acid than untreated fruit results. These observations are similar to those of the current study. This increase in vitamin C content was reported by Mahmud *et al.* (2008) for papaya treated with $CaCl_2$, Sharma *et al.* (2013) on Royal Delicious Apples (*Malus x domestica* Borkh) treated with calcium sprays and postharvest hot water and Kazemi *et al.* (2013) assessing the effects of sodium and calcium treatments on pomegranate, but Amin & Hossain (2013) reported decreased vitamin C content after treating banana fruit with different temperature and time, and Shahkoomahally & Ramezanian (2013) assessing the effect of hot water and calcium solution dipping on quality in kiwi-fruit observed maintenance of vitamin C content.

In a hot water and calcium chloride treatment, the optimum condition is the one that carries out to the higher firmness and the maintenance of ash and vitamin C content. For Cavendish banana fruits hot water dipping and calcium chloride treatment, the performed statistical analysis based on the CCD resulted on the following ranges: 50 ºC to 60 ºC of hot water temperature and 2 to 3 % calcium chloride concentration.

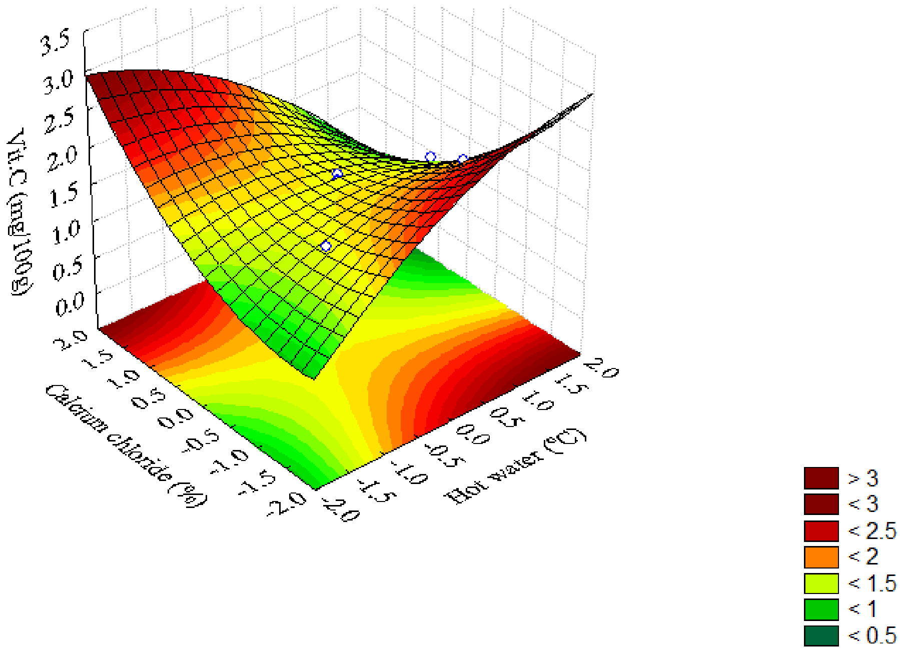

Figure 11. Surface responses from the predicted model of banana vitamin C
Hot water codes correspond: -2.0 (45 ºC), -1.5 (47.5 ºC), -1.0 (50 ºC), -0.5 (52.5 ºC), 0.0 (55 ºC), 0.5 (57.5 ºC), 1.0 (60 ºC), 1.5 (62.5 ºC) and 2.0 (65 ºC). Calcium chloride codes correspond: -2.0 (1.0 %), -1.5 (1.5 %), -1.0 (2.0 %), -0.5 (2.5 %), 0.0 (3.0 %), 0.5 (3.5 %), 1.0 (4.0 %), 1.5 (4.5 %) and 2.0 (5.0 %).

4.2.5 Optimization of process variables through the desirability function

The results obtained by central composite design (CCD) showed that only the predicted models of b*, pH and mango fruits titratable acidity were adjusted to describe the experimental data. Thus, the hot water dipping and calcium chloride treatment process optimization of Keitt mango fruits, using the desirability function and considering the condition of the process that results in the higher titratable acidity, the maintenance of b* and reducing the pH values, was performed.

Simultaneous evaluation of mangoes responses in total desirability profile is shown in Figure 12. By applying the desirability function, the optimal conditions of the hot water dipping and calcium chloride treatment of Keitt mango fruits are 55 ºC of hot water temperature and 3% of calcium chloride concentration. Under these conditions, b* colour attribute is maintained, pH is reduced and fruit titratable acidity is maximized, which presented predicted values of 20.07, 4.05 and 0.07 %, respectively.

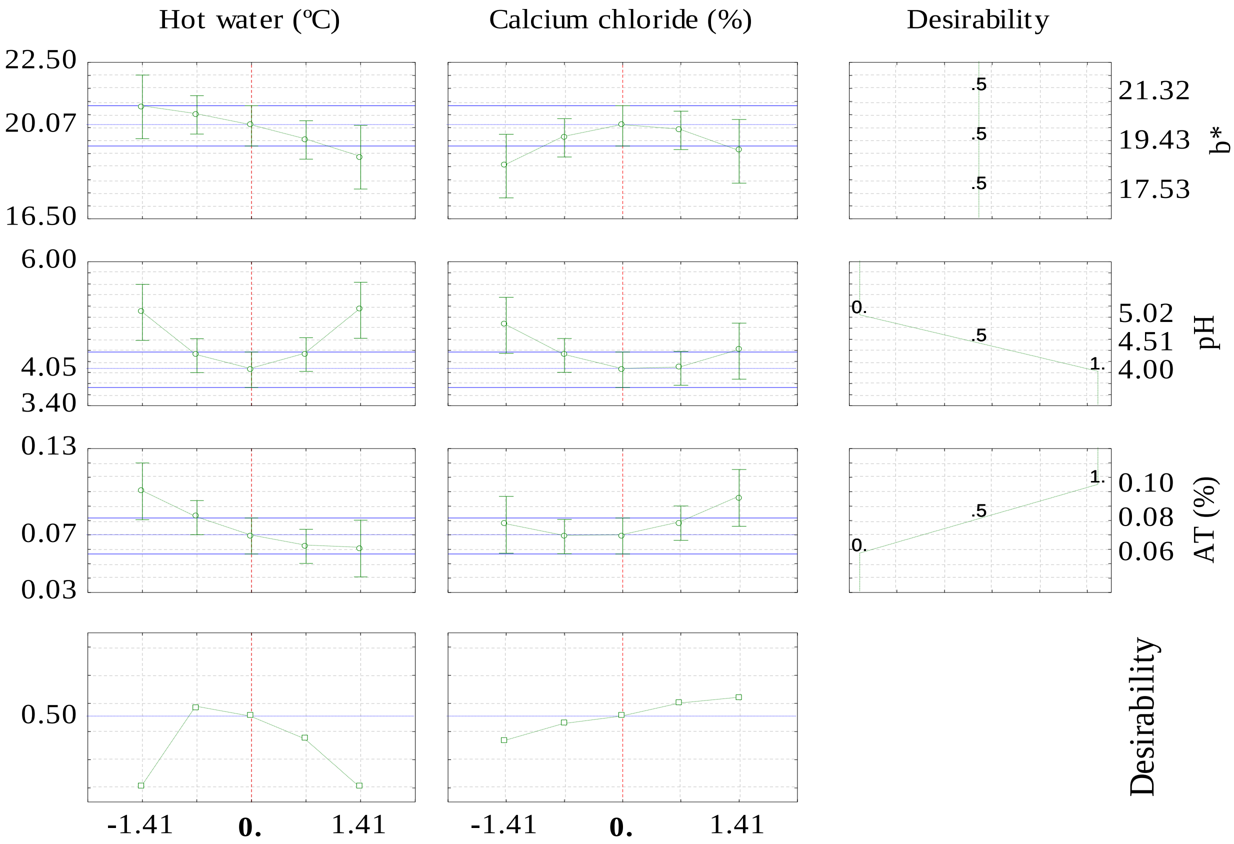

Figure 12. Profile for mango fruits predicted values and desirability
Hot water codes correspond: -1.41 (47.95 ºC), 0.0 (55 ºC) and 1.41 (62.05. Calcium chloride codes correspond: -1.41 (0.88 %), 0.0 (3.0 %) and 1.41 (5.02 %).

In a similar way, the results obtained by central composite design (CCD) for banana fuits showed that only the predicted models of firmness, ash and vitamin C were adjusted to describe the experimental data. Thus, the hot water dipping and calcium chloride treatment process optimization of Cavendish banana fruits, using the desirability function and considering the condition of the process that results in the higher firmness and the maintenance of ash and vitamin C content, was performed.

Simultaneous evaluation of responses of banana in total desirability profile is shown in Figure 13. By applying the desirability function, the optimal conditions of the hot water dipping and calcium chloride treatment of Cavendish banana fruits are, coincidentally, 55 ºC of hot water temperature and 3 % of calcium chloride concentration. Under these conditions, firmness is maximized, ash and vitamin C maintained, which presented predicted values of 7.75 Pa, 0.63 % and 1.68 mg/100g, respectively.

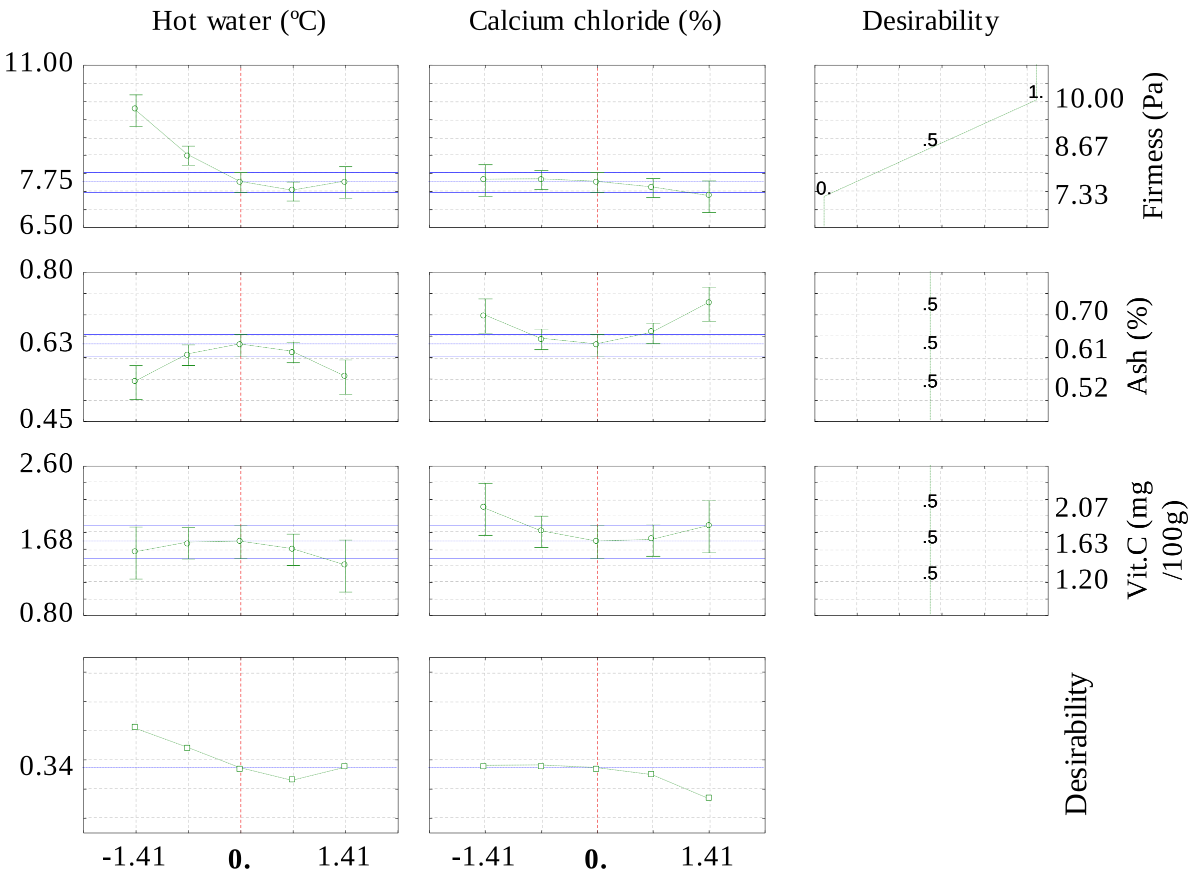

Figure 13. Profile for banana fruits predicted values and desirability

Hot water codes correspond: -1.41 (47.95 ºC), 0.0 (55 ºC) and 1.41 (62.05. Calcium chloride codes correspond: -1.41 (0.88 %), 0.0 (3.0 %) and 1.41 (5.02 %).

Optimal results were validated through an experiment on the optimal point. The Keitt mango fruits experimental data obtained (b* = 20.14, pH = 4.01 and titratable acidity = 0.08%) were similar to the responses predicted by the models, and the standard deviations were relatively low (0.19, 0.12 and 0.01, respectively), indicating that the models suit the responses.

For Cavendish banana fruit, the experimental obtained values (firmness = 7.77 Pa, ash = 0.62% and vitamin C = 1.66 mg/100g) were, also, similar to the responses predicted by the models, and the standard deviations were relatively low (0.03, 0.03 and 0.01, respectively), indicating that the models suit the responses.

4.3 Determination of the effect of hot water dipping and calcium treatment on the ripening of banana and mango fruits

4.3.1 Effect of hot water and calcium chloride on the fruit water activity

The water activity (A_w) of Keitt mango and Cavendish banana fruits collected at different ripening stage from different regions of Mozambique and subjected to different postharvest treatment is presented in Figure 14.

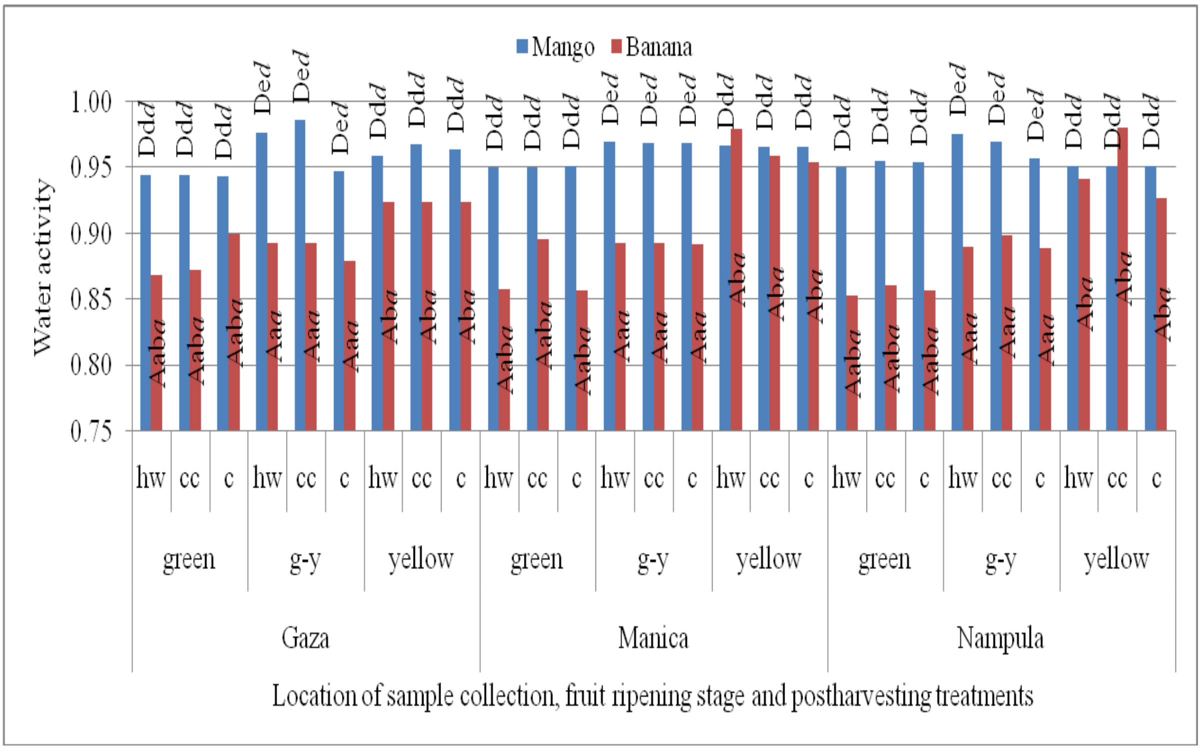

Figure 14. A_w of Keitt mangoes and Cavendish banana fruits from different regions at different maturity stage subjected to different treatment

Bars followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same small letters are not significantly different between fruit ripening stages and italic letter are not significantly different between the postharvest treatments. Where *a*, *b* and *c* for banana and *d*, *e* and *f* for mango fruits. (hw – hot water, cc – calcium chloride and c – control).

It can be observed, that low Keitt mangoes A_w values were obtained in untreated green fruits (A_w = 0.94) collected in Gaza, South part of Mozambique and high values were obtained in green-yellow fruits (A_w = 0.98) from Gaza and Nampula treated with hot water. These results indicated that the hot water and calcium chloride were not influential factor over the fruits water activity studied. Therefore, in the present study, mangoes water activity was not statistically affected ($p < 0.05$) by, hot water dipping and calcium chloride treatment or by the location of sample collection. Only, mangoes water activity was statistically affected ($p < 0.05$) by fruit ripening stage showing increasing behaviour as the fruit ripe and decreasing when it overripe.

For Cavendish banana fruits, it can be observed in Figure 14, that low A_w values were obtained in green fruits (A_w = 0.86) treated with hot water and collected in Nampula Province, the North part of Mozambique and high values were obtained in yellow fruits (0.98) from Nampula and Manica. Similarly, with mango fruits, Cavendish banana fruits were not statistically influenced by hot water dipping and calcium chloride treatment or by the location of sample collection over the fruits water activity studied. Banana fruits water activity was statistically affected ($P < 0.05$) by fruit ripening stage showing increasing behaviour as the fruit ripe.

Reports on the effects of hot water and calcium chloride on the mango and banana fruits water activity during ripening are scarce or totally missing, however, Corrêa *et al.* (2014) optimizing the vacuum pulse osmotic dehydration of blanched pumpkin observed that A_w is directly influenced by water loss and solid gain variables related with mass transference going in agreement with this work where the whole fruit immersed in the treatments was not allowing easy mass fluidness.

4.3.2 Effect of hot water and calcium chloride on the total soluble solids

The total soluble solids (TSS) of Keitt mango and Cavendish banana fruits collected at different ripening stage from different regions of Mozambique and subjected to different postharvest treatment is presented in Figure 15.

From the Figure 15, low Keitt mangoes TSS values were obtained in green fruits (TSS = 11 %) collected in Manica treated with calcium chloride and high values were obtained in green-yellow and yellow fruits (TSS = 40 %) from Gaza treated with hot water. The results indicated that mangoes total soluble solids were varying depending on location of fruit collection and statistical differences ($p < 0.05$) were found on mangoes from Gaza compared with others regions. Mangoes TSS was, also, statistically affected ($p < 0.05$) by fruit ripening stage showing increasing behaviour as the fruit ripe. These results indicated that the hot water and calcium chloride influential factor on the fruits TSS studied showing calcium chloride reducing the fruit ripening better than hot water and untreated samples.

For Cavendish banana fruits, can be observed in this Figure 13, that low TSS values were obtained in green fruits (TSS = 13 %) collected in all regions of the country and treated with calcium chloride and high values were obtained in green-yellow and yellow treated fruits (TSS = 22 %) from Manica and Nampula, respectively. The results showed that banana total soluble solids were varying depending on location of fruit collection and statistic differences ($p < 0.05$) were found on banana fruits from three locations of sample collection. Banana TSS were, also, affected by fruit ripening stage showing increasing behaviour as the fruit ripen without statistical differences ($p < 0.05$) between green-yellow with yellow fruits. Contrarily with mango fruits, Cavendish banana fruits were not statistically influenced by either hot water dipping or calcium chloride treatment showing that the huge pellicle involving the banana pulp did not, easily, allow the mass transfer.

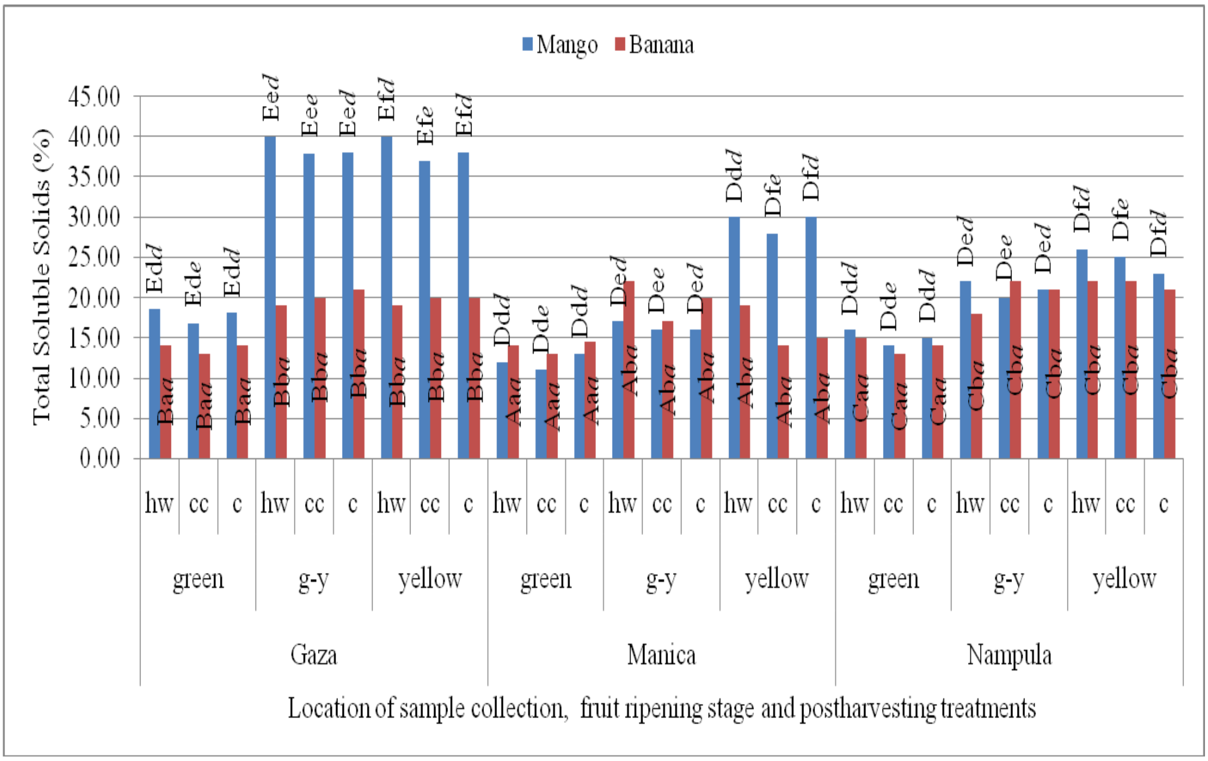

Figure 15. TSS of Keitt mangoes and Cavendish banana fruits from different regions at different maturity stage subjected to different treatment

Bars followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same small letters are not significantly different between fruit ripening stages and italic letter are not significantly different between the postharvest treatments. Where *a*, *b* and *c* for banana and *d*, *e* and *f* for mango fruits. (hw – hot water, cc – calcium chloride and c – control).

High TSS has been associated with high sucrose content in banana pulp (Akhter *et al*., 2012). Reports on the effects of hot water and calcium chloride for both mango and banana fruits on TSS are scarce however, Ngamchuachit *et al.* (2014) assessing the effectiveness of calcium chloride and calcium lactate on maintenance of textural and sensory qualities of fresh-cut mangoes reported that treatment with higher concentrations of $CaCl_2$ reduced the TSS. Kumah *et al.* (2011) assessing the effect of hot water treatment on quality and shelf-life of Keitt mango reported general increasing trend in the total soluble solids (TSS) in the 'Keitt' mango fruits with days in storage showing that independently of treatment TSS increase as the fruit ripe.

Amin & Hossain (2013) assessing the reduction of postharvest loss and prolong the shelf -life of banana through hot water treatment reported increased total soluble solid during ripening period but hot water brought about TSS reduction when it was increasing. Maureen *et al.* (2016) studying the effects of induced ripening on the proximate, biochemical and mineral compositions of *Musa sapientum* (Banana) noted that hot water treatment was not ripening accelerator method agreeing with this work where hot water was not influent on banana fruit ripening. Tapre & Jain (2012) studying the advanced maturity stages of banana reported that at stage 7, maximum TSS was observed (23.07ºBrix) followed by 6^{th} and 5^{th} stage of ripening and associated the increased behavoiur of TSS as the fruit ripe with the hydrolysis of starch into soluble sugars such as glucose, sucrose and fructose.

The data obtained in this investigation are similar to those reported by Amin & Hossain (2013), Maureen *et al.* (2016), Appiah *et al*. (2011) and Akhter *et al*. (2012) where there will be a higher concentration of total soluble solids in the samples harvested in later maturation stages than in those fruits that were collected in an early maturation stage. Postharvest treatments were influential factor for mangoes than for banana total soluble solids assessed.

4.3.3 Effect of hot water and calcium chloride on the pH

Various studies have shown that changes in cell pH by altered physical conditions affect the mineral, biochemical and proximate contents of plant since the vacuolar acidity influences the formation of the various chemical forms (Maureen *et al.*, 2016).

In this work, the pH of Keitt mango and Cavendish banana fruits collected at different ripening stage from different regions of Mozambique and subjected to different postharvest treatment is presented in Figure 16.

As shown in Figure 16, low Keitt mangoes pH values were obtained in yellow fruits (pH = 3.00) collected in Gaza and treated with calcium chloride and high values were obtained in green fruits (pH = 4.50) from Manica and treated with hot water. These observations were attributed to the conversion of citric acid and ascorbic acid into sugar and other products with the ripening process and whose rate of conversion increased with the temperature of the solutions (Baloch & Bibi, 2012).

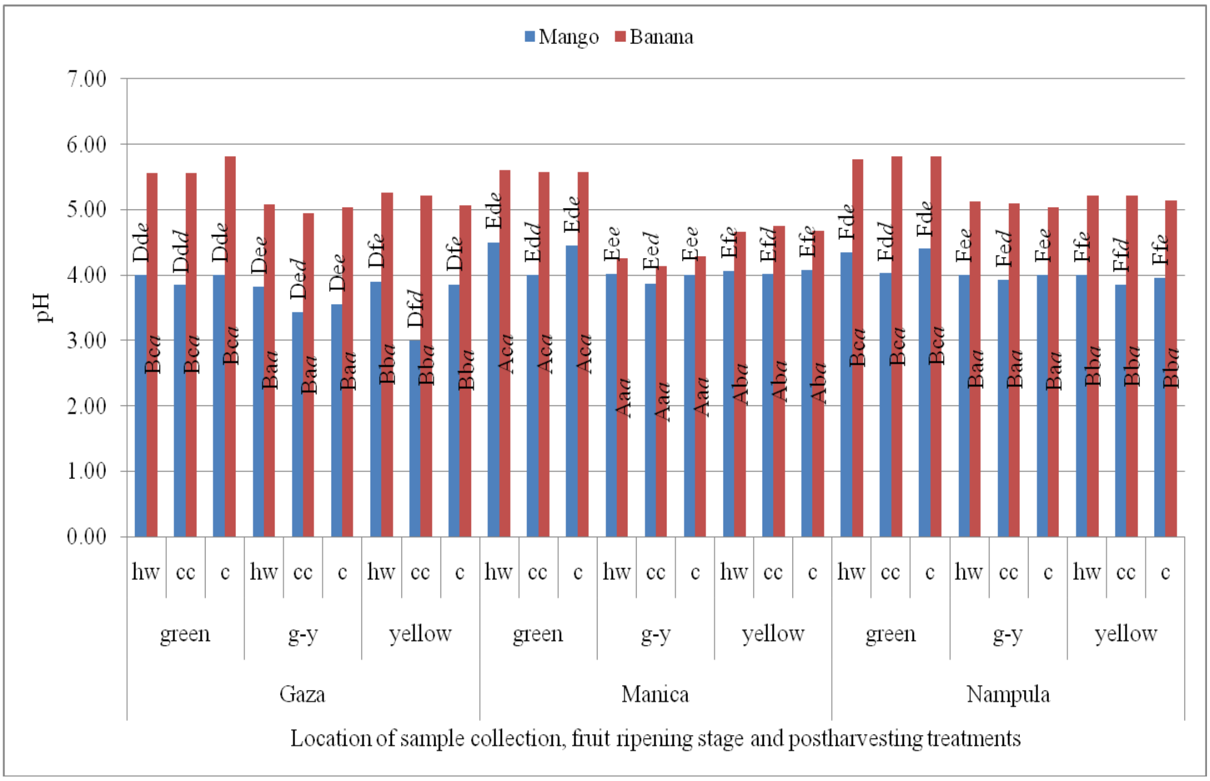

Figure 16. The pH of Keitt mangoes and Cavendish banana fruits from different regions at different maturity stage subjected to different treatment

Bars followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same small letters are not significantly different between fruit ripening stages and italic letter are not significantly different between the postharvest treatments. Where *a*, *b* and *c* for banana and *d*, *e* and *f* for mango fruits. (hw – hot water, cc – calcium chloride and c – control).

The results indicated that mangoes pH were varying depending on location of fruit collection and statistic differences ($p < 0.05$) were found on the mangoes from all locations of fruit collection. Mangoes pH was, also, statistically affected ($p < 0.05$) by fruit ripening stage showing decreasing behaviour as the fruit ripen. These results indicated that the hot water and calcium chloride treatments influential factors on the fruits pH studied, showing calcium chloride reducing the fruit ripening better than hot water and untreated samples.

For Cavendish banana fruits, it can be observed in this Figure 16, that low pH values were obtained in green-yellow fruits (pH = 4.14) collected in Manica and treated with calcium chloride and high values were obtained in untreated green fruits (pH = 5.82) from

Gaza and Nampula. The results showed that banana pH was varying depending on location of fruit collection and statistic differences ($P < 0.05$) were found on banana fruits from Manica having lower pH than Gaza and Nampula. Banana pH was, also, affected by fruit ripening stage showing decreasing behaviour as the fruit ripe and from time to time, green-yellow fruit with lower pH than the yellow one. Contrary to mango fruits, Cavendish banana fruits were not statistically influenced ($P < 0.05$) by either hot water dipping or calcium chloride treatment showing that the huge pellicle involving the banana pulp did not, easily, facilitate the environment acidity chance.

The decrease behaviour in pH as the fruit ripe is associated to the activity of dehydrogenases and to the organic acids that are used as substrates for respiration in the synthesis of new components during maturation (Kulkarni *et al.*, 2011). Kumah *et al.* (2011) assessing the effect of hot water treatment on quality and shelf-life of Keitt mango reported general increasing trend in the ‘Keitt’ mango fruits pH who indicated that the pH values of fruit flesh increased with the onset of maturation till ripening.

Reports on both hot water and calcium chloride on the Keitt mango fruits pH are scarce but Kumah *et al.* (2011) reported increasing trend in the pH values as the hot water temperature and the processing time were increasing, contrasting with this work where the optimum point was used. Chéour & Souiden (2015) assessing the calcium delays the postharvest ripening and related membrane-Lipid changes of tomato noted high untreated samples pH than treated with calcium.

4.3.4 Effect of hot water and calcium chloride on the titratable acidity

The titratable acidity (TA) of Keitt mango and Cavendish banana fruits collected at different ripening stage from different regions of Mozambique and subjected to different postharvest treatment is presented in Figure 17.

From Figure 17, low Keitt mangoes TA values were obtained in untreated green fruits (TA = 0.10 %) collected in Gaza and high values were obtained in yellow fruits (TA = 0.24 %) from Manica and treated with calcium chloride. Mangoes titratable acidity were varying depending on location of fruit collection and statistic differences ($p < 0.05$) were found on mangoes from Manica compared with others regions. Mangoes TA were, also, statistically affected ($p < 0.05$) by fruit ripening stage showing increasing behaviour as the fruit ripe. These results indicated that the hot water and calcium chloride were influent variables over the fruits TA studied showing either calcium chloride or hot water increased fruit titratable acidity than untreated mangoes.

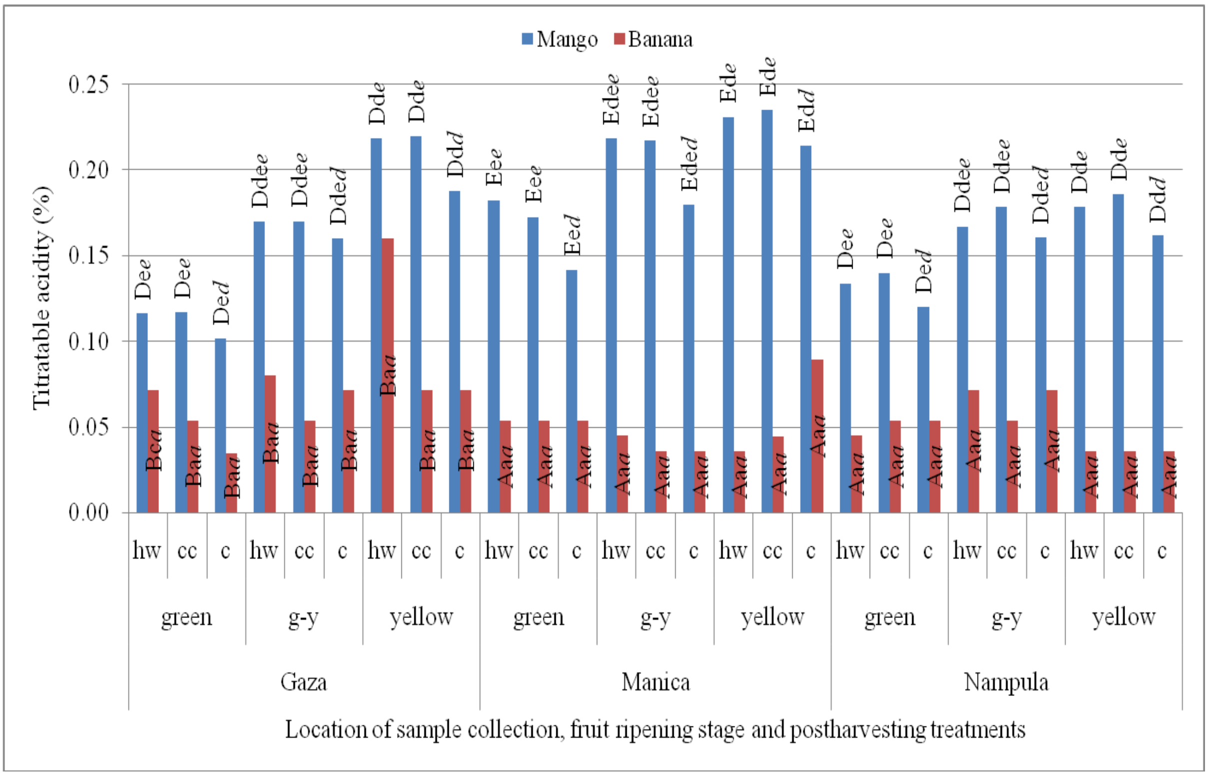

Figure 17. The titratable acidity of Keitt mangoes and Cavendish banana fruits from different regions at different maturity stage subjected to different treatment

Bars followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same small letters are not significantly different between fruit ripening stages and italic letter are not significantly different between the postharvest treatments. Where *a*, *b* and *c* for banana and *d*, *e* and *f* for mango fruits. (hw – hot water, cc – calcium chloride and c – control).

For Cavendish banana fruits, can be observed in Figure 17, that low TA values were obtained in untreated green fruits (TA = 0.03 %) collected in Gaza and high values were obtained in yellow fruits (TA = 0.16 %) from Gaza and treated with hot water. The results showed that banana titratable acidity was varying depending on location of fruit collection and statistic differences ($p < 0.05$) were found on banana fruits from Gaza compared with others location of sample collection. In this study, banana TA were not statistically affected ($p < 0.05$) by fruit ripening stage showing that as the banana fruits ripe the content of malic acid is not increasing significantly. Contrarily with mango fruits, Cavendish banana fruits were not statistically influenced by either hot water dipping or calcium chloride treatment showing that the huge pellicle involving the banana pulp did not, easily, facilitate organic compound production on the fruit pulp.

The results of this work are, also, in accordance with Kumah *et al.* (2011) assessing the effect of hot water treatment on quality and shelf-life of Keitt mango where reported general decreasing trend in the titratable acidity in the ‘Keitt’ mango fruits with days in storage and there were no differences between treatments and low hot water temperature showed high titratable acidity. Ngamchuachit *et al.* (2014) assessing the effectiveness of calcium chloride and calcium Lactate on maintenance of textural and sensory qualities of fresh-cut mangoes reported that treatment with higher concentrations of $CaCl_2$ maintained higher TA and thus lowered the SSC/TA ($p < 0.001$), differently with Chéour & Souiden (2015) who noted no differences between untreated and treated citric acid of the tomato samples.

For banana fruits, Amin & Hossain (2013) assessing the reduction of postharvest loss and prolong the shelf -life of banana through hot water treatment reported increased titratable acidity during ripening period and associated the fruit tartness with malic and citric acids and the astringency with oxalic acid that are the three major titratable banana acids. Tapre & Jain (2012) studying the advanced maturity stages of banana reported a significant difference ($p < 0.05$) between titratable acidity of pulp of three different maturity stages. Mean values of titratable acidity shows that this parameter increases gradually until the fruit reaches to full-ripe stage.

4.3.5 Effect of hot water and calcium chloride on the vitamin C content

The vitamin C content of Keitt mango and Cavendish banana fruits collected at different ripening stage from different regions of Mozambique and subjected to different postharvest treatment is presented in Figure 18.

From Figure 18, low Keitt mangoes vitamin C content were obtained in green fruits (vitamin C content = 8.5 %) collected in Nampula treated with hot water and high values were obtained in yellow fruits (vitamin C content = 14.90 %) from Manica treated with hot water. The results showed that mangoes vitamin C content was varying depending on location of fruit collection and statistic differences ($p < 0.05$) were found on mangoes from different regions. Mangoes vitamin C content were, also, statistically affected ($p < 0.05$) by fruit ripening stage showing increasing vitamin C as the fruit ripe. These results indicated that the hot water and calcium chloride did not influence the fruits vitamin C content studied.

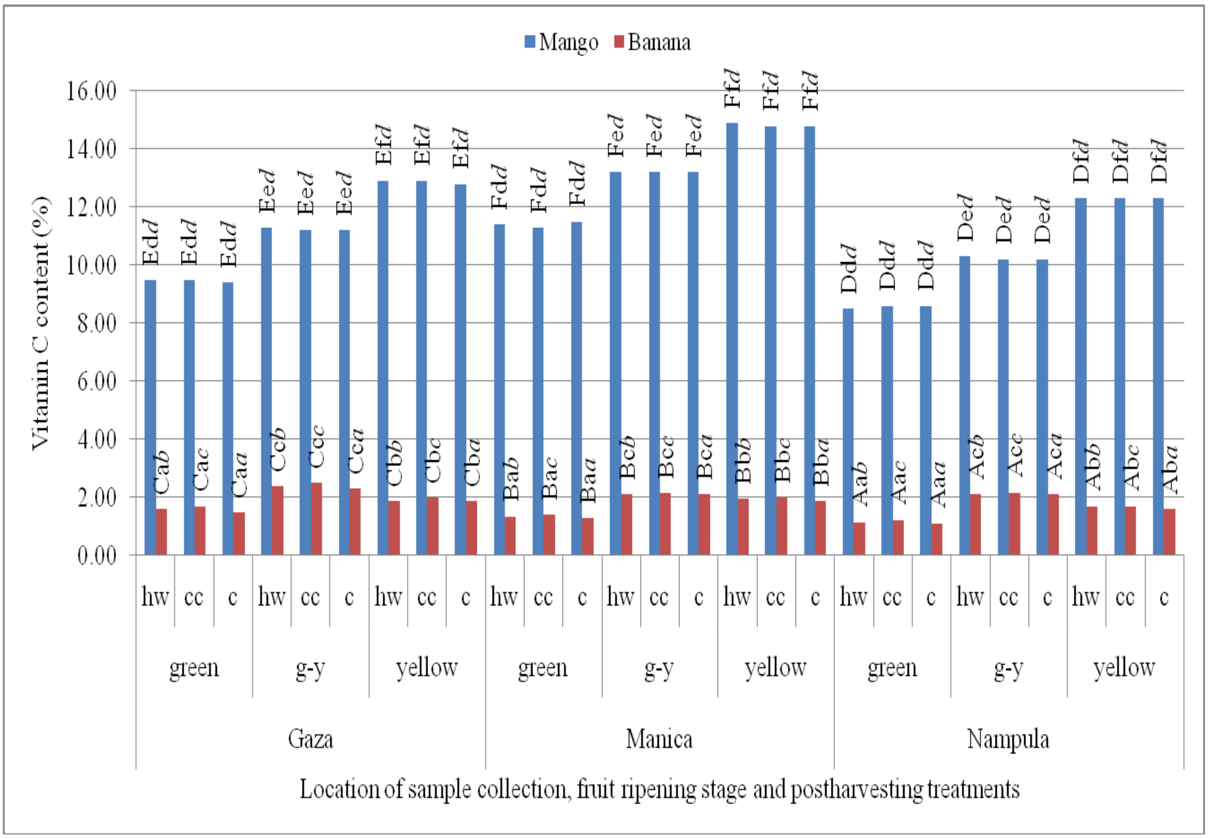

Figure 18. The vitamin C content of Keitt mangoes and Cavendish banana fruits from different regions at different maturity stage subjected to different treatment

Bars followed by the same capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same small letters are not significantly different between fruit ripening stages and italic letter are not significantly different between the postharvest treatments. Where *a*, *b* and *c* for banana and *d*, *e* and *f* for mango fruits. (hw – hot water, cc – calcium chloride and c – control).

For Cavendish banana fruits, it can be observed in Figure 18, that low vitamin C content values were obtained in untreated green fruits (vitamin C content = 1.10 %) collected in Nampula and high values were obtained in green-yellow fruits (vitamin C content = 2.50 %) from Gaza. The results indicated that banana vitamin C content were varying depending on location of fruit collection and statistic differences ($p < 0.05$) were found on banana fruits from all locations of sample collection. Banana vitamin C content was, also, statistically affected ($p < 0.05$) by fruit ripening stage showing high vitamin C content on green-yellow fruits than other ripening stages. Differently with mango fruits, Cavendish banana fruits were statistically influenced by hot water dipping or calcium chloride treatment, showing calcium chloride treatment presenting better vitamin C content.

Anwar & Malik (2007) assessing the effect of hot water treatment on ripening quality and storage life of mango (*Mangifera indica* L.) obtained high values of vitamin C (47.06 mg/100g – 65.54 mg/100) than reported in this work, but as the hot water temperature increased ascorbic acid content is maintained. Amin & Hossain (2013) assessing the reduction of postharvest loss and prolong the shelf -life of banana through hot water treatment reported gradual decrease in all the varieties as they proceeded towards ripening and senescence. In these work, untreated fruits vitamin C content was higher than those of the treated bananas throughout the ripening stages and associated the reduction in vitamin C content during ripening to the oxidation of ascorbic acid as the fruit ripen.

4.3.6 Effect of hot water and calcium chloride on the fruit sensory parameter

The sensory attributes associated with the functional properties of fruit products are important aspects to be considered for the consumer acceptance. In this work, the sensory attributes of Cavendish banana and Keitt mango fruits collected from different regions of Mozambique assessed by 52 panelists as six samples prepared according to the fruit ripening stage and postharvest treatment undergone are presented in Table 8a and 8b, respectively.

Ripened banana fruit showed that fruit pulp flavour preferred by the panelists, ranked maximum score for yellow fruit immersed in calcium chloride (sample E scored 3.86) from Manica that was more sweet-smelling and attractive as compared to untreated fruits (Table 8a). Therefore, bananas flavour was varying depending on location of fruit collection and statistic differences ($p < 0.05$) were found on bananas from Manica than others regions. The banana fruits flavour were, also, statistically affected ($p < 0.05$) by postharvest treatment stage showing that treated samples were better scored than untreated and samples on calcium chloride presented the best flavour.

The sensory qualities evaluated on ripening banana fruit showed that fruit pulp sweetness preferred by the panelists, ranked maximum score for yellow fruit immersed in hot water (sample D scored 4.61) from Manica that was sweeter as compared to untreated fruits. This banana sensory characteristic was varying depending on location of fruit collection and statistic differences ($p < 0.05$) were found on bananas from Manica than others regions. Even in Manica the banana fruits sweeteness was, also, statistically affected ($p < 0.05$) by postharvest treatment stage showing that treated samples better scored than untreated and samples on hot water presented the best sweetness.

Table 8a. Sensory parameters of Cavendish banana fruits from different regions at different maturity stage subjected to different treatments

Location	Sample	Flavour	Sweetness	Astringency	Overall acceptance
Gaza	A	3.17^{Ab}	3.40^{Aa}	2.05^{Aa}	3.56^{Aa}
	B	3.27^{Aab}	3.27^{Aa}	2.13^{Aa}	3.50^{Aa}
	C	2.83^{Aa}	2.94^{Aa}	2.38^{Aa}	3.40^{Aa}
	D	2.83^{Aa}	2.96^{Aa}	2.07^{Aa}	3.55^{Aa}
	E	3.15^{Aab}	2.79^{Aa}	2.12^{Aa}	3.32^{Aa}
	F	3.12^{Aab}	2.02^{Aa}	2.24^{Aa}	3.42^{Aa}
Manica	A	3.73^{Bb}	4.52^{Bb}	1.75^{Aa}	4.83^{Ab}
	B	3.83^{Bb}	4.45^{Bb}	1.62^{Aa}	4.52^{Ab}
	C	3.06^{Ba}	3.98^{Ba}	2.08^{Aa}	3.71^{Aa}
	D	3.66^{Bb}	4.61^{Bb}	1.83^{Aa}	4.78^{Ab}
	E	3.86^{Bb}	4.54^{Bb}	1.65^{Aa}	4.58^{Ab}
	F	3.12^{Ba}	3.50^{Ba}	1.52^{Aa}	3.54^{Aa}
Nampula	A	2.92^{Aa}	3.90^{Aa}	2.00^{Aa}	3.67^{Aa}
	B	3.02^{Aa}	3.52^{Aa}	2.07^{Aa}	3.48^{Aa}
	C	3.27^{Aa}	3.04^{Aa}	2.46^{Aa}	3.31^{Aa}
	D	3.07^{Aa}	3.87^{Aa}	2.11^{Aa}	3.60^{Aa}
	E	3.36^{Aa}	3.71^{Aa}	2.23^{Aa}	3.25^{Aa}
	F	2.88^{Aa}	2.79^{Aa}	2.12^{Aa}	3.42^{Aa}

Where: A – green-yellow fruit immersed in hot water, B – green-yellow fruit immersed in calcium treatment, C – green-yellow without treatment, D – yellow fruit immersed in hot water, E – yellow fruit immersed in calcium chloride, F – yellow fruit without treatment. Each column and for the same location of sample collection, means followed by the same script capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same lower case is not significantly different between samples.

Flavour and taste of the mango fruits is an important quality parameter (Anjum & Ali, 2004). The organoleptic quality evaluation of ripened mango fruit showed that fruit pulp flavour preferred by the 52 panelists, ranked maximum score for green-yellow fruit immersed in calcium chloride (sample B scored 3.87) from Nampula that was more sweet-smelling and attractive as compared to hot water treated and untreated fruits (Table 8b). The results showed that mangoes flavour was varying depending on location of fruit collection and statistic differences ($p < 0.05$) were found on mangoes from Nampula than others regions. Mangoes flavour were, also, statistically affected ($p < 0.05$) by postharvest treatment stage showing that treated samples were better scored than untreated and samples on calcium chloride presented the best flavour.

Table 8b. Sensory parameters of Keitt mangoes fruits from different regions at different maturity stage subjected to different treatments

Location	Sample	Flavour	Sweetness	Astringency	Overall acceptance
Gaza	A	3.68^{De}	3.52^{De}	3.35^{Ed}	3.50^{Dd}
	B	3.73^{De}	3.29^{Dde}	3.23^{Ed}	3.56^{Dd}
	C	3.56^{Dd}	2.96^{Dde}	3.38^{Ed}	3.65^{Dd}
	D	3.66^{De}	3.02^{Dde}	3.19^{Ed}	3.12^{Dd}
	E	3.78^{De}	2.77^{Dd}	3.24^{Ed}	3.40^{Dd}
	F	3.12^{Dd}	2.98^{Dde}	3.34^{Ed}	3.52^{Dd}
Manica	A	2.94^{Dd}	3.12^{Dd}	2.09^{Dd}	3.48^{Dd}
	B	3.02^{Dd}	2.90^{Dd}	2.07^{Dd}	3.67^{Dd}
	C	3.19^{Dd}	3.04^{Dd}	2.16^{Dd}	3.31^{Dd}
	D	3.03^{Dd}	3.40^{Dd}	2.11^{Dd}	3.25^{Dd}
	E	3.04^{Dd}	3.31^{Dd}	2.03^{Dd}	3.60^{Dd}
	F	2.87^{Dd}	2.79^{Dd}	2.29^{Dd}	3.42^{Dd}
Nampula	A	3.55^{Ee}	4.52^{Ee}	2.17^{Dd}	4.56^{De}
	B	3.87^{Ee}	4.55^{Ee}	1.63^{Dd}	4.83^{De}
	C	2.83^{Ed}	3.15^{Ed}	1.46^{Dd}	3.71^{Dd}
	D	3.79^{Ee}	3.71^{Ee}	2.11^{Dd}	3.73^{Dd}
	E	3.85^{Ee}	4.64^{Ee}	2.06^{Dd}	4.78^{De}
	F	3.02^{Ed}	3.00^{Ed}	2.49^{Dd}	3.54^{Dd}

Where: A – green-yellow fruit immersed in hot water, B – green-yellow fruit immersed in calcium treatment, C – green-yellow without treatment, D – yellow fruit immersed in hot water, E – yellow fruit immersed in calcium chloride, F – yellow fruit without treatment. Each column and for the same location of sample collection, means followed by the same script capital letter are not significantly different ($p < 0.05$) by Tukey test between the location of sample collection. In a similar way, the same lower case is not significantly different between samples.

Highest mango fruit sweetness score where found for yellow fruit immersed in calcium chloride (sample E scored 4.64) from Nampula that presented very good sweetness as compared to hot water treated and untreated fruits. Mangoes sweetness was varying depending on location of fruit collection and statistic differences ($p < 0.05$) were found on mangoes from Nampula than others regions. Mangoes sweetness were, also, statistically affected by postharvest treatment stage showing that treated samples better scored than untreated and samples on calcium chloride presented the best sweetness sensory parameter.

Changes in fruit astringency seemed not to be influenced by hot water dipping and calcium treatment because non-significant differences were recorded regarding this sensory parameter ($p < 0.05$) for both fruits. Mango astringency was just varying depending on location of fruit collection and statistic differences ($p < 0.05$) were found on mangoes from Gaza than others regions. Mango fruit showed, also, that fruit pulp astringency ranked maximum score for untreated green-yellow fruit (sample C scored 3.38) from Gaza that was more astringency.

For banana fruit, pulp astringency preferred by the panelists, ranked maximum score for untreated green-yellow (sample C scored 2.46) from Nampula but was not statistically different compared to other samples showing that fruit astringency is not dependant postharvest treatment.

The overall samples acceptance of ripened mango fruit showed that the panelists preferred, with very high acceptability (4.83 score). The green-yellow fruit immersed in calcium chloride (sample B) from Nampula that was more attractive as compared to untreated samples but was not statistically different with hot water treated fruit samples. The results showed that mangoes overall acceptance was not statistically ($p < 0.05$) varying depending on location of fruit collection.

For banana fruit, overall acceptance preferred by the panelists, ranked maximum score for green-yellow (sample A scored 4.83) from Manica but was not statistically different compared to calcium treated samples showing that fruit postharvest treated bananas improve their overall acceptance by the consumer independently of the Mozambique locations of sample collection.

Some literatures reported that a slow decrease in acidity, with increased total soluble solids and total sugar content is an intrinsic process during ripening of fruits to impart the sensory attributes (Maureen *et al.*, 2016). Anjum & Ali (2004) assessing the effect of various calcium salts on ripening of mango fruits reported that treatments of the fruits with the all the three calcium salts resulted in reduced flavour and taste, contrarily with this work where the treated samples were more preferred. This happened, because were used the optimum calcium chloride concentration that resulted in better flavour and taste of the fruit than untreated.

Mahmud *et al*. (2015), assessing the effects of CaC_2 and different calcium salt on mango fruits ripening in Bangladesh reported that as all the fruits were treated in different concentration of the CaC_2 and all calcium salts, but was clear that in all the concentration, the flavour and taste of the fruits were also reduced similarly, contrarily with this work because there were using high concentration of salts (0 – 10%).

Baloch & Bibi (2012) assessing the effect of harvesting and storage conditions on the post harvest quality and shelf life of mango (*Mangifera indica* L.) fruit reported that the organoleptic characteristics were lowest for 20 °C and highest for 40 °C storage temperature. This trend was attributed to the fact that the ripening of mango fruit is characterized by loss of firmness due to cell wall digestion by pectinesterase, polygalacturonase, and other enzymes and this process was increased by the increase in storage temperature.

4.4 Effect of hot water dipping and calcium treatment on the shelf life of banana and mango fruits

4.4.1 Effect of hot water and calcium chloride and storage conditions on the moisture of Keitt mango and Cavendish banana fruits from Mozambique

The moisture of Cavendish bananas and Keitt mangoes collected in different regions of Mozambique is presented in Table 9a nd 9b, respectively. In these tables, moisture of the banana and mango fruits pulp decreased till the fruit was inedible throughout the experimental period. Moisture content of mango and banana fruits showed no significant differences ($p < 0.05$) from different regions where high moisture values were reported being 92.88 % and 82.25 %, in fruits from Manica and Nampula, respectively.

For all banana fruit samples collected in different regions of the country (Table 9a), moisture content was not affected by postharvest treatment but, by storage conditions showing refrigerator conditions presenting low values and samples better kept than freezing and room temperature conditions and statistical differences ($p < 0.05$) were found from the fourth day of samples storage.

Mangoes samples moisture content (Table 9b) was affected by storage conditions showing room temperature conditions presenting low values and samples better kept than others storage conditions and statistical differences ($p < 0.05$) were found from the fourth day of fruit storage.

Amin & Hossain (2013) assessing the reduction of postharvest loss and prolong the shelf -life of banana through hot water treatment reported that weight loss of these treatments increased gradually in all the varieties as they proceeded towards ripening and senescence. Since weight loss is inversely proportional to the weight of the samples the reported data are in accordance with this work. It occurred owing to refrigerator conditions treatment that caused the acceleration of evaporation rate from the fruit surface.

Table 9a: Fruit moisture of Cavendish bananas from different regions of Mozambique

Fruit native	Postharvest treatment	Storage conditions	Banana fruits storage days 0	4	8	12	16	20
Gaza	cc	freez	79.27^{Ddd}	77.12^{Ddd}	74.67^{Ddd}	74.17^{Ddd}	72.56^{Ddd}	NA
Gaza	cc	refrig	77.81^{Ddd}	75.32^{Dde}	73.28^{Dde}	73.17^{Dde}	71.17^{Dde}	69.98^{Dde}
Gaza	cc	rt	78.34^{Ddd}	76.19^{Ddd}	73.74^{Ddd}	73.24^{Ddd}	71.63^{Ddd}	NA
Gaza	hw	freez	77.88^{Ddd}	76.73^{Ddd}	74.12^{Ddd}	72.39^{Ddd}	NA	-
Gaza	hw	refrig	76.95^{Ddd}	71.80^{Dde}	69.35^{Dde}	68.85^{Dde}	67.24^{Dde}	NA
Gaza	hw	rt	75.80^{Ddd}	73.65^{Ddd}	71.20^{Ddd}	70.70^{Ddd}	NA	-
Gaza	control	freez	78.11^{Ddd}	75.96^{Ddd}	73.51^{Ddd}	73.01^{Ddd}	NA	-
Gaza	control	refrig	69.56^{Ddd}	67.41^{Dde}	64.96^{Dde}	64.46^{Dde}	62.85^{Dde}	NA
Gaza	control	rt	77.42^{Ddd}	75.27^{Ddd}	72.82^{Ddd}	NA	-	-
Manica	cc	freez	81.58^{Ddd}	79.43^{Ddd}	76.98^{Ddd}	76.48^{Ddd}	74.87^{Ddd}	73.68^{Ddd}
Manica	cc	refrig	79.65^{Ddd}	75.50^{Dde}	73.05^{Dde}	72.55^{Dde}	70.94^{Dde}	69.75^{Dde}
Manica	cc	rt	77.13^{Ddd}	78.89^{Ddd}	75.14^{Ddd}	76.76^{Ddd}	74.19^{Ddd}	71.14^{Ddd}
Manica	hw	freez	78.63^{Ddd}	76.41^{Ddd}	74.10^{Ddd}	73.28^{Ddd}	71.00^{Ddd}	NA
Manica	hw	refrig	74.41^{Ddd}	72.26^{Dde}	69.81^{Dde}	69.31^{Dde}	67.70^{Dde}	NA
Manica	hw	rt	76.16^{Ddd}	74.41^{Ddd}	70.25^{Ddd}	72.32^{Ddd}	70.71^{Ddd}	NA
Manica	control	freez	73.50^{Ddd}	77.35^{Ddd}	74.90^{Ddd}	74.40^{Ddd}	72.79^{Ddd}	NA
Manica	control	refrig	79.49^{Ddd}	71.34^{Dde}	68.89^{Dde}	68.39^{Dde}	66.78^{Dde}	NA
Manica	control	rt	78.34^{Ddd}	76.19^{Ddd}	73.74^{Ddd}	73.24^{Ddd}	NA	-
Nampula	cc	freez	82.25^{Ddd}	80.01^{Ddd}	75.76^{Ddd}	75.06^{Ddd}	74.22^{Ddd}	73.89^{Ddd}
Nampula	cc	refrig	80.65^{Ddd}	78.50^{Dde}	76.05^{Dde}	75.55^{Dde}	73.94^{Dde}	72.75^{Dde}
Nampula	cc	rt	79.73^{Ddd}	77.58^{Ddd}	75.13^{Ddd}	74.63^{Ddd}	73.02^{Ddd}	NA
Nampula	hw	freez	74.14^{Ddd}	71.17^{Ddd}	69.38^{Ddd}	68.11^{Ddd}	69.68^{Ddd}	NA
Nampula	hw	refrig	77.19^{Ddd}	75.04^{Dde}	72.59^{Dde}	72.09^{Dde}	70.48^{Dde}	69.29^{Dde}
Nampula	hw	rt	77.73^{Ddd}	74.91^{Ddd}	72.12^{Ddd}	72.78^{Ddd}	72.45^{Ddd}	NA
Nampula	control	freez	78.57^{Ddd}	76.42^{Ddd}	73.97^{Ddd}	73.47^{Ddd}	71.86^{Ddd}	NA
Nampula	control	refrig	73.88^{Ddd}	73.73^{Dde}	70.28^{Dde}	69.78^{Dde}	68.17^{Dde}	NA
Nampula	control	rt	74.03^{Ddd}	70.88^{Ddd}	68.43^{Ddd}	67.93^{Ddd}	66.32^{Ddd}	NA
		σ	1.75	1.79	1.97	2.03	1.83	2.01
		CV	6.96	7.44	8.4	8.88	8.39	7.25

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refri - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA - fruit sample not acceptable to be eaten. σ - Standard deviation. CV- coefficient of variation.

Table 9b: Fruit moisture of Keitt mangoes from different regions of Mozambique

Fruit native	Postharvest treatment	Storage conditions	Mango fruits storage days 0	4	8	12	16	20
Gaza	cc	freez	89.91^{Aaa}	87.01^{Aaa}	85.31^{Aaa}	84.81^{Aaa}	83.20^{Aaa}	NA
Gaza	cc	refrig	86.67^{Aaa}	83.77^{Aaa}	82.07^{Aaa}	81.57^{Aaa}	79.96^{Aaa}	78.97^{Aaa}
Gaza	cc	rt	85.59^{Aaa}	82.69^{Aab}	80.99^{Aab}	80.49^{Aab}	78.88^{Aab}	NA
Gaza	hw	freez	84.51^{Aaa}	81.61^{Aaa}	79.91^{Aaa}	NA	-	-
Gaza	hw	refrig	83.16^{Aaa}	80.26^{Aaa}	78.56^{Aaa}	78.06^{Aaa}	76.45^{Aaa}	NA
Gaza	hw	rt	81.27^{Aaa}	78.37^{Aab}	76.67^{Aab}	NA	-	-
Gaza	control	freez	90.16^{Aaa}	87.45^{Aaa}	84.10^{Aaa}	NA	-	-
Gaza	control	refrig	83.97^{Aaa}	81.07^{Aaa}	79.37^{Aaa}	78.87^{Aaa}	77.26^{Aaa}	76.27^{Aaa}
Gaza	control	rt	80.46^{Aaa}	78.56^{Aab}	75.86^{Aab}	NA	-	-
Manica	cc	freez	91.26^{Aaa}	88.36^{Aaa}	86.66^{Aaa}	86.16^{Aaa}	84.55^{Aaa}	NA
Manica	cc	refrig	88.56^{Aaa}	85.66^{Aaa}	83.96^{Aaa}	83.46^{Aaa}	81.85^{Aaa}	80.86^{Aaa}
Manica	cc	rt	86.94^{Aaa}	84.04^{Aab}	82.34^{Aab}	81.84^{Aab}	80.23^{Aab}	NA
Manica	hw	freez	86.13^{Aaa}	83.23^{Aaa}	81.53^{Aaa}	81.03^{Aaa}	NA	-
Manica	hw	refrig	80.73^{Aaa}	77.83^{Aaa}	76.13^{Aaa}	75.63^{Aaa}	74.02^{Aaa}	NA
Manica	hw	rt	68.58^{Aaa}	65.68^{Aab}	63.98^{Aab}	63.48^{Aab}	NA	-
Manica	control	freez	92.88^{Aaa}	89.98^{Aaa}	88.28^{Aaa}	87.78^{Aaa}	NA	-
Manica	control	refrig	85.41^{Aaa}	84.89^{Aaa}	81.16^{Aaa}	82.25^{Aaa}	78.92^{Aaa}	NA
Manica	control	rt	88.56^{Aaa}	85.66^{Aab}	83.96^{Aab}	NA	-	-
Nampula	cc	freez	91.77^{Aaa}	91.87^{Aaa}	90.17^{Aaa}	89.67^{Aaa}	88.06^{Aaa}	87.07^{Aaa}
Nampula	cc	refrig	90.80^{Aaa}	88.90^{Aaa}	87.20^{Aaa}	86.70^{Aaa}	85.09^{Aaa}	84.10^{Aaa}
Nampula	cc	rt	89.64^{Aaa}	86.74^{Aab}	85.04^{Aab}	84.54^{Aab}	82.93^{Aab}	NA
Nampula	hw	freez	90.45^{Aaa}	87.98^{Aaa}	84.63^{Aaa}	85.76^{Aaa}	85.16^{Aaa}	NA
Nampula	hw	refrig	88.29^{Aaa}	85.39^{Aaa}	83.69^{Aaa}	83.19^{Aaa}	81.58^{Aaa}	NA
Nampula	hw	rt	87.75^{Aaa}	84.85^{Aab}	83.15^{Aab}	82.65^{Aab}	NA	-
Nampula	control	freez	88.83^{Aaa}	85.93^{Aaa}	84.23^{Aaa}	83.73^{Aaa}	NA	-
Nampula	control	refrig	87.21^{Aaa}	83.31^{Aaa}	82.61^{Aaa}	82.11^{Aaa}	80.50^{Aaa}	NA
Nampula	control	rt	84.24^{Aaa}	81.34^{Aab}	79.64^{Aab}	NA	-	-
		σ	1.45	1.23	1.36	1.28	1.17	1.79
		CV	5.64	4.71	5.32	4.55	4.72	4.83

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refri - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA - fruit sample not acceptable to be eaten. σ - Standard deviation. CV- coefficient of variation.

4.4.2 Effect of hot water and calcium chloride and storage conditions on the firmness of mango and banana fruits

The firmness of Keitt mangoes and Cavendish bananas collected in different regions of Mozambique is presented in Table 10a and 10b, respectively. The firmness of their peel was decreasing directly from the start of measurement until when the fresh product could not be eaten or visually was broken.

Therefore, for all samples collected in different regions of the country, slight loss of firmness was recorded in samples submitted to calcium chloride treatment. However, the refrigeration conditions kept samples firmer than other storage conditions. Statistically significant differences ($p < 0.05$) were found on fourth and eighth days of banana storage and no statistical differences for mango fruits. Furthermore, low temperature of the storage conditions kept the firmness of the peel of fresh fruits products longer than higher temperatures.

According to Baloch & Bibi (2012) physiological aspects of fruit peel softening occur naturally due to decrease of pectin content in the fruit. The desired effect of calcium infiltration on maintaining fruit firmness may be due to the calcium binding to free carboxyl groups of polygalacturonate polymer, stabilizing and strengthening the cell walls.

Amin & Hossain (2013) reported that fruit firmness decreased with storage at a faster rate in the untreated fruits than hot water treated fruit. Higher firmness of fruit was found in *Sabri Kola* than that of *BARI Kola 1* banana varieties. This was associated with the change in cell wall component and starch degradation. Similar fruit peel firmness behaviour was reported by Kulkarni *et al*. (2011) studying the physico-chemical changes during artificial ripening of banana (*Musa sp*) variety ‘Robusta’. It was reported that the texture of fruits decreased at a faster rate in treated fruits with increase in ethephon concentration. The texture degradation was associated with the breakdown of insoluble protopectin into soluble pectin or by cellular disintegration leading to membrane permeability.

The current results confirm the earlier findings of Jha *et al.* (2013) who observed that the peel firmness of mango cultivars varied decreasingly from initial level of 13.4–27.1 N to 3.9–24.5 N during ripening period of 10 days. Similarly, Ezz & Awad (2011) reported that increasing storage temperatures from 8 to 13 °C significantly decreased the firmness of mango fruits. However, no significant differences were found, except between fruits treated with potassium permanganate compared to those treated with hot water and those of the control.

The current results are also in agreement with those by Anwar & Malik (2007) on mango (*Mangifera indica* L.), Mahmud *et al.* (2008) on papaya (*Carica Papaya* L.) and Karakurt & Toka (2015) on mushrooms who reported similar trends.

Table 10a: Fruit firmness of Cavendish bananas from different regions of Mozambique

Fruit native	Postharvest treatment	Storage conditions	Banana fruits storage days					
			0	4	8	12	16	20
Gaza	cc	freez	13.50^{Ddd}	11.00^{Ded}	11.00^{Ded}	9.00^{Ddd}	8.00^{Ddd}	NA
Gaza	cc	refrig	12.50^{Ddd}	11.50^{Dee}	11.00^{Ded}	9.00^{Ddd}	7.50^{Ddd}	7.00^{Ddd}
Gaza	cc	rt	13.00^{Ddd}	11.00^{Ded}	11.00^{Ded}	9.00^{Ddd}	7.00^{Ddd}	NA
Gaza	hw	freez	13.00^{Ddd}	10.00^{Ded}	10.00^{Ded}	8.00^{Ddd}	NA	-
Gaza	hw	refrig	13.00^{Ddd}	10.00^{Ded}	10.00^{Ded}	8.00^{Ddd}	6.00^{Ddd}	NA
Gaza	hw	rt	13.00^{Ddd}	9.00^{Ddd}	9.00^{Ddd}	7.00^{Ddd}	NA	-
Gaza	control	freez	13.50^{Ddd}	7.00^{Ddd}	7.00^{Ddd}	5.00^{Ddd}	NA	-
Gaza	control	refrig	14.00^{Ddd}	9.00^{Ddd}	9.00^{Ddd}	8.00^{Ddd}	6.00^{Ddd}	NA
Gaza	control	rt	13.50^{Ddd}	8.00^{Ddd}	8.00^{Ddd}	NA	-	-
Manica	cc	freez	12.50^{Ddd}	10.50^{Ded}	10.50^{Ded}	9.50^{Ddd}	8.00^{Ddd}	8.00^{Ddd}
Manica	cc	refrig	13.50^{Ddd}	11.50^{Dee}	11.50^{Dee}	9.50^{Ddd}	7.50^{Ddd}	6.50^{Ddd}
Manica	cc	rt	13.00^{Ddd}	11.00^{Ded}	11.00^{Ded}	9.00^{Ddd}	7.00^{Ddd}	7.00^{Ddd}
Manica	hw	freez	14.00^{Ddd}	12.50^{Dee}	10.50^{Ded}	8.50^{Ddd}	7.00^{Ddd}	NA
Manica	hw	refrig	14.20^{Ddd}	10.20^{Ded}	11.20^{Ded}	10.20^{Ded}	7.20^{Ddd}	NA
Manica	hw	rt	13.00^{Ddd}	11.00^{Ded}	11.00^{Ded}	9.00^{Ddd}	7.00^{Ddd}	NA
Manica	control	freez	14.00^{Ddd}	9.00^{Ddd}	8.50^{Ddd}	7.00^{Ddd}	6.00^{Ddd}	NA
Manica	control	refrig	14.00^{Ddd}	9.00^{Ddd}	8.50^{Ddd}	7.00^{Ddd}	6.50^{Ddd}	NA
Manica	control	rt	13.00^{Ddd}	9.00^{Ddd}	8.50^{Ddd}	7.00^{Ddd}	NA	-
Nampula	cc	freez	13.00^{Ddd}	12.00^{Dee}	12.00^{Dee}	10.00^{Ded}	8.00^{Ddd}	6.00^{Ddd}
Nampula	cc	refrig	14.00^{Ddd}	12.00^{Dee}	12.00^{Dee}	10.00^{Ded}	8.00^{Ddd}	7.50^{Ddd}
Nampula	cc	rt	13.00^{Ddd}	12.00^{Dee}	12.00^{Dee}	10.00^{Ded}	8.00^{Ddd}	NA
Nampula	hw	freez	12.80^{Ddd}	9.50^{Ddd}	9.50^{Ddd}	7.50^{Ddd}	6.00^{Ddd}	NA
Nampula	hw	refrig	12.00^{Ddd}	9.00^{Ddd}	9.00^{Ddd}	7.00^{Ddd}	7.50^{Ddd}	6.00^{Ddd}
Nampula	hw	rt	12.50^{Ddd}	10.50^{Ded}	10.50^{Ded}	8.50^{Ddd}	6.50^{Ddd}	NA
Nampula	control	freez	12.50^{Ddd}	9.50^{Ddd}	8.50^{Ddd}	8.50^{Ddd}	6.50^{Ddd}	NA
Nampula	control	refrig	14.00^{Ddd}	7.00^{Ddd}	8.50^{Ddd}	8.50^{Ddd}	7.00^{Ddd}	NA
Nampula	control	rt	14.20^{Ddd}	8.50^{Ddd}	8.50^{Ddd}	8.50^{Ddd}	7.00^{Ddd}	NA

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refri - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA – fruit sample not acceptable to be eaten.

Table 10b: Fruit firmness of Keitt mangoes from different regions of Mozambique

Fruit native	Postharvest treatment	Storage conditions	Mango fruits storage days					
			0	4	8	12	16	20
Gaza	cc	freez	8.50^{Aaa}	6.50^{Aba}	6.00^{Aba}	4.00^{Aaa}	3.00^{Aaa}	NA
Gaza	cc	refrig	7.50^{Aaa}	7.00^{Abb}	6.00^{Aba}	4.00^{Aaa}	2.50^{Aaa}	2.00^{Aaa}
Gaza	cc	rt	8.00^{Aaa}	6.00^{Aba}	6.00^{Aba}	4.00^{Aaa}	2.00^{Aaa}	NA
Gaza	hw	freez	8.00^{Aaa}	5.00^{Aba}	5.00^{Aba}	NA	-	-
Gaza	hw	refrig	8.00^{Aaa}	5.00^{Aba}	5.00^{Aba}	3.00^{Aaa}	2.00^{Aaa}	NA
Gaza	hw	rt	8.00^{Aaa}	4.00^{Aaa}	4.00^{Aaa}	NA	-	-
Gaza	control	freez	8.50^{Aaa}	2.00^{Aaa}	2.00^{Aaa}	NA	-	-
Gaza	control	refrig	9.00^{Aaa}	4.00^{Aaa}	4.00^{Aaa}	3.00^{Aaa}	2.00^{Aaa}	2.00^{Aaa}
Gaza	control	rt	8.50^{Aaa}	3.00^{Aaa}	3.00^{Aaa}	NA	-	-
Manica	cc	freez	7.50^{Aaa}	5.50^{Aba}	5.50^{Aba}	4.50^{Aaa}	3.00^{Aaa}	NA
Manica	cc	refrig	8.50^{Aaa}	6.50^{Aba}	6.50^{Aba}	4.50^{Aaa}	2.50^{Aaa}	2.00^{Aaa}
Manica	cc	rt	8.00^{Aaa}	6.00^{Aba}	6.00^{Aba}	4.00^{Aaa}	2.00^{Aaa}	NA
Manica	hw	freez	9.00^{Aaa}	6.50^{Aba}	5.50^{Aba}	3.50^{Aaa}	NA	-
Manica	hw	refrig	9.20^{Aaa}	6.20^{Aba}	6.20^{Aba}	5.20^{Aba}	2.20^{Aaa}	NA
Manica	hw	rt	8.00^{Aaa}	6.00^{Aba}	6.00^{Aba}	4.00^{Aaa}	NA	-
Manica	control	freez	9.00^{Aaa}	4.00^{Aaa}	3.50^{Aaa}	2.00^{Aaa}	NA	-
Manica	control	refrig	9.00^{Aaa}	4.00^{Aaa}	3.50^{Aaa}	2.00^{Aaa}	1.50^{Aaa}	NA
Manica	control	rt	8.00^{Aaa}	4.00^{Aaa}	3.50^{Aaa}	NA	-	-
Nampula	cc	freez	8.00^{Aaa}	7.00^{Abb}	6.30^{Aba}	5.00^{Aba}	3.00^{Aaa}	1.00^{Aaa}
Nampula	cc	refrig	9.00^{Aaa}	7.30^{Abb}	6.30^{Aba}	5.00^{Aba}	3.00^{Aaa}	2.50^{Aaa}
Nampula	cc	rt	8.00^{Aaa}	7.00^{Abb}	6.60^{Aba}	5.00^{Aba}	3.00^{Aaa}	NA
Nampula	hw	freez	7.80^{Aaa}	4.50^{Aaa}	4.50^{Aaa}	2.50^{Aaa}	1.00^{Aaa}	NA
Nampula	hw	refrig	7.00^{Aaa}	4.00^{Aaa}	4.00^{Aaa}	2.00^{Aaa}	2.50^{Aaa}	NA
Nampula	hw	rt	7.50^{Aaa}	5.50^{Aaa}	5.50^{Aba}	3.50^{Aaa}	NA	-
Nampula	control	freez	7.50^{Aaa}	4.50^{Aaa}	3.50^{Aaa}	3.50^{Aaa}	NA	-
Nampula	control	refrig	9.00^{Aaa}	2.00^{Aaa}	3.50^{Aaa}	3.50^{Aaa}	2.00^{Aaa}	NA
Nampula	control	rt	9.20^{Aaa}	3.50^{Aaa}	3.50^{Aaa}	NA	-	-

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refri - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA – fruit sample not acceptable to be eaten.

4.4.3 Effect of hot water and calcium chloride and storage conditions on the total soluble solids of the fruits

The total soluble solids (TSS) presented as ºBrix of Cavendish bananas and Keitt mangoes are presented in Tables 11a and 11b. In this tables, the ºBrix of the banana and mango fruits pulp increased till the fruit was inedible. In the first eight days, for both fruits, there was a significant increase of ºBrix throughout the experimental period.

From Table 11a, banana fruit raw material showed statistical differences between native fruit where samples from Manica presented high ºBrix. High banana fruit ºBrix was also recorded in all treated and untreated samples and kept on room temperature followed by refrigerator conditions. However, significant statistical differences ($p < 0.05$) between postharvest treatments were found on fourth day of banana storage showing hot water dipping presenting high values. Statistical differences ($p < 0.05$) were also found between storage conditions on eighth and twelfth days of banana storage time showing samples kept on room temperature presenting high values.

For mango fruit (Table 11b), high ºBrix was reported in all samples collected in different regions of the country, treated and untreated by the postharvest treatments and kept on refrigerator conditions. Significant statistical differences ($p < 0.05$) between postharvest treatments were found on fourth day of mango fruit storage time showing the control presenting low values. Statistical differences ($p < 0.05$) were also found between storage conditions on fourth day of mango storage time showing samples kept on refrigerator presenting high values.

The increase in TSS mostly in the room temperature conditions can be associated to the conversion of carbohydrates into simple sugars (Kulkarni *et al.*, 2011). This occurs through a complex mechanism during the storage and increases with the increase in temperature. This conversion is also considered to be one of the important indexes of ripening process in mango and other climacteric fruits (Torres *et al.*, 2009; Ezz & Awad, 2011; Amin & Hossain, 2013).

The total soluble solids and skin firmness had good positive correlation. Thus, it can be used as an indicator for the judgment of quality of the fruit, without destroying it. Calcium, also is related in reducing SSC content of fruits due to slowing down respiration and metabolism activity hence, retarding the ripening process (Mahmud *et al.*, 2008). The slower respiration also slows down the synthesis and use of metabolites resulting in lower SSC due to the slower change from carbohydrates to sugars.

Table 11a. Total soluble solids of Cavendish bananas

Fruit native	Posth treat	Stor cond	Banana fruit storage days					
			0	4	8	12	16	20
Gaza	cc	freez	$7.50^{\mathrm{Dd}d}$	$13.00^{\mathrm{Dd}d}$	$21.00^{\mathrm{De}d}$	$23.00^{\mathrm{De}d}$	$25.50^{\mathrm{De}d}$	NA
Gaza	cc	refrig	$10.00^{\mathrm{Dd}d}$	$14.00^{\mathrm{Dd}d}$	$17.00^{\mathrm{De}d}$	$23.00^{\mathrm{De}d}$	$27.00^{\mathrm{De}d}$	$27.50^{\mathrm{De}d}$
Gaza	cc	rt	$8.50^{\mathrm{Dd}d}$	$15.00^{\mathrm{Dd}d}$	$24.00^{\mathrm{De}e}$	$27.00^{\mathrm{De}e}$	$28.50^{\mathrm{De}d}$	NA
Gaza	hw	freez	$9.50^{\mathrm{Dd}d}$	$17.00^{\mathrm{De}d}$	$17.00^{\mathrm{De}d}$	$21.00^{\mathrm{De}d}$	NA	-
Gaza	hw	refrig	$8.00^{\mathrm{Dd}d}$	$19.00^{\mathrm{De}d}$	$19.00^{\mathrm{De}d}$	$19.00^{\mathrm{De}d}$	$17.00^{\mathrm{De}d}$	NA
Gaza	hw	rt	$8.50^{\mathrm{Dd}d}$	$18.00^{\mathrm{De}d}$	$18.00^{\mathrm{De}e}$	$22.00^{\mathrm{De}e}$	NA	-
Gaza	control	freez	$7.50^{\mathrm{Dd}d}$	$12.00^{\mathrm{Dd}d}$	$18.00^{\mathrm{De}d}$	$19.00^{\mathrm{De}d}$	NA	-
Gaza	control	refrig	$8.50^{\mathrm{Dd}d}$	$11.00^{\mathrm{Dd}d}$	$19.00^{\mathrm{De}d}$	$23.00^{\mathrm{De}d}$	$26.00^{\mathrm{De}d}$	NA
Gaza	control	rt	$7.00^{\mathrm{Dd}d}$	$12.00^{\mathrm{Dd}d}$	$22.00^{\mathrm{De}e}$	NA	-	-
Manica	cc	freez	$19.00^{\mathrm{Ed}d}$	$21.00^{\mathrm{De}d}$	$27.00^{\mathrm{De}d}$	$28.00^{\mathrm{De}d}$	$30.50^{\mathrm{De}d}$	$32.00^{\mathrm{De}d}$
Manica	cc	refrig	$17.00^{\mathrm{Ed}d}$	$24.00^{\mathrm{De}d}$	$26.00^{\mathrm{De}d}$	$27.00^{\mathrm{De}d}$	$31.00^{\mathrm{De}d}$	$32.00^{\mathrm{De}d}$
Manica	cc	rt	$17.00^{\mathrm{Ed}d}$	$26.00^{\mathrm{De}d}$	$28.00^{\mathrm{De}e}$	$29.00^{\mathrm{De}e}$	$32.00^{\mathrm{De}d}$	$33.50^{\mathrm{De}d}$
Manica	hw	freez	$15.00^{\mathrm{Ed}d}$	$21.00^{\mathrm{De}d}$	$26.00^{\mathrm{De}d}$	$28.00^{\mathrm{De}d}$	$30.00^{\mathrm{De}d}$	NA
Manica	hw	refrig	$12.00^{\mathrm{Ed}d}$	$17.00^{\mathrm{De}d}$	$21.00^{\mathrm{De}d}$	$27.00^{\mathrm{De}d}$	$29.00^{\mathrm{De}d}$	NA
Manica	hw	rt	$13.00^{\mathrm{Ed}d}$	$22.00^{\mathrm{De}d}$	$27.00^{\mathrm{De}e}$	$29.00^{\mathrm{De}e}$	$30.50^{\mathrm{De}d}$	NA
Manica	control	freez	$12.00^{\mathrm{Ed}d}$	$17.00^{\mathrm{De}d}$	$20.00^{\mathrm{De}d}$	$22.00^{\mathrm{De}d}$	$26.50^{\mathrm{De}d}$	NA
Manica	control	refrig	$11.50^{\mathrm{Ed}d}$	$15.00^{\mathrm{Dd}d}$	$20.00^{\mathrm{De}d}$	$27.00^{\mathrm{De}d}$	$29.00^{\mathrm{De}d}$	NA
Manica	control	rt	$16.00^{\mathrm{Ed}d}$	$20.00^{\mathrm{De}d}$	$25.00^{\mathrm{De}e}$	$29.00^{\mathrm{De}e}$	NA	-
Nampula	cc	freez	$14.00^{\mathrm{Dd}d}$	$19.00^{\mathrm{De}d}$	$23.00^{\mathrm{De}d}$	$26.00^{\mathrm{De}d}$	$29.00^{\mathrm{De}d}$	$32.00^{\mathrm{De}d}$
Nampula	cc	refrig	$13.00^{\mathrm{Dd}d}$	$18.50^{\mathrm{De}d}$	$24.00^{\mathrm{De}d}$	$27.00^{\mathrm{De}d}$	$29.50^{\mathrm{De}d}$	$31.00^{\mathrm{De}d}$
Nampula	cc	rt	$14.00^{\mathrm{Dd}d}$	$21.00^{\mathrm{De}d}$	$26.00^{\mathrm{De}e}$	$27.00^{\mathrm{De}e}$	$30.00^{\mathrm{De}d}$	NA
Nampula	hw	freez	$13.50^{\mathrm{Dd}d}$	$19.50^{\mathrm{De}d}$	$24.50^{\mathrm{De}d}$	$24.50^{\mathrm{De}d}$	$28.50^{\mathrm{De}d}$	NA
Nampula	hw	refrig	$11.50^{\mathrm{Dd}d}$	$20.50^{\mathrm{De}d}$	$19.50^{\mathrm{De}d}$	$24.50^{\mathrm{De}d}$	$27.50^{\mathrm{De}d}$	$31.00^{\mathrm{De}d}$
Nampula	hw	rt	$8.50^{\mathrm{Dd}d}$	$15.50^{\mathrm{Dd}d}$	$25.50^{\mathrm{De}e}$	$25.50^{\mathrm{De}e}$	$29.00^{\mathrm{De}d}$	NA
Nampula	control	freez	$10.50^{\mathrm{Dd}d}$	$15.50^{\mathrm{Dd}d}$	$18.50^{\mathrm{De}d}$	$20.50^{\mathrm{De}d}$	$25.50^{\mathrm{De}d}$	NA
Nampula	control	refrig	$10.00^{\mathrm{Dd}d}$	$13.50^{\mathrm{Dd}d}$	$18.50^{\mathrm{De}d}$	$25.50^{\mathrm{De}d}$	$27.50^{\mathrm{De}d}$	NA
Nampula	control	rt	$12.50^{\mathrm{Dd}d}$	$16.50^{\mathrm{Dd}d}$	$23.50^{\mathrm{De}e}$	$27.50^{\mathrm{De}e}$	$28.50^{\mathrm{De}d}$	NA

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refri - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA – fruit sample not acceptable to be eaten.

Reports on the effects of hot water and calcium chloride for both mango and banana fruits on TSS are scarce. However, Lima *et al.* (2014) reported that TSS tends to be reduced in ripe fruit with longer cold storage periods.

Table 11b. Total soluble solids of Keitt mangoes

Fruit native	Posth treat	Stor cond	Mango fruit storage days					
			0	4	8	12	16	20
Gaza	cc	freez	11.50$^{Aa\mathit{a}}$	17.00$^{Ab\mathit{a}}$	25.00$^{Ab\mathit{a}}$	27.00$^{Ab\mathit{a}}$	29.50$^{Ab\mathit{a}}$	NA
Gaza	cc	refrig	14.00$^{Aa\mathit{a}}$	21.00$^{Ab\mathit{b}}$	21.00$^{Aa\mathit{a}}$	28.90$^{Ab\mathit{a}}$	31.00$^{Ab\mathit{a}}$	31.50$^{Ab\mathit{a}}$
Gaza	cc	rt	12.50$^{Aa\mathit{a}}$	15.00$^{Ab\mathit{a}}$	18.00$^{Ab\mathit{a}}$	21.00$^{Ab\mathit{a}}$	24.50$^{Ab\mathit{a}}$	NA
Gaza	hw	freez	13.50$^{Aa\mathit{a}}$	21.00$^{Ab\mathit{a}}$	21.00$^{Aa\mathit{a}}$	NA	-	-
Gaza	hw	refrig	12.00$^{Aa\mathit{a}}$	23.00$^{Ab\mathit{b}}$	23.00$^{Aa\mathit{a}}$	23.00$^{Ab\mathit{a}}$	21.00$^{Aa\mathit{a}}$	NA
Gaza	hw	rt	10.00$^{Aa\mathit{a}}$	20.00$^{Ab\mathit{a}}$	22.00$^{Aa\mathit{a}}$	NA	-	-
Gaza	control	freez	11.00$^{Aa\mathit{a}}$	16.00$^{Aa\mathit{a}}$	22.00$^{Aa\mathit{a}}$	NA	-	-
Gaza	control	refrig	10.50$^{Aa\mathit{a}}$	15.00$^{Aa\mathit{b}}$	23.00$^{Ab\mathit{a}}$	27.00$^{Ab\mathit{a}}$	30.00$^{Ab\mathit{a}}$	31.00$^{Ab\mathit{a}}$
Gaza	control	rt	11.00$^{Aa\mathit{a}}$	13.50$^{Aa\mathit{a}}$	16.00$^{Ab\mathit{a}}$	NA	-	-
Manica	cc	freez	20.00$^{Ba\mathit{a}}$	23.00$^{Ab\mathit{a}}$	27.00$^{Ab\mathit{a}}$	30.00$^{Ab\mathit{a}}$	32.00$^{Ab\mathit{a}}$	NA
Manica	cc	refrig	17.00$^{Ba\mathit{a}}$	22.50$^{Ab\mathit{b}}$	30.00$^{Ab\mathit{a}}$	31.00$^{Ab\mathit{a}}$	32.50$^{Ab\mathit{a}}$	35.00$^{Ab\mathit{a}}$
Manica	cc	rt	18.00$^{Ba\mathit{a}}$	25.00$^{Ab\mathit{a}}$	29.00$^{Ab\mathit{a}}$	31.50$^{Ab\mathit{a}}$	33.00$^{Ab\mathit{a}}$	NA
Manica	hw	freez	17.50$^{Ba\mathit{a}}$	23.50$^{Ab\mathit{a}}$	28.50$^{Ab\mathit{a}}$	30.50$^{Ab\mathit{a}}$	NA	-
Manica	hw	refrig	15.50$^{Ba\mathit{a}}$	24.50$^{Ab\mathit{b}}$	29.50$^{Ab\mathit{a}}$	30.50$^{Ab\mathit{a}}$	31.50$^{Ab\mathit{a}}$	NA
Manica	hw	rt	12.50$^{Ba\mathit{a}}$	20.50$^{Ab\mathit{a}}$	23.50$^{Ab\mathit{a}}$	29.50$^{Ab\mathit{a}}$	NA	-
Manica	control	freez	14.50$^{Ba\mathit{a}}$	19.50$^{Aa\mathit{a}}$	22.50$^{Aa\mathit{a}}$	24.50$^{Ab\mathit{a}}$	NA	-
Manica	control	refrig	14.00$^{Ba\mathit{a}}$	17.50$^{Aa\mathit{b}}$	25.50$^{Aa\mathit{a}}$	29.50$^{Ab\mathit{a}}$	31.50$^{Ab\mathit{a}}$	NA
Manica	control	rt	16.50$^{Ba\mathit{a}}$	17.50$^{Aa\mathit{a}}$	23.50$^{Ab\mathit{a}}$	NA	-	-
Nampula	cc	freez	23.00$^{Ba\mathit{a}}$	25.00$^{Ab\mathit{a}}$	31.00$^{Ab\mathit{a}}$	32.00$^{Ab\mathit{a}}$	34.50$^{Ab\mathit{a}}$	36.00$^{Ab\mathit{a}}$
Nampula	cc	refrig	21.00$^{Ba\mathit{a}}$	28.00$^{Ab\mathit{b}}$	30.00$^{Ab\mathit{a}}$	31.00$^{Ab\mathit{a}}$	35.00$^{Ab\mathit{a}}$	36.00$^{Ab\mathit{a}}$
Nampula	cc	rt	21.00$^{Ba\mathit{a}}$	25.00$^{Ab\mathit{a}}$	29.00$^{Ab\mathit{a}}$	30.00$^{Ab\mathit{a}}$	32.00$^{Ab\mathit{a}}$	NA
Nampula	hw	freez	19.00$^{Ba\mathit{a}}$	20.00$^{Ab\mathit{a}}$	29.00$^{Ab\mathit{a}}$	32.00$^{Ab\mathit{a}}$	31.00$^{Ab\mathit{a}}$	NA
Nampula	hw	refrig	17.00$^{Ba\mathit{a}}$	22.50$^{Ab\mathit{b}}$	29.00$^{Ab\mathit{a}}$	32.00$^{Ab\mathit{a}}$	33.00$^{Ab\mathit{a}}$	NA
Nampula	hw	rt	16.00$^{Ba\mathit{a}}$	22.00$^{Ab\mathit{a}}$	29.00$^{Ab\mathit{a}}$	33.00$^{Ab\mathit{a}}$	NA	-
Nampula	control	freez	16.00$^{Ba\mathit{a}}$	15.00$^{Aa\mathit{a}}$	24.00$^{Ab\mathit{a}}$	26.00$^{Ab\mathit{a}}$	NA	-
Nampula	control	refrig	15.50$^{Ba\mathit{a}}$	19.00$^{Aa\mathit{b}}$	25.00$^{Ab\mathit{a}}$	31.00$^{Ab\mathit{a}}$	33.00$^{Ab\mathit{a}}$	NA
Nampula	control	rt	18.00$^{Ba\mathit{a}}$	18.50$^{Aa\mathit{a}}$	23.00$^{Ab\mathit{a}}$	NA	-	-

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refri - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA – fruit sample not acceptable to be eaten.

Ezz & Awad (2011) assessing the effect of some post harvest treatments under different low temperature on two mango cultivars reported that increasing the storage temperature increased the TSS. Fruits treated with hot water and those of control had a significant value compared to those treated with potassium permanganate and those wrapped with shrink film. These researchers reported that cold storage possibly affected starch to sugar conversion, a process that explains most of the soluble solids accumulation in banana.

Kulkarni *et al*. (2011) observed that TSS increased with increase in the concentration of ethephon during ripening and associated with the breakdown of starch into soluble sugars. Similar trends were reported by Amin & Hossain (2013) on banana, Baloch & Bibi (2012) on mango (*Mangifera indica* L.), Anwar & Malik (2007) on mango (*Mangifera indica* L.), Torres *et al*., (2009) on atemoya fruits and Falah *et al*. (2015) on fresh-cut melon (*Cucumis melo* L.) and Papaya (*Carica papaya* L.).

The data obtained in this investigation are similar with those reported by Mohammed & Brecht (2002) on mango, Mahmud *et al.* (2008) on papaya (*Carica papaya* L.) and Araújo *et al*. (2017) on passion fruit where there will be a higher concentration of total soluble solids in the samples either treated nor untreated and kept in room temperature than in those fruits that were kept in controlled temperature for both mangoes and banana total soluble solids assessed.

4.4.4 Effect of hot water and calcium chloride and storage conditions on the titratable acidity of Keitt mango and Cavendish banana fruits from Mozambique

The titratable acidity of Cavendish bananas and Keitt mangoes collected in different regions of Mozambique, submitted to different postharvest treatment and stored in different conditions is presented in Tablea 12a and 12b, respectively. In this tables, the titratable acidity of the banana and mango fruits pulp was increasing directly from the start of measurement until condition the fresh fruit could not be eaten or visually was broken.

For banana fruits (Table 12a), titratable acidity content of the samples showed no significant differences ($p < 0.05$) between location of sample collection, but on postharvest treatment and storage conditions assessed. For all banana samples collected in different regions of the country, fruit titratable acidity was high on samples treated with calcium chloride than other postharvest treatments and statistical differences were seen from the fourth day. And also, high banana titratable acidity was reported on the samples on refrigerator and statistical differences were observed with the fruits kept in the freezer and room temperature storage conditions.

The titratable acidity of mango fruits (Table 12b) showed significant differences ($p < 0.05$) between location of sample collection, postharvest treatment and storage conditions. Therefore, high titratable acidity content was reported on samples from Manica statistically different with other Mozambique regions.

Table 12a. Titratable acidity of Cavendish bananas from different regions of Mozambique

Fruit native	Postharvest treatment	Storage conditions	Banana fruits storage days 0	4	8	12	16	20
Gaza	cc	freez	$0.04^{\mathrm{Dd}d}$	$0.01^{\mathrm{De}d}$	$0.06^{\mathrm{De}d}$	$0.12^{\mathrm{De}d}$	$0.13^{\mathrm{De}d}$	NA
Gaza	cc	refrig	$0.07^{\mathrm{Dd}d}$	$0.05^{\mathrm{De}e}$	$0.11^{\mathrm{De}e}$	$0.15^{\mathrm{De}e}$	$0.18^{\mathrm{De}e}$	$0.18^{\mathrm{De}e}$
Gaza	cc	rt	$0.07^{\mathrm{Dd}d}$	$0.04^{\mathrm{De}d}$	$0.10^{\mathrm{De}d}$	$0.15^{\mathrm{De}d}$	$0.17^{\mathrm{De}d}$	NA
Gaza	hw	freez	$0.03^{\mathrm{Dd}d}$	$0.02^{\mathrm{Dd}d}$	$0.05^{\mathrm{Dd}d}$	$0.11^{\mathrm{Dd}d}$	NA	-
Gaza	hw	refrig	$0.08^{\mathrm{Dd}d}$	$0.05^{\mathrm{Dd}e}$	$0.13^{\mathrm{Dd}e}$	$0.16^{\mathrm{Dd}e}$	$0.17^{\mathrm{Dd}e}$	-
Gaza	hw	rt	$0.07^{\mathrm{Dd}d}$	$0.03^{\mathrm{Dd}d}$	$0.09^{\mathrm{Dd}d}$	$0.09^{\mathrm{Dd}d}$	NA	-
Gaza	control	freez	$0.05^{\mathrm{Dd}d}$	$0.04^{\mathrm{Dd}d}$	$0.07^{\mathrm{Dd}d}$	$0.11^{\mathrm{Dd}d}$	NA	-
Gaza	control	refrig	$0.04^{\mathrm{Dd}d}$	$0.09^{\mathrm{Dd}e}$	$0.14^{\mathrm{Dd}e}$	$0.14^{\mathrm{Dd}e}$	$0.14^{\mathrm{Dd}e}$	NA
Gaza	control	rt	$0.10^{\mathrm{Dd}d}$	$0.07^{\mathrm{Dd}d}$	$0.13^{\mathrm{Dd}d}$	NA	-	-
Manica	cc	freez	$0.02^{\mathrm{Dd}d}$	$0.04^{\mathrm{De}d}$	$0.05^{\mathrm{De}d}$	$0.10^{\mathrm{De}d}$	$0.15^{\mathrm{De}d}$	$0.16^{\mathrm{De}d}$
Manica	cc	refrig	$0.08^{\mathrm{Dd}d}$	$0.13^{\mathrm{De}e}$	$0.15^{\mathrm{De}e}$	$0.19^{\mathrm{De}e}$	$0.18^{\mathrm{De}e}$	$0.19^{\mathrm{De}e}$
Manica	cc	rt	$0.15^{\mathrm{Dd}d}$	$0.13^{\mathrm{De}d}$	$0.14^{\mathrm{De}d}$	$0.13^{\mathrm{De}d}$	$0.15^{\mathrm{De}d}$	$0.16^{\mathrm{De}d}$
Manica	hw	freez	$0.04^{\mathrm{Dd}d}$	$0.05^{\mathrm{Dd}d}$	$0.07^{\mathrm{Dd}d}$	$0.11^{\mathrm{Dd}d}$	$0.16^{\mathrm{Dd}d}$	NA
Manica	hw	refrig	$0.04^{\mathrm{Dd}d}$	$0.04^{\mathrm{Dd}e}$	$0.09^{\mathrm{Dd}e}$	$0.13^{\mathrm{Dd}e}$	$0.14^{\mathrm{Dd}e}$	NA
Manica	hw	rt	$0.04^{\mathrm{Dd}d}$	$0.02^{\mathrm{Dd}d}$	$0.07^{\mathrm{Dd}d}$	$0.12^{\mathrm{Dd}d}$	$0.14^{\mathrm{Dd}d}$	NA
Manica	control	freez	$0.06^{\mathrm{Dd}d}$	$0.05^{\mathrm{Dd}d}$	$0.08^{\mathrm{Dd}d}$	$0.15^{\mathrm{Dd}d}$	$0.15^{\mathrm{Dd}d}$	NA
Manica	control	refrig	$0.04^{\mathrm{Dd}d}$	$0.06^{\mathrm{Dd}e}$	$0.10^{\mathrm{Dd}e}$	$0.13^{\mathrm{Dd}e}$	$0.14^{\mathrm{Dd}e}$	NA
Manica	control	rt	$0.05^{\mathrm{Dd}d}$	$0.04^{\mathrm{Dd}d}$	$0.07^{\mathrm{Dd}d}$	$0.11^{\mathrm{Dd}d}$	NA	-
Nampula	cc	freez	$0.05^{\mathrm{Dd}d}$	$0.03^{\mathrm{De}d}$	$0.08^{\mathrm{De}d}$	$0.13^{\mathrm{De}d}$	$0.15^{\mathrm{De}d}$	$0.16^{\mathrm{De}d}$
Nampula	cc	refrig	$0.09^{\mathrm{Dd}d}$	$0.06^{\mathrm{De}e}$	$0.12^{\mathrm{De}e}$	$0.17^{\mathrm{De}e}$	$0.19^{\mathrm{De}e}$	$0.20^{\mathrm{De}e}$
Nampula	cc	rt	$0.03^{\mathrm{Dd}d}$	$0.02^{\mathrm{De}d}$	$0.06^{\mathrm{De}d}$	$0.10^{\mathrm{De}d}$	$0.11^{\mathrm{De}d}$	NA
Nampula	hw	freez	$0.04^{\mathrm{Dd}d}$	$0.01^{\mathrm{Dd}d}$	$0.07^{\mathrm{Dd}d}$	$0.14^{\mathrm{Dd}d}$	$0.16^{\mathrm{Dd}d}$	NA
Nampula	hw	refrig	$0.04^{\mathrm{Dd}d}$	$0.06^{\mathrm{Dd}e}$	$0.11^{\mathrm{Dd}e}$	$0.16^{\mathrm{Dd}e}$	$0.17^{\mathrm{Dd}e}$	$0.17^{\mathrm{Dd}e}$
Nampula	hw	rt	$0.06^{\mathrm{Dd}d}$	$0.04^{\mathrm{Dd}d}$	$0.09^{\mathrm{Dd}d}$	$0.12^{\mathrm{Dd}d}$	$0.13^{\mathrm{Dd}d}$	NA
Nampula	control	freez	$0.07^{\mathrm{Dd}d}$	$0.05^{\mathrm{Dd}d}$	$0.12^{\mathrm{Dd}d}$	$0.11^{\mathrm{Dd}d}$	$0.12^{\mathrm{Dd}d}$	NA
Nampula	control	refrig	$0.04^{\mathrm{Dd}d}$	$0.05^{\mathrm{Dd}e}$	$0.08^{\mathrm{Dd}e}$	$0.13^{\mathrm{Dd}e}$	$0.14^{\mathrm{Dd}e}$	NA
Nampula	control	rt	$0.04^{\mathrm{Dd}d}$	$0.01^{\mathrm{Dd}d}$	$0.06^{\mathrm{Dd}d}$	$0.12^{\mathrm{Dd}d}$	$0.13^{\mathrm{Dd}d}$	NA
		σ	0.01	0.03	0.01	0.01	0.03	0.02
		CV	12.43	15.11	5.07	6.16	7.12	9.14

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refri - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA - fruit sample not acceptable to be eaten. σ - Standard deviation. CV- coefficient of variation.

Table 12b. Titratable acidity of Keitt mangoes from different regions of Mozambique

Fruit native	Postharvest treatment	Storage conditions	Mango fruits storage days					
			0	4	8	12	16	20
Gaza	cc	freez	$0.12^{\mathrm{Aa}a}$	$0.17^{\mathrm{Ab}a}$	$0.20^{\mathrm{Ab}a}$	$0.21^{\mathrm{Ab}a}$	$0.19^{\mathrm{Ab}a}$	NA
Gaza	cc	refrig	$0.16^{\mathrm{Aa}a}$	$0.19^{\mathrm{Ab}b}$	$0.21^{\mathrm{Ab}b}$	$0.22^{\mathrm{Ab}b}$	$0.23^{\mathrm{Ab}b}$	$0.23^{\mathrm{Ab}b}$
Gaza	cc	rt	$0.20^{\mathrm{Aa}a}$	$0.12^{\mathrm{Ab}ab}$	$0.12^{\mathrm{Ab}ab}$	$0.18^{\mathrm{Ab}ab}$	$0.16^{\mathrm{Ab}ab}$	NA
Gaza	hw	freez	$0.12^{\mathrm{Aa}a}$	$0.16^{\mathrm{Aa}a}$	$0.19^{\mathrm{Aa}a}$	NA	-	-
Gaza	hw	refrig	$0.17^{\mathrm{Aa}a}$	$0.20^{\mathrm{Aa}b}$	$0.21^{\mathrm{Aa}b}$	$0.22^{\mathrm{Aa}b}$	$0.21^{\mathrm{Aa}b}$	NA
Gaza	hw	rt	$0.19^{\mathrm{Aa}a}$	$0.13^{\mathrm{Aa}ab}$	$0.12^{\mathrm{Aa}ab}$	NA	-	-
Gaza	control	freez	$0.12^{\mathrm{Aa}a}$	$0.12^{\mathrm{Aa}a}$	$0.19^{\mathrm{Aa}a}$	NA	-	-
Gaza	control	refrig	$0.17^{\mathrm{Aa}a}$	$0.17^{\mathrm{Aa}b}$	$0.19^{\mathrm{Aa}b}$	$0.21^{\mathrm{Aa}b}$	$0.22^{\mathrm{Aa}b}$	$0.22^{\mathrm{Aa}b}$
Gaza	control	rt	$0.19^{\mathrm{Aa}a}$	$0.14^{\mathrm{Aa}ab}$	$0.21^{\mathrm{Aa}ab}$	NA	-	-
Manica	cc	freez	$0.21^{\mathrm{Ba}a}$	$0.21^{\mathrm{Bb}a}$	$0.21^{\mathrm{Bb}a}$	$0.21^{\mathrm{Bb}a}$	$0.21^{\mathrm{Bb}a}$	NA
Manica	cc	refrig	$0.18^{\mathrm{Ba}a}$	$0.21^{\mathrm{Bb}b}$	$0.22^{\mathrm{Bb}b}$	$0.22^{\mathrm{Bb}b}$	$0.22^{\mathrm{Bb}b}$	$0.18^{\mathrm{Bb}b}$
Manica	cc	rt	$0.21^{\mathrm{Ba}a}$	$0.12^{\mathrm{Bb}ab}$	$0.16^{\mathrm{Bb}ab}$	$0.17^{\mathrm{Bb}ab}$	$0.17^{\mathrm{Bb}ab}$	NA
Manica	hw	freez	$0.23^{\mathrm{Ba}a}$	$0.18^{\mathrm{Ba}a}$	$0.21^{\mathrm{Ba}a}$	$0.12^{\mathrm{Ba}a}$	NA	-
Manica	hw	refrig	$0.19^{\mathrm{Ba}a}$	$0.21^{\mathrm{Ba}b}$	$0.22^{\mathrm{Ba}b}$	$0.17^{\mathrm{Ba}b}$	$0.17^{\mathrm{Ba}b}$	NA
Manica	hw	rt	$0.21^{\mathrm{Ba}a}$	$0.12^{\mathrm{Ba}ab}$	$0.17^{\mathrm{Ba}ab}$	$0.19^{\mathrm{Ba}ab}$	NA	-
Manica	control	freez	$0.21^{\mathrm{Ba}a}$	$0.23^{\mathrm{Ba}a}$	$0.21^{\mathrm{Ba}a}$	$0.21^{\mathrm{Ba}a}$	NA	-
Manica	control	refrig	$0.21^{\mathrm{Ba}a}$	$0.29^{\mathrm{Ba}b}$	$0.24^{\mathrm{Ba}b}$	$0.45^{\mathrm{Ba}b}$	$0.25^{\mathrm{Ba}b}$	NA
Manica	control	rt	$0.21^{\mathrm{Ba}a}$	$0.21^{\mathrm{Ba}ab}$	$0.17^{\mathrm{Ba}ab}$	NA	-	-
Nampula	cc	freez	$0.18^{\mathrm{Aa}a}$	$0.16^{\mathrm{Ab}a}$	$0.18^{\mathrm{Ab}a}$	$0.18^{\mathrm{Ab}a}$	$0.18^{\mathrm{Ab}a}$	$0.19^{\mathrm{Ab}a}$
Nampula	cc	refrig	$0.18^{\mathrm{Aa}a}$	$0.18^{\mathrm{Ab}b}$	$0.21^{\mathrm{Ab}b}$	$0.23^{\mathrm{Ab}b}$	$0.23^{\mathrm{Ab}b}$	$0.21^{\mathrm{Ab}b}$
Nampula	cc	rt	$0.18^{\mathrm{Aa}a}$	$0.21^{\mathrm{Ab}ab}$	$0.18^{\mathrm{Ab}ab}$	$0.19^{\mathrm{Ab}ab}$	$0.19^{\mathrm{Ab}ab}$	NA
Nampula	hw	freez	$0.13^{\mathrm{Aa}a}$	$0.18^{\mathrm{Aa}a}$	$0.18^{\mathrm{Aa}a}$	$0.21^{\mathrm{Aa}a}$	$0.21^{\mathrm{Aa}a}$	NA
Nampula	hw	refrig	$0.16^{\mathrm{Aa}a}$	$0.18^{\mathrm{Aa}b}$	$0.23^{\mathrm{Aa}b}$	$0.21^{\mathrm{Aa}b}$	$0.21^{\mathrm{Aa}b}$	NA
Nampula	hw	rt	$0.18^{\mathrm{Aa}a}$	$0.21^{\mathrm{Aa}ab}$	$0.19^{\mathrm{Aa}ab}$	$0.21^{\mathrm{Aa}ab}$	NA	-
Nampula	control	freez	$0.16^{\mathrm{Aa}a}$	$0.13^{\mathrm{Aa}a}$	$0.18^{\mathrm{Aa}a}$	$0.18^{\mathrm{Aa}a}$	NA	-
Nampula	control	refrig	$0.16^{\mathrm{Aa}a}$	$0.16^{\mathrm{Aa}b}$	$0.21^{\mathrm{Aa}b}$	$0.21^{\mathrm{Aa}b}$	$0.21^{\mathrm{Aa}b}$	NA
Nampula	control	rt	$0.18^{\mathrm{Aa}a}$	$0.18^{\mathrm{Aa}ab}$	$0.21^{\mathrm{Aa}ab}$	NA	-	-
		σ	0.01	0.03	0.01	0.01	0.01	0.02
		CV	11.31	8.91	8.39	7.58	10.11	9.13

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refri - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA - fruit sample not acceptable to be eaten. σ - Standard deviation. CV- coefficient of variation.

Still in Table 12b, calcium chloride presented high titratable acidity content than other postharvest treatments and statistical differences were seen from the fourth day. And also, high titratable acidity content was reported on samples kept on refrigerator and statistical differences were observed with samples from the freezer but not those kept at room temperature.

Ezz & Awad (2011) assessing the effect of some post harvest treatments under different low temperature on two mango cultivars reported that increasing the storage temperature decreased was the acidity, near the values found in this study. Falah *et al*. (2015) assessed the effects of storage conditions on quality and shelf-life of fresh-cut Melon (*Cucumis melo* L.) and Papaya (*Carica papaya* L.). They reported that acidity content slowly increased during storage under different temperature storage conditions until shelf-life of the products expired.

Torres *et al*. (2009) assessing the effects of heat treatment and calcium on postharvest storage of atemoya fruits observed an increase in TTA contents from 0.109 to 0.3765 %, up to 8 days of storage. These authors, discussing these low values, pointed out those differences in organic acid concentrations can be due to a variety of factors, such as: cultivar, climatic conditions, cultivation practices and harvest time.

4.4.5 Effect of hot water and calcium chloride and storage conditions on the ascorbic acid content of the fruits

The ascorbic acid, known as vitamin C content, of Cavendish bananas and Keitt mangoes collected from different regions of Mozambique and subjected to different postharvest treatment and stored in different conditions is presented in Tables 13a and 13b, respectively. In these tables, vitamin C content of their pulp was decreased with storage time until the condition that the fresh product could not be eaten.

For all samples collected from different regions of the country, high banana fruit (Table 13a) vitamin C content was recorded in samples from Manica with statistic differences ($p < 0.05$) with samples from Gaza. Besides, postharvest treatments were not affecting the banana fruit storage but, statistical differences ($p < 0.05$) were found between storage conditions on fourth, eighth and twelfth days of banana storage time showing samples kept on refrigerator presenting high vitamin C content.

Mango samples collected from Nampula (Table 13b) showed high fruit vitamin C content without statistical differences ($p < 0.05$) with samples from Manica. Although, postharvest treatments were not affecting the mango fruit vitamin C content, statistical differences ($p < 0.05$) were found between storage conditions on fourth and eighth days of mango storage time showing samples kept in the room temperature followed by refrigerator conditions presenting high content of vitamin C.

Ascorbic acid is one of the most abundant antioxidants present in fruits (Torres *et al*., 2009). The loss in ascorbic acid content with the progress of storage period could be attributed to rapid conversion of L-ascorbic acid into dihydro-ascorbic acid in the presence of L-ascorbic acid oxidase.

Amin & Hossain (2013) observed that Vitamin C content of these treatments decreased gradually in all the varieties as they proceeded towards ripening and senescence. However, in the untreated fruits, vitamin C content was higher than those of the treated bananas throughout the ripening stages.

Ezz & Awad (2011) assessing the effect of some post harvest treatments under different low temperature on two mango cultivars reported that vitamin C values significantly decreased with increasing storage temperature. The reduction in vitamin C contents during ripening was attributed to the oxidation of ascorbic acid as ripening progressed.

The current results confirmed the earlier findings by Anwar & Malik (2007) assessing the hot water treatment effects on ripening quality and storage life of mango (*Mangifera indica* L.), Baloch & Bibi (2012) evaluating the effect of harvesting and storage conditions on the post harvest quality and shelf life of mango (*Mangifera indica* L.) and Kulkarni *et al*. (2011) studying on physico-chemical changes during artificial ripening of banana (*Musa sp*) variety 'Robusta' fruit. In these reports vitamin C content decreased with the ripening of the fruit or with the increase in storage temperature.

Similar trends were reported by Mahmud *et al.* (2008) assessing different concentrations and applications of calcium on storage life of papaya (*Carica papaya* L.), Torres *et al*. (2009) assessing the heat treatment and calcium on postharvest storage of atemoya fruits and Falah *et al*. (2015) evaluating storage conditions on quality and shelf-life of melon (*Cucumis melo* L.) and papaya (*Carica papaya* L.)

Table 13a. Vitamin C content of Cavendish bananas from different regions of Mozambique

Fruit native	Postharvest treatment	Storage conditions	Banana fruit storage days					
			0	4	8	12	16	20
Gaza	cc	freez	2.70^{Ddd}	2.40^{Ddd}	1.80^{Ddd}	1.50^{Ddd}	1.70^{Ddd}	NA
Gaza	cc	refrig	3.15^{Ddd}	3.10^{Dde}	3.10^{Dde}	3.00^{Dde}	3.00^{Ddd}	2.90^{Ddd}
Gaza	cc	rt	1.50^{Ddd}	1.40^{Ddd}	1.30^{Ddd}	1.10^{Ddd}	1.10^{Ddd}	NA
Gaza	hw	freez	2.40^{Ddd}	2.20^{Ddd}	2.30^{Ddd}	1.60^{Ddd}	NA	-
Gaza	hw	refrig	2.80^{Ddd}	2.70^{Dde}	2.60^{Dde}	2.60^{Dde}	2.50^{Ddd}	NA
Gaza	hw	rt	2.70^{Ddd}	2.60^{Ddd}	2.50^{Ddd}	2.50^{Ddd}	NA	-
Gaza	control	freez	2.10^{Ddd}	1.80^{Ddd}	1.40^{Ddd}	1.50^{Ddd}	NA	-
Gaza	control	refrig	2.90^{Ddd}	2.90^{Dde}	2.80^{Dde}	2.80^{Dde}	2.60^{Ddd}	NA
Gaza	control	rt	1.90^{Ddd}	1.70^{Ddd}	1.50^{Ddd}	NA	-	-
Manica	cc	freez	6.40^{Edd}	6.20^{Edd}	6.50^{DEdd}	5.80^{Ddd}	5.10^{Ddd}	5.10^{Ddd}
Manica	cc	refrig	6.60^{Edd}	6.50^{Ede}	6.50^{DEde}	6.40^{Dde}	6.30^{Ddd}	5.30^{Ddd}
Manica	cc	rt	7.20^{Edd}	7.00^{Edd}	6.90^{DEdd}	6.80^{Ddd}	6.00^{Ddd}	6.10^{Ddd}
Manica	hw	freez	5.70^{Edd}	5.40^{Edd}	4.90^{DEdd}	4.50^{Ddd}	4.50^{Ddd}	NA
Manica	hw	refrig	6.00^{Edd}	5.90^{Ede}	5.90^{DEde}	5.80^{Dde}	5.70^{Ddd}	NA
Manica	hw	rt	6.40^{Edd}	6.20^{Edd}	6.10^{DEdd}	5.80^{Ddd}	5.70^{Ddd}	NA
Manica	control	freez	6.30^{Edd}	6.00^{Edd}	5.40^{DEdd}	5.10^{Ddd}	4.90^{Ddd}	NA
Manica	control	refrig	7.10^{Edd}	7.00^{Ede}	7.00^{DEde}	6.90^{Dde}	6.90^{Ddd}	NA
Manica	control	rt	6.50^{Edd}	6.40^{Edd}	6.60^{DEdd}	5.90^{Ddd}	NA	-
Nampula	cc	freez	4.00^{DEdd}	3.80^{DEdd}	3.50^{DEdd}	3.40^{Ddd}	3.60^{Ddd}	3.40^{Ddd}
Nampula	cc	refrig	4.10^{DEdd}	4.00^{DEde}	4.00^{DEde}	3.90^{Dde}	3.70^{Ddd}	3.60^{Ddd}
Nampula	cc	rt	3.50^{DEdd}	3.30^{DEdd}	3.20^{DEdd}	3.20^{Ddd}	3.10^{Ddd}	NA
Nampula	hw	freez	3.90^{DEdd}	3.50^{DEdd}	3.20^{DEdd}	3.20^{Ddd}	3.10^{Ddd}	NA
Nampula	hw	refrig	4.20^{DEdd}	4.15^{DEde}	4.10^{DEde}	4.10^{Dde}	4.00^{Ddd}	3.90^{Ddd}
Nampula	hw	rt	4.30^{DEdd}	4.10^{DEdd}	4.10^{DEdd}	3.80^{Ddd}	3.70^{Ddd}	NA
Nampula	control	freez	3.70^{DEdd}	3.50^{DEdd}	3.30^{DEdd}	3.20^{Ddd}	3.10^{Ddd}	NA
Nampula	control	refrig	4.00^{DEdd}	3.90^{DEde}	3.90^{DEde}	3.80^{Dde}	3.70^{Ddd}	NA
Nampula	control	rt	4.40^{DEdd}	4.30^{DEdd}	4.20^{DEdd}	4.15^{Ddd}	4.00^{Ddd}	NA

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refri - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA – fruit sample not acceptable to be eaten.

Table 13b. Vitamin C content of Keitt mangoes from different regions of Mozambique

Fruit native	Postharvest treatment	Storage conditions	Mango fruit storage days					
			0	4	8	12	16	20
Gaza	cc	freez	14.70$^{Aa\mathit{a}}$	14.40$^{Aa\mathit{a}}$	13.80$^{Aa\mathit{a}}$	13.50$^{Ba\mathit{a}}$	12.90$^{Ba\mathit{a}}$	NA
Gaza	cc	refrig	13.50$^{Aa\mathit{a}}$	12.40$^{Aa\mathit{a}}$	13.30$^{Aa\mathit{a}}$	13.10$^{Ba\mathit{a}}$	13.10$^{Ba\mathit{a}}$	13.00$^{Ba\mathit{a}}$
Gaza	cc	rt	15.15$^{Aa\mathit{a}}$	15.10$^{Aa\mathit{b}}$	15.10$^{Aa\mathit{b}}$	15.00$^{Ba\mathit{a}}$	15.00$^{Ba\mathit{a}}$	NA
Gaza	hw	freez	14.40$^{Aa\mathit{a}}$	14.20$^{Aa\mathit{a}}$	13.20$^{Aa\mathit{a}}$	NA	-	-
Gaza	hw	refrig	14.70$^{Aa\mathit{a}}$	14.60$^{Aa\mathit{a}}$	14.50$^{Aa\mathit{a}}$	14.50$^{Ba\mathit{a}}$	14.40$^{Ba\mathit{a}}$	NA
Gaza	hw	rt	14.80$^{Aa\mathit{a}}$	14.70$^{Aa\mathit{b}}$	14.60$^{Aa\mathit{b}}$	NA	-	-
Gaza	control	freez	14.10$^{Aa\mathit{a}}$	13.80$^{Aa\mathit{a}}$	13.40$^{Aa\mathit{a}}$	NA	-	-
Gaza	control	refrig	13.90$^{Aa\mathit{a}}$	13.70$^{Aa\mathit{a}}$	13.50$^{Aa\mathit{a}}$	13.20$^{Ba\mathit{a}}$	13.20$^{Ba\mathit{a}}$	8.50$^{Ba\mathit{a}}$
Gaza	control	rt	14.90$^{Aa\mathit{a}}$	14.90$^{Aa\mathit{b}}$	14.80$^{Aa\mathit{b}}$	NA	-	-
Manica	cc	freez	16.00$^{ABa\mathit{a}}$	15.80$^{ABa\mathit{a}}$	15.50$^{ABa\mathit{a}}$	15.40$^{Ba\mathit{a}}$	15.60$^{Ba\mathit{a}}$	NA
Manica	cc	refrig	15.50$^{ABa\mathit{a}}$	14.30$^{ABa\mathit{a}}$	14.20$^{ABa\mathit{a}}$	14.20$^{Ba\mathit{a}}$	15.10$^{Ba\mathit{a}}$	13.70$^{Ba\mathit{a}}$
Manica	cc	rt	16.10$^{ABa\mathit{a}}$	16.00$^{ABa\mathit{b}}$	16.00$^{ABa\mathit{b}}$	15.90$^{Ba\mathit{a}}$	15.70$^{Ba\mathit{a}}$	NA
Manica	hw	freez	15.90$^{ABa\mathit{a}}$	15.50$^{ABa\mathit{a}}$	15.20$^{ABa\mathit{a}}$	15.20$^{Ba\mathit{a}}$	NA	-
Manica	hw	refrig	16.30$^{ABa\mathit{a}}$	16.10$^{ABa\mathit{a}}$	16.10$^{ABa\mathit{a}}$	15.80$^{Ba\mathit{a}}$	15.70$^{Ba\mathit{a}}$	NA
Manica	hw	rt	16.20$^{ABa\mathit{a}}$	16.15$^{ABa\mathit{b}}$	16.10$^{ABa\mathit{b}}$	16.10$^{Ba\mathit{a}}$	NA	-
Manica	control	freez	15.70$^{ABa\mathit{a}}$	15.50$^{ABa\mathit{a}}$	15.30$^{ABa\mathit{a}}$	15.20$^{Ba\mathit{a}}$	NA	-
Manica	control	refrig	16.40$^{ABa\mathit{a}}$	16.30$^{ABa\mathit{a}}$	16.20$^{ABa\mathit{a}}$	16.15$^{Ba\mathit{a}}$	16.00$^{Ba\mathit{a}}$	NA
Manica	control	rt	16.00$^{ABa\mathit{a}}$	15.90$^{ABa\mathit{b}}$	15.90$^{ABa\mathit{b}}$	NA	-	-
Nampula	cc	freez	18.40$^{Ba\mathit{a}}$	18.20$^{Ba\mathit{a}}$	18.50$^{Ba\mathit{a}}$	17.80$^{Ba\mathit{a}}$	17.10$^{Ba\mathit{a}}$	17.10$^{Ba\mathit{a}}$
Nampula	cc	refrig	19.20$^{Ba\mathit{a}}$	18.00$^{Ba\mathit{a}}$	18.90$^{Ba\mathit{a}}$	18.80$^{Ba\mathit{a}}$	18.00$^{Ba\mathit{a}}$	18.10$^{Ba\mathit{a}}$
Nampula	cc	rt	18.60$^{Ba\mathit{a}}$	18.50$^{Ba\mathit{b}}$	18.50$^{Ba\mathit{b}}$	18.40$^{Ba\mathit{a}}$	18.30$^{Ba\mathit{a}}$	NA
Nampula	hw	freez	17.70$^{Ba\mathit{a}}$	17.40$^{Ba\mathit{a}}$	16.90$^{Ba\mathit{a}}$	16.50$^{Ba\mathit{a}}$	16.50$^{Ba\mathit{a}}$	NA
Nampula	hw	refrig	18.40$^{Ba\mathit{a}}$	18.20$^{Ba\mathit{a}}$	18.10$^{Ba\mathit{a}}$	17.80$^{Ba\mathit{a}}$	17.70$^{Ba\mathit{a}}$	NA
Nampula	hw	rt	18.00$^{Ba\mathit{a}}$	17.90$^{Ba\mathit{b}}$	17.90$^{Ba\mathit{b}}$	17.80$^{Ba\mathit{a}}$	NA	-
Nampula	control	freez	18.30$^{Ba\mathit{a}}$	18.00$^{Ba\mathit{a}}$	17.40$^{Ba\mathit{a}}$	17.10$^{Ba\mathit{a}}$	NA	-
Nampula	control	refrig	18.50$^{Ba\mathit{a}}$	18.40$^{Ba\mathit{a}}$	18.60$^{Ba\mathit{a}}$	17.90$^{Ba\mathit{a}}$	17.70$^{Ba\mathit{a}}$	16.00$^{Ba\mathit{a}}$
Nampula	control	rt	19.10$^{Ba\mathit{a}}$	19.00$^{Ba\mathit{b}}$	19.00$^{Ba\mathit{b}}$	NA	-	-

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refri - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA – fruit sample not acceptable to be eaten.

In this work, treated or untreated fruits lost their vitamin C content. Generally, the freezing conditions allowed faster mango and banana vitamin C content loss throughout up to the senescence stages. This can be associated with the reduction in vitamin C content during ripening due to the oxidation of ascorbic acid as the fruit ripened.

4.4.6 Effect of hot water and calcium chloride and storage conditions on the sensory attributes of Keitt mango and Cavendish banana fruits from Mozambique

4.4.6.1 Effect of hot water and calcium chloride and storage conditions on the flavour of Keitt mango and Cavendish banana fruits from Mozambique

In this work, flavour scores of Cavendish bananas and Keitt mangoes from different regions of Mozambique subjected to different treatment and stored in different conditions assessed by 52 panelists are presented in Tables 14a and 14b. In these tables, the flavour of the mango and banana fruits pulp was increasing directly from the start of measurement until condition the fresh fruit could not be eaten or visually was broken.

Although mango fruits from Gaza presented low flavour scores (Table 14b), statistical differences were not reported between fruit native but there were a significant increase of flavour scores for treated and untreated samples showing calcium chloride treatment better scored from the first day of sample assessment until the twelfth day of experiment measurement with statistical differences ($p < 0.05$).

From Table 14a, banana fruits flavour scores of the samples showed no significant differences ($p < 0.05$) between location of sample collection, but on postharvest treatment and storage conditions assessed. Therefore, for all banana samples collected in different regions of the country, fruit flavour scores was high on samples treated with calcium chloride than others postharvest treatments and statistical differences were observed from the fourth day up to sixteenth day.

After treatment, all treated and untreated samples showed increased the flavour scores. Samples kept on refrigerator conditions allowed better preservation and maintained their fresh qualities for both mango and banana fruits, than other storage conditions and statistical differences ($p < 0.05$) were found on fourth day up to the end of the experiment.

Earlier findings by Anwar & Malik (2007) showed that hot water treatment affects ripening quality and storage life of mango (*Mangifera indica* L.). They concluded same remarks where significant differences were observed among storage periods for taste, flavour and aroma while no significant change in pulp colour and texture was observed with respect to change in storage periods.

Table 14a. Flavour of Cavendish bananas from different regions of Mozambique

Sample		Cavendish banana storage time (days)					
		0	4	8	12	16	20
Gaza	A	$3.11^{\mathrm{Aa}a}$	$3.36^{\mathrm{Ab}a}$	$3.61^{\mathrm{Ab}a}$	$4.01^{\mathrm{Ab}a}$	$4.31^{\mathrm{Ab}a}$	NA
Gaza	B	$3.15^{\mathrm{Aa}a}$	$3.40^{\mathrm{Ab}b}$	$3.65^{\mathrm{Ab}b}$	$4.05^{\mathrm{Ab}b}$	$4.35^{\mathrm{Ab}b}$	$3.88^{\mathrm{Aa}b}$
Gaza	C	$3.09^{\mathrm{Aa}a}$	$3.32^{\mathrm{Ab}a}$	$3.60^{\mathrm{Ab}a}$	$3.99^{\mathrm{Ab}a}$	$4.29^{\mathrm{Ab}a}$	NA
Gaza	D	$3.00^{\mathrm{Aa}a}$	$3.25^{\mathrm{Aa}a}$	$3.50^{\mathrm{Aa}a}$	$3.90^{\mathrm{Aa}a}$	NA	-
Gaza	E	$3.09^{\mathrm{Aa}a}$	$3.34^{\mathrm{Aa}b}$	$3.59^{\mathrm{Aa}b}$	$4.00^{\mathrm{Aa}b}$	$4.12^{\mathrm{Aa}b}$	NA
Gaza	F	$2.92^{\mathrm{Aa}a}$	$3.17^{\mathrm{Aa}a}$	$3.42^{\mathrm{Aa}a}$	$3.82^{\mathrm{Aa}a}$	NA	-
Gaza	G	$3.07^{\mathrm{Aa}a}$	$3.32^{\mathrm{Aa}a}$	$3.57^{\mathrm{Aa}a}$	$3.97^{\mathrm{Aa}a}$	NA	-
Gaza	H	$3.10^{\mathrm{Aa}a}$	$3.34^{\mathrm{Aa}b}$	$3.60^{\mathrm{Aa}b}$	$4.00^{\mathrm{Aa}b}$	$4.30^{\mathrm{Aa}b}$	NA
Gaza	I	$2.73^{\mathrm{Aa}a}$	$2.98^{\mathrm{Aa}a}$	$3.23^{\mathrm{Aa}a}$	NA	-	-
Manica	A	$3.21^{\mathrm{Aa}a}$	$3.46^{\mathrm{Ab}a}$	$3.71^{\mathrm{Ab}a}$	$4.11^{\mathrm{Ab}a}$	$4.41^{\mathrm{Ab}a}$	$4.81^{\mathrm{Aa}a}$
Manica	B	$3.25^{\mathrm{Aa}a}$	$3.50^{\mathrm{Ab}b}$	$3.75^{\mathrm{Ab}b}$	$4.15^{\mathrm{Ab}b}$	$4.45^{\mathrm{Ab}b}$	$4.85^{\mathrm{Aa}b}$
Manica	C	$3.08^{\mathrm{Aa}a}$	$3.33^{\mathrm{Ab}a}$	$3.58^{\mathrm{Ab}a}$	$3.98^{\mathrm{Ab}a}$	$4.28^{\mathrm{Ab}a}$	$4.68^{\mathrm{Aa}a}$
Manica	D	$3.07^{\mathrm{Aa}a}$	$3.32^{\mathrm{Aa}a}$	$3.57^{\mathrm{Aa}a}$	$3.97^{\mathrm{Aa}a}$	$4.27^{\mathrm{Aa}a}$	NA
Manica	E	$3.08^{\mathrm{Aa}a}$	$3.35^{\mathrm{Aa}b}$	$3.60^{\mathrm{Aa}b}$	$3.99^{\mathrm{Aa}b}$	$4.28^{\mathrm{Aa}b}$	NA
Manica	F	$2.94^{\mathrm{Aa}a}$	$3.19^{\mathrm{Aa}a}$	$3.44^{\mathrm{Aa}a}$	$3.84^{\mathrm{Aa}a}$	$4.14^{\mathrm{Aa}a}$	NA
Manica	G	$3.11^{\mathrm{Aa}a}$	$3.36^{\mathrm{Aa}a}$	$3.61^{\mathrm{Aa}a}$	$4.01^{\mathrm{Aa}a}$	$3.90^{\mathrm{Aa}a}$	NA
Manica	H	$3.16^{\mathrm{Aa}a}$	$3.41^{\mathrm{Aa}b}$	$3.66^{\mathrm{Aa}b}$	$4.06^{\mathrm{Aa}b}$	$4.36^{\mathrm{Aa}b}$	NA
Manica	I	$2.90^{\mathrm{Aa}a}$	$3.15^{\mathrm{Aa}a}$	$3.40^{\mathrm{Aa}a}$	$4.18^{\mathrm{Aa}a}$	NA	-
Nampula	A	$3.17^{\mathrm{Aa}a}$	$3.42^{\mathrm{Ab}a}$	$3.67^{\mathrm{Ab}a}$	$4.07^{\mathrm{Ab}a}$	$4.37^{\mathrm{Ab}a}$	$4.77^{\mathrm{Aa}a}$
Nampula	B	$3.25^{\mathrm{Aa}a}$	$3.50^{\mathrm{Ab}b}$	$3.75^{\mathrm{Ab}b}$	$4.15^{\mathrm{Ab}b}$	$4.45^{\mathrm{Ab}b}$	$4.80^{\mathrm{Aa}b}$
Nampula	C	$3.21^{\mathrm{Aa}a}$	$3.46^{\mathrm{Ab}a}$	$3.71^{\mathrm{Ab}a}$	$4.11^{\mathrm{Ab}a}$	$4.41^{\mathrm{Ab}a}$	NA
Nampula	D	$3.09^{\mathrm{Aa}a}$	$3.34^{\mathrm{Aa}a}$	$3.59^{\mathrm{Aa}a}$	$3.99^{\mathrm{Aa}a}$	$4.29^{\mathrm{Aa}a}$	NA
Nampula	E	$2.88^{\mathrm{Aa}a}$	$3.13^{\mathrm{Aa}b}$	$3.38^{\mathrm{Aa}b}$	$3.78^{\mathrm{Aa}b}$	$4.08^{\mathrm{Aa}b}$	$4.07^{\mathrm{Aa}b}$
Nampula	F	$3.06^{\mathrm{Aa}a}$	$3.31^{\mathrm{Aa}a}$	$3.56^{\mathrm{Aa}a}$	$3.96^{\mathrm{Aa}a}$	$4.06^{\mathrm{Aa}a}$	NA
Nampula	G	$2.88^{\mathrm{Aa}a}$	$3.13^{\mathrm{Aa}a}$	$3.38^{\mathrm{Aa}a}$	$3.78^{\mathrm{Aa}a}$	$3.29^{\mathrm{Aa}a}$	NA
Nampula	H	$3.12^{\mathrm{Aa}a}$	$3.37^{\mathrm{Aa}b}$	$3.62^{\mathrm{Aa}b}$	$3.96^{\mathrm{Aa}b}$	$4.15^{\mathrm{Aa}b}$	NA
Nampula	I	$2.96^{\mathrm{Aa}a}$	$3.19^{\mathrm{Aa}a}$	$3.13^{\mathrm{Aa}a}$	$3.86^{\mathrm{Aa}a}$	$4.02^{\mathrm{Aa}a}$	NA
	CV	4.69	4.38	5.46	5.02	4.12	2.89
	σ	0.04	0.04	0.05	0.05	0.04	0.01

A (fruit treated with calcium and kept on freezer), B (fruit treated with calcium and kept on refrigerator), C (fruit treated with calcium and kept on room temperature), D (fruit treated with hot water and kept on freezer), E (fruit treated with hot water and kept on refrigerator), F (fruit treated with hot water and kept on room temperature), G (untreated fruit and kept on freezer), H (untreated fruit and kept on refrigerator), I (untreated fruit and kept on room temperature). Ma – mango fruit; Ba - Banana fruit. Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA - fruit sample not acceptable to be eaten. σ - Standard deviation. CV- coefficient of variation.

Table 14b. Flavour of Keitt mangoes from different regions of Mozambique

Sample		Keitt mangoes storage time (days)					
		0	4	8	12	16	20
Gaza	A	2.94^{Ded}	3.19^{Ded}	3.44^{Ded}	3.84^{Ded}	4.14^{Ddd}	NA
Gaza	B	3.10^{Ded}	3.35^{Dee}	3.60^{Dee}	4.00^{Dee}	4.30^{Dde}	4.70^{Dde}
Gaza	C	2.98^{Ded}	3.23^{Ded}	3.48^{Ded}	3.88^{Ded}	4.18^{Ddd}	NA
Gaza	D	2.78^{Ddd}	3.03^{Ddd}	3.28^{Ddd}	NA	-	-
Gaza	E	2.90^{Ddd}	3.15^{Dde}	3.40^{Dde}	3.80^{Dde}	4.10^{Dde}	NA
Gaza	F	2.85^{Ddd}	3.10^{Ddd}	3.35^{Ddd}	NA	-	-
Gaza	G	2.75^{Ddd}	3.00^{Ddd}	3.25^{Ddd}	NA	-	-
Gaza	H	3.09^{Ddd}	2.34^{Dde}	3.59^{Dde}	3.99^{Dde}	4.29^{Dde}	4.69^{Dde}
Gaza	I	2.88^{Ddd}	3.13^{Ddd}	3.38^{Ddd}	NA	-	-
Manica	A	2.99^{Ded}	3.24^{Ded}	3.49^{Ded}	3.89^{Ded}	4.19^{Ddd}	NA
Manica	B	3.15^{Ded}	3.40^{Dee}	3.65^{Dee}	4.05^{Dee}	4.35^{Dde}	4.75^{Dde}
Manica	C	3.05^{Ded}	3.30^{Ded}	3.55^{Ded}	3.95^{Ded}	4.25^{Ddd}	NA
Manica	D	2.31^{Ddd}	2.56^{Ddd}	2.81^{Ddd}	3.21^{Ddd}	NA	-
Manica	E	2.96^{Ddd}	3.21^{Dde}	3.46^{Dde}	3.86^{Dde}	4.16^{Dde}	NA
Manica	F	2.76^{Ddd}	3.01^{Ddd}	3.26^{Ddd}	3.66^{Ddd}	NA	-
Manica	G	3.05^{Ddd}	3.29^{Ddd}	3.55^{Ddd}	3.95^{Ddd}	NA	-
Manica	H	3.21^{Ddd}	3.46^{Dde}	3.71^{Dde}	4.11^{Dde}	4.41^{Dde}	NA
Manica	I	2.98^{Ddd}	3.23^{Ddd}	3.48^{Ddd}	NA	-	-
Nampula	A	3.09^{Ded}	3.34^{Ded}	3.59^{Ded}	3.99^{Ded}	4.29^{Ddd}	4.69^{Ddd}
Nampula	B	3.28^{Ded}	3.53^{Dee}	3.78^{Dee}	4.18^{Dee}	4.48^{Dde}	4.88^{Dde}
Nampula	C	3.17^{Ded}	2.42^{Ded}	3.67^{Ded}	4.07^{Ded}	4.37^{Ddd}	NA
Nampula	D	3.02^{Ddd}	3.27^{Ddd}	3.52^{Ddd}	3.92^{Ddd}	4.22^{Ddd}	NA
Nampula	E	3.10^{Ddd}	3.35^{Dde}	3.60^{Dde}	4.00^{Dde}	4.30^{Dde}	NA
Nampula	F	3.04^{Ddd}	3.29^{Ddd}	3.54^{Ddd}	3.94^{Ddd}	NA	-
Nampula	G	2.89^{Ddd}	3.14^{Ddd}	3.39^{Ddd}	3.79^{Ddd}	NA	-
Nampula	H	3.06^{Ddd}	3.31^{Dde}	3.56^{Dde}	3.61^{Dde}	4.06^{Dde}	NA
Nampula	I	3.00^{Ddd}	3.15^{Ddd}	3.44^{Ddd}	NA	-	-
	CV	4.97	5.53	6.11	5.27	6.04	5.03
	σ	0.05	0.05	0.06	0.05	0.06	0.05

A (fruit treated with calcium and kept on freezer), B (fruit treated with calcium and kept on refrigerator), C (fruit treated with calcium and kept on room temperature), D (fruit treated with hot water and kept on freezer), E (fruit treated with hot water and kept on refrigerator), F (fruit treated with hot water and kept on room temperature), G (untreated fruit and kept on freezer), H (untreated fruit and kept on refrigerator), I (untreated fruit and kept on room temperature). Ma – mango fruit; Ba - Banana fruit. Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA - fruit sample not acceptable to be eaten. σ - Standard deviation. CV- coefficient of variation.

Anjum & Ali (2004) reported that treatments of the fruits with the all the three calcium salts resulted in reduced flavour and taste. Mahmud *et al.* (2015) assessing the effects of CaC_2 and different calcium salt on mango fruits ripening in Bangladesh reported that CaC_2 and other treated fruits with salts namely, $CaCl_2.2H_2O$, $CaSO_4.2H_2O$ and $Ca[NH_4NO_3]_2$ resulted in reduced flavor and taste.

Mohammed & Brecht (2002) reported that M2 (half-mature) fruit displayed superior flavour and aroma profiles after 6 days at 20ºC compared to M1 (immature) and M3 (mature) fruit. While the flavour of the fruit proceeded from poor to worse after 18 days at 5 ºC.

4.4.6.2 Effect of hot water and calcium chloride and storage conditions on the astringency of Keitt mango and Cavendish banana fruits from Mozambique

In Tables 15a and 15b, the astringency scores are presented for Cavendish bananas and Keitt mangoes, respectively, from different regions of Mozambique subjected to different treatment and stored in different conditions assessed by 52 panelists. In these tables, the astringency of the mango and banana fruits pulp was decreasing directly from the start of measurement until the condition the fresh fruit could not be eaten or visually was broken.

Mango fruits (Table 15b) from Gaza presented high astringency scores and statistical differences were reported between fruit from Gaza and other fruit on the first until the eighth day of samples storage. There were no statistical differences ($p < 0.05$) of astringency scores for treated and untreated samples showing either hot water or calcium chloride treatment was not affecting the samples astringency from the first day of sample assessment until the twentieth day of experiment measurement. Similar astringency behaviour was reported in relation to the storage conditions showing that freezing or refrigeration was not affecting the samples astringency from the start of measurement until the fruit was inedible throughout the experimental period.

For banana fruits (15a), samples from Manica presented low astringency scores and statistical differences ($p < 0.05$) were reported between fruit from Manica and other location native fruit just on the first day of measurement. At the same significance level, there were no statistical differences of astringency scores for treated and untreated banana samples showing that hot water or calcium chloride treatment was not affecting the samples astringency up to the end of the experiment. But, banana high astringency scores were reported in the samples kept in the freezer showing that the storage conditions affected the samples astringency from the fourth until the eighth day of experimental period.

Table 15a. Astringency of Cavendish bananas from different regions of Mozambique

Sample		Cavendish banana storage time (days)					
		0	4	8	12	16	20
Gaza	A	$2.41^{\mathrm{Ba}a}$	$2.28^{\mathrm{Aa}b}$	$2.12^{\mathrm{Aa}b}$	$2.09^{\mathrm{Aa}a}$	$1.82^{\mathrm{Aa}a}$	NA
Gaza	B	$2.51^{\mathrm{Ba}a}$	$2.18^{\mathrm{Aa}a}$	$2.03^{\mathrm{Aa}a}$	$2.19^{\mathrm{Aa}a}$	$1.92^{\mathrm{Aa}a}$	$1.86^{\mathrm{Aa}a}$
Gaza	C	$2.47^{\mathrm{Ba}a}$	$2.20^{\mathrm{Aa}a}$	$2.06^{\mathrm{Aa}a}$	$2.15^{\mathrm{Aa}a}$	$1.88^{\mathrm{Aa}a}$	NA
Gaza	D	$2.45^{\mathrm{Ba}a}$	$2.32^{\mathrm{Aa}b}$	$2.24^{\mathrm{Aa}b}$	$2.13^{\mathrm{Aa}a}$	NA	-
Gaza	E	$2.55^{\mathrm{Ba}a}$	$2.22^{\mathrm{Aa}a}$	$2.12^{\mathrm{Aa}a}$	$2.23^{\mathrm{Aa}a}$	$1.96^{\mathrm{Aa}a}$	NA
Gaza	F	$2.55^{\mathrm{Ba}a}$	$2.19^{\mathrm{Aa}a}$	$2.12^{\mathrm{Aa}a}$	$2.23^{\mathrm{Aa}a}$	NA	-
Gaza	G	$2.39^{\mathrm{Ba}a}$	$2.26^{\mathrm{Aa}b}$	$2.18^{\mathrm{Aa}b}$	$2.07^{\mathrm{Aa}a}$	NA	-
Gaza	H	$2.38^{\mathrm{Ba}a}$	$2.15^{\mathrm{Aa}a}$	$2.17^{\mathrm{Aa}a}$	$2.06^{\mathrm{Aa}a}$	$1.79^{\mathrm{Aa}a}$	NA
Gaza	I	$2.51^{\mathrm{Ba}a}$	$2.08^{\mathrm{Aa}a}$	$2.03^{\mathrm{Aa}a}$	NA	-	-
Manica	A	$2.03^{\mathrm{Aa}a}$	$2.17^{\mathrm{Aa}b}$	$2.09^{\mathrm{Aa}b}$	$1.98^{\mathrm{Aa}a}$	$1.71^{\mathrm{Aa}a}$	$1.65^{\mathrm{Aa}a}$
Manica	B	$2.07^{\mathrm{Aa}a}$	$2.14^{\mathrm{Aa}a}$	$2.16^{\mathrm{Aa}a}$	$2.05^{\mathrm{Aa}a}$	$1.78^{\mathrm{Aa}a}$	$1.72^{\mathrm{Aa}a}$
Manica	C	$2.30^{\mathrm{Aa}a}$	$2.16^{\mathrm{Aa}a}$	$2.18^{\mathrm{Aa}a}$	$2.07^{\mathrm{Aa}a}$	$1.08^{\mathrm{Aa}a}$	$1.74^{\mathrm{Aa}a}$
Manica	D	$2.13^{\mathrm{Aa}a}$	$2.16^{\mathrm{Aa}b}$	$2.11^{\mathrm{Aa}b}$	$2.07^{\mathrm{Aa}a}$	$1.80^{\mathrm{Aa}a}$	NA
Manica	E	$2.11^{\mathrm{Aa}a}$	$2.15^{\mathrm{Aa}a}$	$2.02^{\mathrm{Aa}a}$	$2.06^{\mathrm{Aa}a}$	$1.79^{\mathrm{Aa}a}$	NA
Manica	F	$2.18^{\mathrm{Aa}a}$	$1.95^{\mathrm{Aa}a}$	$1.97^{\mathrm{Aa}a}$	$1.86^{\mathrm{Aa}a}$	$1.59^{\mathrm{Aa}a}$	NA
Manica	G	$2.02^{\mathrm{Aa}a}$	$2.13^{\mathrm{Aa}b}$	$2.17^{\mathrm{Aa}b}$	$1.09^{\mathrm{Aa}a}$	$1.63^{\mathrm{Aa}a}$	NA
Manica	H	$2.24^{\mathrm{Aa}a}$	$1.99^{\mathrm{Aa}a}$	$2.03^{\mathrm{Aa}a}$	$1.92^{\mathrm{Aa}a}$	$1.65^{\mathrm{Aa}a}$	NA
Manica	I	$2.16^{\mathrm{Aa}a}$	$2.07^{\mathrm{Aa}a}$	$2.15^{\mathrm{Aa}a}$	$2.04^{\mathrm{Aa}a}$	NA	-
Nampula	A	$2.37^{\mathrm{Ba}a}$	$2.14^{\mathrm{Aa}b}$	$2.16^{\mathrm{Aa}b}$	$2.05^{\mathrm{Aa}a}$	$1.78^{\mathrm{Aa}a}$	$1.72^{\mathrm{Aa}a}$
Nampula	B	$2.41^{\mathrm{Ba}a}$	$2.10^{\mathrm{Aa}a}$	$2.20^{\mathrm{Aa}a}$	$2.09^{\mathrm{Aa}a}$	$1.82^{\mathrm{Aa}a}$	$1.76^{\mathrm{Aa}a}$
Nampula	C	$2.18^{\mathrm{Ba}a}$	$1.95^{\mathrm{Aa}a}$	$1.97^{\mathrm{Aa}a}$	$1.86^{\mathrm{Aa}a}$	$1.59^{\mathrm{Aa}a}$	NA
Nampula	D	$2.04^{\mathrm{Ba}a}$	$2.17^{\mathrm{Aa}b}$	$2.19^{\mathrm{Aa}b}$	$2.08^{\mathrm{Aa}a}$	$1.81^{\mathrm{Aa}a}$	NA
Nampula	E	$2.46^{\mathrm{Ba}a}$	$2.03^{\mathrm{Aa}a}$	$1.87^{\mathrm{Aa}a}$	$2.14^{\mathrm{Aa}a}$	$1.87^{\mathrm{Aa}a}$	$1.81^{\mathrm{Aa}a}$
Nampula	F	$2.42^{\mathrm{Ba}a}$	$2.11^{\mathrm{Aa}a}$	$2.01^{\mathrm{Aa}a}$	$2.01^{\mathrm{Aa}a}$	$1.83^{\mathrm{Aa}a}$	NA
Nampula	G	$2.03^{\mathrm{Ba}a}$	$1.80^{\mathrm{Aa}b}$	$1.99^{\mathrm{Aa}b}$	$1.71^{\mathrm{Aa}a}$	$1.44^{\mathrm{Aa}a}$	NA
Nampula	H	$2.02^{\mathrm{Ba}a}$	$1.97^{\mathrm{Aa}a}$	$1.82^{\mathrm{Aa}a}$	$1.88^{\mathrm{Aa}a}$	$1.61^{\mathrm{Aa}a}$	NA
Nampula	I	$2.26^{\mathrm{Ba}a}$	$2.03^{\mathrm{Aa}a}$	$1.45^{\mathrm{Aa}a}$	$1.94^{\mathrm{Aa}a}$	$1.67^{\mathrm{Aa}a}$	NA
	CV	7.98	9.16	8.46	9.72	5.72	5.79
	σ	0.06	0.07	0.07	0.08	0.05	0.05

A (fruit treated with calcium and kept on freezer), B (fruit treated with calcium and kept on refrigerator), C (fruit treated with calcium and kept on room temperature), D (fruit treated with hot water and kept on freezer), E (fruit treated with hot water and kept on refrigerator), F (fruit treated with hot water and kept on room temperature), G (untreated fruit and kept on freezer), H (untreated fruit and kept on refrigerator), I (untreated fruit and kept on room temperature). Ma – mango fruit; Ba - Banana fruit. Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA – fruit sample not acceptable to be eaten. σ - Standard deviation. CV- coefficient of variation.

Table 15b. Astringency of Keitt mangoes from different regions of Mozambique

Sample		Keitt mangoes storage time (days)					
		0	4	8	12	16	20
Gaza	A	2.04^{Edd}	1.81^{Edd}	1.59^{Edd}	1.49^{Ddd}	1.45^{Ddd}	NA
Gaza	B	2.09^{Edd}	1.86^{Edd}	1.64^{Edd}	1.54^{Ddd}	1.50^{Ddd}	1.44^{Ddd}
Gaza	C	2.19^{Edd}	1.96^{Edd}	1.74^{Edd}	1.64^{Ddd}	1.06^{Ddd}	NA
Gaza	D	2.20^{Edd}	1.97^{Edd}	1.75^{Edd}	NA	-	-
Gaza	E	2.25^{Edd}	2.02^{Edd}	1.80^{Edd}	1.70^{Ddd}	1.66^{Ddd}	NA
Gaza	F	2.38^{Edd}	2.15^{Edd}	1.93^{Edd}	NA	-	-
Gaza	G	2.08^{Edd}	1.85^{Edd}	1.63^{Edd}	NA	-	-
Gaza	H	2.15^{Edd}	1.92^{Edd}	1.70^{Edd}	1.60^{Ddd}	1.56^{Ddd}	1.50^{Ddd}
Gaza	I	2.27^{Edd}	2.04^{Edd}	1.82^{Edd}	NA	-	-
Manica	A	1.88^{Ddd}	1.65^{Ddd}	1.43^{Ddd}	1.33^{Ddd}	1.29^{Ddd}	NA
Manica	B	1.41^{Ddd}	1.18^{Ddd}	0.96^{Ddd}	0.86^{Ddd}	0.82^{Ddd}	0.76^{Ddd}
Manica	C	2.12^{Ddd}	1.89^{Ddd}	1.67^{Ddd}	1.57^{Ddd}	1.53^{Ddd}	NA
Manica	D	2.00^{Ddd}	1.77^{Ddd}	1.55^{Ddd}	1.45^{Ddd}	NA	-
Manica	E	2.06^{Ddd}	1.83^{Ddd}	1.61^{Ddd}	1.51^{Ddd}	1.47^{Ddd}	NA
Manica	F	2.20^{Ddd}	1.97^{Ddd}	1.75^{Ddd}	1.65^{Ddd}	NA	-
Manica	G	1.95^{Ddd}	1.72^{Ddd}	1.50^{Ddd}	1.40^{Ddd}	NA	-
Manica	H	1.86^{Ddd}	1.63^{Ddd}	1.41^{Ddd}	1.31^{Ddd}	1.27^{Ddd}	NA
Manica	I	2.14^{Ddd}	1.91^{Ddd}	1.69^{Ddd}	NA	-	-
Nampula	A	1.85^{Ddd}	1.62^{Ddd}	1.40^{Ddd}	1.03^{Ddd}	1.26^{Ddd}	1.02^{Ddd}
Nampula	B	2.15^{Ddd}	1.92^{Ddd}	1.70^{Ddd}	1.60^{Ddd}	1.56^{Ddd}	1.05^{Ddd}
Nampula	C	1.99^{Ddd}	1.76^{Ddd}	1.54^{Ddd}	1.44^{Ddd}	1.04^{Ddd}	NA
Nampula	D	2.19^{Ddd}	1.96^{Ddd}	1.74^{Ddd}	1.64^{Ddd}	1.60^{Ddd}	NA
Nampula	E	2.31^{Ddd}	2.08^{Ddd}	1.86^{Ddd}	1.76^{Ddd}	1.72^{Ddd}	NA
Nampula	F	2.16^{Ddd}	1.93^{Ddd}	1.71^{Ddd}	1.61^{Ddd}	NA	-
Nampula	G	1.98^{Ddd}	1.75^{Ddd}	1.53^{Ddd}	1.43^{Ddd}	NA	-
Nampula	H	2.08^{Ddd}	1.85^{Ddd}	1.63^{Ddd}	1.53^{Ddd}	1.49^{Ddd}	NA
Nampula	I	2.10^{Ddd}	1.87^{Ddd}	1.65^{Ddd}	NA	-	-
	CV	4.97	5.53	6.11	5.21	6.02	4.88
	σ	0.05	0.05	0.06	0.05	0.05	0.04

A (fruit treated with calcium and kept on freezer), B (fruit treated with calcium and kept on refrigerator), C (fruit treated with calcium and kept on room temperature), D (fruit treated with hot water and kept on freezer), E (fruit treated with hot water and kept on refrigerator), F (fruit treated with hot water and kept on room temperature), G (untreated fruit and kept on freezer), H (untreated fruit and kept on refrigerator), I (untreated fruit and kept on room temperature). Ma – mango fruit; Ba - Banana fruit. Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA – fruit sample not acceptable to be eaten. σ - Standard deviation. CV- coefficient of variation.

Astringency is the dry, puckering mouthfeel caused by tannins that are commonly found in many fruits, especially when they are unripe and was reported in ripe fruits include blackthorn, aronia (chokeberry), chokecherry, birdcherry, quince and persimmon fruits and banana skins (Duffy *et al*., 2017).

Reports related to astringency in banana and or mango fruits are scarce in the literature but Baloch & Bibi (2012) assessing the effect of harvesting and storage conditions on the post harvest quality and shelf life of mango (*Mangifera indica* L.) fruit reported that the organoleptic characteristics were increasing as the storage temperature increased, a trend observed in this work. This trend can be attributed to the fact that the ripening of fruit is characterized by loss of polyphenolic biomolecules (tannoids) that binds to and precipitates proteins and various others organic compounds including amino acids.

4.4.6.3 Effect of hot water and calcium chloride and storage conditions on the overall acceptance of Keitt mango and Cavendish banana fruits from Mozambique

In this work, overall acceptance scores of Cavendish bananas and Keitt mangoes from different regions of Mozambique subjected to in different treatments and stored in different conditions assessed by 52 panelists are presented in Tables 16a and 16b, respectively. In this tables, the overall acceptance of the mango and banana fruits was increasing directly from the start of measurement until condition the fresh fruit could not be eaten or visually was broken.

For both mango and banana fruits, overall acceptance scores of the samples showed no significant differences ($p < 0.05$) between location of sample collection but on postharvest treatment and storage conditions assessed.

In Table 16b, mango fruits presented a significant increase of overall acceptance scores of the samples showing calcium chloride treatment scored better from the fourth day of sample assessment until the sixteenth day of experiment measurement with statistical differences ($p < 0.05$).

Banana fruit overall acceptance scores (Table 16a) was also high, for samples treated with calcium chloride than other postharvest treatments and statistical differences were observed from the fourth up to sixteenth day.

After treatment, as the overall acceptance scores increased the, samples kept on refrigerator conditions had better preservation and maintained their fresh qualities for both mango and banana fruits, than others storage conditions. Statistical differences ($p < 0.05$) were found on fourth day up to sixteenth day and the end of the experiment, respectively.

Table 16a. Overall acceptance of Cavendish bananas from different regions of Mozambique

Sample		Cavendish banana storage time					
		0	4	8	12	16	20
Gaza	A	3.17^{Aaa}	3.41^{Aba}	3.80^{Aba}	3.90^{Aba}	4.09^{Aba}	NA
Gaza	B	3.33^{Aaa}	3.57^{Abb}	3.96^{Abb}	4.06^{Abb}	4.25^{Abb}	4.32^{Aab}
Gaza	C	3.21^{Aaa}	3.45^{Aba}	3.84^{Aba}	3.94^{Aba}	4.13^{Aba}	NA
Gaza	D	3.01^{Aaa}	3.25^{Aaa}	3.64^{Aaa}	3.74^{Aaa}	NA	-
Gaza	E	3.13^{Aaa}	3.37^{Aab}	3.76^{Aab}	3.86^{Aab}	4.05^{Aab}	NA
Gaza	F	3.08^{Aaa}	3.32^{Aaa}	3.71^{Aaa}	3.81^{Aaa}	NA	-
Gaza	G	2.98^{Aaa}	3.22^{Aaa}	3.61^{Aaa}	3.71^{Aaa}	NA	-
Gaza	H	3.32^{Aaa}	3.56^{Aab}	3.95^{Aab}	4.05^{Aab}	4.24^{Aab}	
Gaza	I	3.11^{Aaa}	3.35^{Aaa}	3.74^{Aaa}	NA	-	-
Manica	A	3.22^{Aaa}	3.46^{Aba}	3.85^{Aba}	3.95^{Aba}	4.14^{Aba}	4.21^{Aaa}
Manica	B	3.37^{Aaa}	3.62^{Abb}	4.01^{Abb}	4.11^{Abb}	4.30^{Abb}	4.37^{Aab}
Manica	C	3.28^{Aaa}	3.52^{Aba}	3.91^{Aba}	4.02^{Aba}	4.20^{Aba}	3.79^{Aaa}
Manica	D	2.54^{Aaa}	2.78^{Aaa}	3.17^{Aaa}	3.27^{Aaa}	3.63^{Aaa}	NA
Manica	E	3.19^{Aaa}	3.43^{Aab}	3.82^{Aab}	3.92^{Aab}	4.11^{Aab}	NA
Manica	F	2.99^{Aaa}	3.23^{Aaa}	3.62^{Aaa}	3.72^{Aaa}	3.91^{Aaa}	NA
Manica	G	3.28^{Aaa}	3.52^{Aaa}	3.91^{Aaa}	4.01^{Aaa}	4.20^{Aaa}	NA
Manica	H	3.45^{Aaa}	3.68^{Aab}	4.07^{Aab}	4.17^{Aab}	4.30^{Aab}	NA
Manica	I	3.21^{Aaa}	3.33^{Aaa}	3.84^{Aaa}	3.99^{Aaa}	NA	-
Nampula	A	3.32^{Aaa}	3.56^{Aba}	3.95^{Aba}	4.05^{Aba}	4.24^{Aaa}	4.28^{Aaa}
Nampula	B	3.51^{Aaa}	3.77^{Abb}	4.14^{Abb}	4.24^{Abb}	4.43^{Aab}	4.31^{Aab}
Nampula	C	3.40^{Aaa}	3.64^{Aba}	4.03^{Aba}	4.13^{Aba}	4.32^{Aaa}	NA
Nampula	D	3.25^{Aaa}	3.49^{Aaa}	3.88^{Aaa}	3.98^{Aaa}	4.17^{Aaa}	NA
Nampula	E	3.33^{Aaa}	3.57^{Aab}	3.96^{Aab}	4.06^{Aab}	4.25^{Aab}	3.33^{Aab}
Nampula	F	3.27^{Aaa}	3.51^{Aaa}	3.90^{Aaa}	4.00^{Aaa}	4.19^{Aaa}	NA
Nampula	G	3.12^{Aaa}	3.36^{Aaa}	3.75^{Aaa}	3.90^{Aaa}	4.00^{Aaa}	NA
Nampula	H	3.29^{Aaa}	3.53^{Aab}	3.92^{Aab}	4.02^{Aab}	4.21^{Aab}	NA
Nampula	I	3.23^{Aaa}	3.47^{Aaa}	3.86^{Aaa}	3.96^{Aaa}	4.15^{Aaa}	NA
	CV	4.94	5.57	6.12	5.97	4.18	3.15
	σ	0.06	0.07	0.07	0.07	0.06	0.06

A (fruit treated with calcium and kept on freezer), B (fruit treated with calcium and kept on refrigerator), C (fruit treated with calcium and kept on room temperature), D (fruit treated with hot water and kept on freezer), E (fruit treated with hot water and kept on refrigerator), F (fruit treated with hot water and kept on room temperature), G (untreated fruit and kept on freezer), H (untreated fruit and kept on refrigerator), I (untreated fruit and kept on room temperature). Ma – mango fruit; Ba - Banana fruit. Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA – fruit sample not acceptable to be eaten

Table 16b. Overall acceptance of Keitt mangoes from different regions of Mozambique

Sample		Keitt mangoes storage time					
		0	4	8	12	16	20
Gaza	A	3.39^{Ddd}	3.66^{Ded}	4.04^{Ded}	4.12^{Ded}	4.31^{Ded}	NA
Gaza	B	3.43^{Ddd}	3.70^{Dee}	4.08^{Dee}	4.16^{Dee}	4.35^{Dee}	4.42^{Ddd}
Gaza	C	3.37^{Ddd}	3.64^{Ded}	4.02^{Ded}	4.10^{Ded}	4.29^{Ded}	NA
Gaza	D	3.28^{Ddd}	3.55^{Ddd}	3.93^{Ddd}	NA	-	-
Gaza	E	3.37^{Ddd}	3.64^{Dde}	4.02^{Dde}	4.10^{Dde}	4.29^{Dde}	NA
Gaza	F	3.20^{Ddd}	3.47^{Ddd}	3.85^{Ddd}	NA	-	-
Gaza	G	3.35^{Ddd}	3.62^{Ddd}	4.00^{Ddd}	NA	-	-
Gaza	H	3.38^{Ddd}	3.65^{Dde}	4.03^{Dde}	4.11^{Dde}	4.30^{Dde}	4.37^{Ddd}
Gaza	I	3.01^{Ddd}	3.28^{Ddd}	3.66^{Ddd}	NA	-	-
Manica	A	3.49^{Ddd}	3.76^{Ded}	4.14^{Ded}	4.22^{Ded}	4.41^{Ded}	
Manica	B	3.53^{Ddd}	3.80^{Dee}	3.18^{Dee}	4.26^{Dee}	4.45^{Dee}	4.52^{Ddd}
Manica	C	3.36^{Ddd}	3.63^{Ded}	4.01^{Ded}	4.09^{Ded}	4.28^{Ded}	NA
Manica	D	3.35^{Ddd}	3.62^{Ddd}	3.99^{Ddd}	4.08^{Ddd}	NA	-
Manica	E	3.38^{Ddd}	3.62^{Dde}	4.05^{Dde}	4.09^{Dde}	4.28^{Dde}	NA
Manica	F	3.22^{Ddd}	3.49^{Ddd}	3.87^{Ddd}	3.95^{Ddd}	NA	-
Manica	G	3.39^{Ddd}	3.66^{Ddd}	4.04^{Ddd}	4.12^{Ddd}	NA	-
Manica	H	3.44^{Ddd}	3.71^{Dde}	4.09^{Dde}	4.17^{Dde}	4.36^{Dde}	NA
Manica	I	3.18^{Ddd}	3.45^{Ddd}	3.83^{Ddd}	3.90^{Ddd}	NA	-
Nampula	A	3.45^{Ddd}	3.72^{Ded}	4.10^{Ded}	4.18^{Ded}	4.37^{Ded}	4.44^{Ddd}
Nampula	B	3.53^{Ddd}	3.80^{Dee}	4.18^{Dee}	4.26^{Dee}	4.45^{Dee}	4.52^{Ddd}
Nampula	C	3.49^{Ddd}	3.76^{Ded}	4.14^{Ded}	4.22^{Ded}	4.41^{Ded}	NA
Nampula	D	3.37^{Ddd}	3.64^{Ddd}	3.98^{Ddd}	4.10^{Ddd}	4.29^{Ddd}	NA
Nampula	E	3.16^{Ddd}	3.43^{Dde}	3.81^{Dde}	3.89^{Dde}	4.08^{Dde}	NA
Nampula	F	3.34^{Ddd}	3.61^{Ddd}	3.99^{Ddd}	4.07^{Ddd}	NA	-
Nampula	G	3.16^{Ddd}	3.40^{Ddd}	3.75^{Ddd}	3.87^{Ddd}	NA	-
Nampula	H	3.40^{Ddd}	3.67^{Dde}	4.05^{Dde}	4.13^{Dde}	4.32^{Dde}	NA
Nampula	I	3.24^{Ddd}	3.51^{Ddd}	3.89^{Ddd}	NA	-	-
	CV	7.78	4.48	4.73	6.22	4.13	6.65
	σ	3.11	0.05	0.05	0.20	0.05	0.05

A (fruit treated with calcium and kept on freezer), B (fruit treated with calcium and kept on refrigerator), C (fruit treated with calcium and kept on room temperature), D (fruit treated with hot water and kept on freezer), E (fruit treated with hot water and kept on refrigerator), F (fruit treated with hot water and kept on room temperature), G (untreated fruit and kept on freezer), H (untreated fruit and kept on refrigerator), I (untreated fruit and kept on room temperature). Ma – mango fruit; Ba - Banana fruit. Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA – fruit sample not acceptable to be eaten

This was expected since 8 °C is an adequate temperature for fruit storage and do not block fruit metabolism which, perhaps, retarded the physiological and biological activities and finally led to the longest shelf-life.

Reports related to overall acceptance are scarce in the literature but Mahmud *et al.* (2015) assessing the effects of CaC_2 and different calcium salt on mango fruits ripening in Bangladesh reported that among the physiological properties, the skin colour of the mango fruits and overall appearance are the vital characteristic for marketing as it makes the commodity more attractive and acceptable by the consumer. Therefore, they reported that fruit salt treated was normal but so attractive and significantly different from the control.

4.4.7 Effect of hot water and calcium chloride and storage conditions on the chilling injury of Keitt mango and Cavendish banana fruits from Mozambique

The chilling injury attribute associated with the visible appearance properties of fruit products are important aspects to be considered for the consumer acceptance. The chilling injury scores of Keitt mangoes and Cavendish bananas given by the panelists are presented in Tables 17a and 17b. In these tables, the fruit chilling injury on the experiment establishment day was not assessed, but scores of the banana and mango fruits pulp were increasing from the beginning of measurement until condition the fresh fruit could not be eaten or visually was broken.

Although banana fruits (Table 17a) from Manica presented low chilling injury scores, statistical differences ($p < 0.05$) were not reported between native fruit. Besides, there was a significant increase of chilling injury scores for the untreated compared to the treated banana samples. The calcium chloride treatment had better scores during the time of experiment measurement with statistical differences ($p < 0.05$) on fourth day. Statistical differences ($p < 0.05$) were found between storage conditions on fourth, eighth and twelfth days of banana storage time showing samples kept on refrigerator presenting low chilling injury scores.

From the table 17b, mango fruit increasing chilling injury scores was reported in all samples collected in different regions of the country without statistical differences. There were found significant statistic differences ($p < 0.05$) between postharvest treatments on fourth day of mango fruit storage time showing the calcium chloride treatment presenting better scores. Statistical differences ($p < 0.05$) were, found between storage conditions on fourth and eighth days of mango storage time showing samples kept on refrigerator presenting low scores.

Table 17a. Chilling injury of Cavendish bananas from different regions of Mozambique subjected to different treatment and stored in different conditions

Fruit native	Postharvest treatment	Storage conditions	Banana fruit storage days					
			0	4	8	12	16	20
Gaza	cc	freez	0.00	0.96^{Ddd}	2.91^{Ddd}	3.35^{Ddd}	4.26^{Ddd}	NA
Gaza	cc	refrig	0.00	0.90^{Dde}	2.70^{Dde}	3.25^{Dde}	3.79^{Ddd}	4.13^{Ddd}
Gaza	cc	rt	0.00	0.98^{Ddd}	2.85^{Ddd}	3.50^{Ddd}	4.15^{Ddd}	NA
Gaza	hw	freez	0.00	1.46^{Ded}	3.41^{Ddd}	3.85^{Ddd}	NA	-
Gaza	hw	refrig	0.00	1.40^{Dee}	3.20^{Dde}	3.65^{Dde}	4.05^{Ddd}	NA
Gaza	hw	rt	0.00	1.49^{Ded}	3.35^{Ddd}	4.10^{Ddd}	NA	-
Gaza	control	freez	0.00	1.38^{Ded}	3.13^{Ddd}	3.57^{Ddd}	NA	-
Gaza	control	refrig	0.00	1.20^{Dee}	2.92^{Dde}	3.37^{Dde}	4.01^{Ddd}	NA
Gaza	control	rt	0.00	2.50^{Ded}	3.99^{Ddd}	NA	-	-
Manica	cc	freez	0.00	0.40^{Ddd}	2.35^{Ddd}	2.79^{Ddd}	3.40^{Ddd}	3.52
Manica	cc	refrig	0.00	0.34^{Dde}	2.14^{Dde}	2.59^{Dde}	3.23^{Ddd}	3.57
Manica	cc	rt	0.00	0.42^{Ddd}	2.29^{Ddd}	2.94^{Ddd}	3.59^{Ddd}	4.10
Manica	hw	freez	0.00	0.99^{Ded}	2.85^{Ddd}	3.29^{Ddd}	3.95^{Ddd}	NA
Manica	hw	refrig	0.00	0.84^{Dee}	2.64^{Dde}	3.09^{Dde}	3.87^{Ddd}	NA
Manica	hw	rt	0.00	0.92^{Ded}	2.79^{Ddd}	3.54^{Ddd}	4.10^{Ddd}	NA
Manica	control	freez	0.00	0.62^{Ded}	2.57^{Ddd}	3.01^{Ddd}	4.20^{Ddd}	NA
Manica	control	refrig	0.00	0.64^{Dee}	2.36^{Dde}	2.81^{Dde}	3.85^{Ddd}	NA
Manica	control	rt	0.00	1.94^{Ded}	3.43^{Ddd}	3.90^{Ddd}	NA	-
Nampula	cc	freez	0.00	0.55^{Ddd}	2.50^{Ddd}	2.94^{Ddd}	3.85^{Ddd}	4.32
Nampula	cc	refrig	0.00	0.49^{Dde}	2.29^{Dde}	2.74^{Dde}	3.38^{Ddd}	3.72
Nampula	cc	rt	0.00	0.57^{Ddd}	2.44^{Ddd}	3.09^{Ddd}	3.74^{Ddd}	NA
Nampula	hw	freez	0.00	1.05^{Ded}	3.00^{Ddd}	3.44^{Ddd}	3.95^{Ddd}	NA
Nampula	hw	refrig	0.00	0.99^{Dee}	2.79^{Dde}	3.10^{Dde}	3.33^{Ddd}	3.54
Nampula	hw	rt	0.00	1.09^{Ded}	2.94^{Ddd}	3.24^{Ddd}	3.99^{Ddd}	NA
Nampula	control	freez	0.00	0.79^{Ded}	2.72^{Ddd}	3.16^{Ddd}	3.85^{Ddd}	NA
Nampula	control	refrig	0.00	0.69^{Dee}	2.51^{Dde}	2.86^{Dde}	3.87^{Ddd}	NA
Nampula	control	rt	0.00	2.09^{Ded}	2.99^{Ddd}	3.40^{Ddd}	4.20^{Ddd}	NA

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refri - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA – fruit sample not acceptable to be eaten.

Mohammed & Brecht (2002) reported that common symptoms of chilling injury in tropical and subtropical fruits are pitting, discoloration, water-soaked appearance, internal breakdown, failure to ripen, off-flavor, and decay. Symptom development depends not only on species and cultivars, but also on maturity, types of tissues, and environmental factors.

Table 17b. Chilling injury of Keitt mangoes from different regions of Mozambique subjected to different treatment and stored in different conditions

Fruit	Postharvest	Storage	Mango fruit storage days					
native	treatment	conditions	0	4	8	12	16	20
Gaza	cc	freez	0.00	$1.52^{\mathrm{Ba}a}$	$3.16^{\mathrm{Ba}a}$	$3.58^{\mathrm{Ba}a}$	$4.40^{\mathrm{Ba}a}$	NA
Gaza	cc	refrig	0.00	$1.54^{\mathrm{Ba}a}$	$2.75^{\mathrm{Ba}b}$	$3.33^{\mathrm{Ba}b}$	$3.41^{\mathrm{Ba}a}$	$4.89^{\mathrm{Ba}a}$
Gaza	cc	rt	0.00	$1.46^{\mathrm{Ba}a}$	$3.2^{\mathrm{Ba}a}$	$3.69^{\mathrm{Ba}a}$	$4.35^{\mathrm{Ba}a}$	NA
Gaza	hw	freez	0.00	$2.22^{\mathrm{Bb}a}$	$4.17^{\mathrm{Ba}a}$	NA	-	-
Gaza	hw	refrig	0.00	$2.24^{\mathrm{Bb}a}$	$2.96^{\mathrm{Ba}b}$	$3.31^{\mathrm{Ba}b}$	$4.81^{\mathrm{Ba}a}$	NA
Gaza	hw	rt	0.00	$2.16^{\mathrm{Bb}a}$	$4.11^{\mathrm{Ba}a}$	NA	-	-
Gaza	control	freez	0.00	$1.94^{\mathrm{Bb}a}$	$3.89^{\mathrm{Ba}a}$	NA	-	-
Gaza	control	refrig	0.00	$1.96^{\mathrm{Bb}a}$	$2.63^{\mathrm{Ba}b}$	$3.10^{\mathrm{Ba}b}$	$3.45^{\mathrm{Ba}a}$	$4.33^{\mathrm{Ba}a}$
Gaza	control	rt	0.00	$3.26^{\mathrm{Bb}a}$	$4.75^{\mathrm{Ba}a}$	NA	-	-
Manica	cc	freez	0.00	$1.31^{\mathrm{Ba}a}$	$3.05^{\mathrm{Ba}a}$	$3.45^{\mathrm{Ba}a}$	$4.0^{\mathrm{Ba}a}$	NA
Manica	cc	refrig	0.00	$1.33^{\mathrm{Ba}a}$	$2.95^{\mathrm{Ba}b}$	$3.25^{\mathrm{Ba}b}$	$3.9^{\mathrm{Ba}a}$	$4.31^{\mathrm{Ba}a}$
Manica	cc	rt	0.00	$1.25^{\mathrm{Ba}a}$	$3.20^{\mathrm{Ba}a}$	$3.85^{\mathrm{Ba}a}$	$4.5^{\mathrm{Ba}a}$	NA
Manica	hw	freez	0.00	$1.81^{\mathrm{Bb}a}$	$3.56^{\mathrm{Ba}a}$	$3.78^{\mathrm{Ba}a}$	NA	-
Manica	hw	refrig	0.00	$1.83^{\mathrm{Bb}a}$	$3.45^{\mathrm{Ba}b}$	$3.68^{\mathrm{Ba}b}$	$4.33^{\mathrm{Ba}a}$	NA
Manica	hw	rt	0.00	$1.75^{\mathrm{Bb}a}$	$3.70^{\mathrm{Ba}a}$	$3.86^{\mathrm{Ba}a}$	NA	-
Manica	control	freez	0.00	$1.53^{\mathrm{Bb}a}$	$3.48^{\mathrm{Ba}a}$	$3.92^{\mathrm{Ba}a}$	NA	-
Manica	control	refrig	0.00	$1.55^{\mathrm{Bb}a}$	$2.57^{\mathrm{Ba}b}$	$3.72^{\mathrm{Ba}b}$	$4.25^{\mathrm{Ba}a}$	NA
Manica	control	rt	0.00	$2.85^{\mathrm{Bb}a}$	$3.75^{\mathrm{Ba}a}$	NA	-	-
Nampula	cc	freez	0.00	$1.16^{\mathrm{Ba}a}$	$3.11^{\mathrm{Ba}a}$	$3.55^{\mathrm{Ba}a}$	$4.16^{\mathrm{Ba}a}$	
Nampula	cc	refrig	0.00	$1.18^{\mathrm{Ba}a}$	$2.90^{\mathrm{Ba}b}$	$3.35^{\mathrm{Ba}b}$	$3.45^{\mathrm{Ba}a}$	
Nampula	cc	rt	0.00	$1.10^{\mathrm{Ba}a}$	$3.05^{\mathrm{Ba}a}$	$3.70^{\mathrm{Ba}a}$	$4.35^{\mathrm{Ba}a}$	NA
Nampula	hw	freez	0.00	$1.66^{\mathrm{Bb}a}$	$3.61^{\mathrm{Ba}a}$	$3.76^{\mathrm{Ba}a}$	$4.25^{\mathrm{Ba}a}$	NA
Nampula	hw	refrig	0.00	$1.68^{\mathrm{Bb}a}$	$3.40^{\mathrm{Ba}b}$	$3.45^{\mathrm{Ba}b}$	$4.26^{\mathrm{Ba}a}$	NA
Nampula	hw	rt	0.00	$1.60^{\mathrm{Bb}a}$	$3.55^{\mathrm{Ba}a}$	$4.30^{\mathrm{Ba}a}$	NA	-
Nampula	control	freez	0.00	$1.38^{\mathrm{Bb}a}$	$3.33^{\mathrm{Ba}a}$	$4.21^{\mathrm{Ba}a}$	NA	-
Nampula	control	refrig	0.00	$1.40^{\mathrm{Bb}a}$	$3.12^{\mathrm{Ba}b}$	$3.57^{\mathrm{Ba}b}$	$4.15^{\mathrm{Ba}a}$	NA
Nampula	control	rt	0.00	$2.70^{\mathrm{Bb}a}$	$4.19^{\mathrm{Ba}a}$	NA	-	-

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refri - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each column, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. NA – fruit sample not acceptable to be eaten.

Other factors affecting the susceptibility to chilling injury include the origin of the crop, genetic makeup of the commodity, stage of development or maturity, metabolic status of the tissue, and a number of environmental factors such as temperature, light, relative humidity, and atmospheric composition.

The finding of this present work samples pitting and peel discoloration was slightly reported on mango and banana fruits from the regions of high production. The pitted areas superimposed on slightly brown areas became more obvious and widespread in the end of the experiment when the samples were at room temperature followed by freezing storage conditions.

Amin & Hossain (2013) observed that the chilling injury percentage of banana fruits of *BARI Kola 1* and *Sabri Kola* increased drastically with the increased of exposure time at 57 °C and the lowest decay of treated fruits of both varieties was observed zero in treatments of 47 °C for 19 and 21 minutes. Ezz & Awad (2011) reported that mean fruit decay percentage markedly increased with increasing storage temperature and hot water immersion treatment was effective in decreasing the severity of many common physiological skin disorders, such as darkened lenticels (small black spots) and anthracnose.

Similar trends were reported by Mohammed & Brecht (2002) assessing the reduction of chilling injury in 'Tommy Atkins' mangoes during ripening and Ranjbar *et al*. (2007) evaluating the effects of calcium chloride, hot water treatment and polyethylene bag packaging on pomegranate who reported that samples treatment caused improvement in the general quality of stored fruit and decreased chilling index as reported in this work.

4.4.8 Effect of hot water and calcium chloride and storage conditions on the shelf-life of Keitt mango and Cavendish banana fruits from Mozambique

The date from fruit harvesting to last edible stage known as shelf-life of Keitt mangoes and Cavendish bananas collected in different regions of Mozambique, subjected to different postharvest treatment and stored in different conditions is presented in Figure 19. In this Figure, the results showed that banana shelf-life was varying depending on location of fruit collection where bananas from Manica followed by Nampula presented high shelf-life and were not statistically ($p < 0.05$) different.

Postharvest treatment was, statistically affecting the banana shelf-life showing calcium chloride presenting longer samples shelf-life followed by hot water and the control. Besides, storage conditions presented statistical effect ($p < 0.05$) on the Cavendish bananas shelf-life showing refrigerator better than freezing and room temperature storage conditions. Therefore, short Cavendish banana fruits shelf-life were obtained in samples from Gaza untreated and kept in freezing storage conditions (shelf-life = 15 days) and high values were obtained in samples from Manica and treated with calcium chloride and kept on refrigerator storage conditions (shelf-life = 25 days).

Still in Figure 19, mangoes shelf-life varied depending on location of fruit collection where statistic differences ($p < 0.05$) were found on mangoes from different regions and samples from Nampula presented longer shelf-life than others Mozambique regions. Mangoes shelf-life was, statistically affected ($p < 0.05$) by postharvest treatment showing calcium chloride presenting longer samples shelf-life followed by hot water and the control. Furthermore, storage conditions showed significant effect on the Keitt mangoes fruits shelf-life showing refrigerator storage conditions better than others conditions.

Therefore, low Keitt mangoes shelf-life were obtained in samples from Gaza untreated and kept at room temperature storage conditions (shelf-life = 11 days) and high values were obtained in samples from Nampula and treated with calcium chloride and kept on refrigerator storage conditions (shelf-life = 27 days). This was expected since 8°C is an adequate temperature for mango banana storage and do not block fruits metabolism and also sample treatment, perhaps, retarded the physiological and biological activities and finally led to the longest shelf-life.

Lima *et al.* (2014) assessing the ripening and shelf life of 'BRS Caipira' banana fruit stored under room temperature or refrigeration reported that cold storage affected fruit ripening and total storage time was extended by five to 19 days due to cold storage when compared with control (no cold storage), without chilling injury to the fruit. Amin & Hossain (2013) reported that shelf-life of *BARI Kola 1* and *Sabri Kola* banana varieties increased gradually with the increase of treatment exposure period and high water temperature caused burning of the skin and damage of the fruit tissues. Mahmud *et al.* (2015) assessing the effects of CaC_2 and different calcium salt on mango fruits ripening in Bangladesh reported delayed ripening with $CaCl_2.2H_2O$ than the control, $CaSO_4.2H_2O$ and $Ca[NH_4NO_3]_2$.

Similar findings were reported by Baloch & Bibi (2012) assessing the storage conditions on mango (*Mangifera indica* L.), Ezz & Awad (2011) analysing the some post harvest treatments on two mango cultivars, Anwar & Malik (2007) assessing the hot water treatment on storage life of mango (*Mangifera indica* L.) and Mahmud *et al.* (2008) evaluating different concentrations and applications of calcium on papaya (*Carica papaya* L.) who also, noticed that fruit shelf life decreased with increasing storage period.

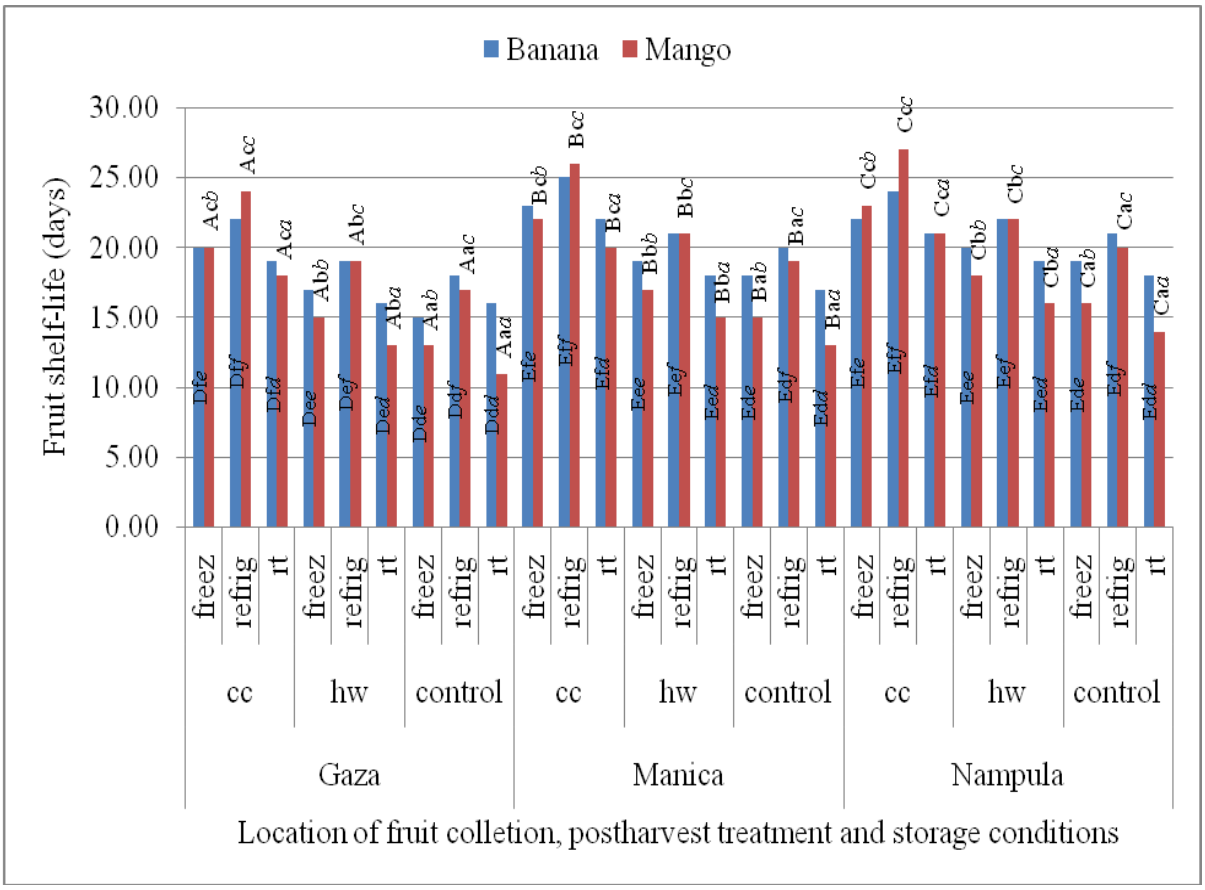

Figure 19. Shelf-life of Keitt mangoes and Cavendish bananas from different regions of Mozambique

hw - hot water temperature (ºC); cc - calcium chloride concentration (%); control - untreated fruit; freez - freezing storage conditions (-1.0 ± 0.3 ºC); refrig - refrigeration conditions (8.0 ±0.2 ºC); rt - room temperature (in non-controlled storage temperature conditions). Each bar, means followed by the same script capital letter are not significantly different ($p < 0.05$) between location of sample collection (fruit native), the lower case between postharvest treatment and italic lower case between storage conditions by Tukey test. Where *a*, *b* and *c* for mango and *d*, *e* and *f* for banana fruits.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions of the study in terms of raw material characterization, post-harvest treatment (hot water dipping and calcium chloride) optimization and the effect of these post-harvest treatments on the ripening and shelf life of Cavendish banana and Keitt mango fruits from Mozambique. Also, the recommendations related to the study carried out are presented.

All evaluated fruits have very close physicochemical characteristics, with desirable qualities for consumption, whether in their native state or processed. This study showed, also that, the quality aspects such as fruit firmness, soluble solids concentrations, ascorbic acid, sensory attributes and chilling injury of Keitt mango and Cavendish banana fruits from Mozambique underwent changes in function of postharvest treatment, storage time and conditions, and therefore, extended fruit shelf-life.

5.1 Conclusions

1. The results obtained in the present study demonstrated that there are differences for mangoes as well as bananas of the same variety, produced and marketed in different regions of Mozambique. This fact must have occurred as a consequence of the form of cultivation (fertilization, irrigation and soil fertility), providing better product quality and better profitability for Keitt mangoes from Nampula and Cavendish bananas from Manica.

    i. Therefore, the null hypothesis at $p < 0.05$ level of significance can be rejected because there are significant differences between Keitt mango and Cavendish banana characteristics of these fruits from Mozambique.

2. The central composite design (CCD) allowed to conclude that the optimization process of Keitt mango and Cavendish banana fruits was affected by hot water dipping and calcium chloride treatment concentration and the methodology of simultaneous optimization using desirability function as applied in this study proved to be an efficient statistics tool in maintaining b* mango colour attribute, reducing fruit pH and maximizing fruit titratable acidity and also, maximizing the banana fruit firmness and maintaining the ash and vitamin C content and the optimum obtained was 55ºC of hot water temperature and 3% of calcium chloride concentration.

    ii. Therefore, the null hypothesis at $p < 0.05$ level of significance can be rejected because there is optimized point of hot water temperature dipping and calcium chloride concentration treatment in order to delay ripening of climacteric Keitt mango and Cavendish banana fruits from Mozambique.

3. The use of optimized hot water dipping and calcium treatment to delineate adoption as a postharvest technology on the basis of fruit ripening is the major aspect of this study. This study examined the effect of these technologies on the dfferent fuit maturity stage in order to delay ripening showing calcium chloride treatment presenting better results for both mango and banana fruits. Green-yellow Keitt mangoes from Nampula and green-yellow Cavendish banananas from Manica showed improvement of their qualities to the consumer and can be extendend to Mozambique small and medium enterprises.

   iii. Therefore, the null hypothesis at $p < 0.05$ level of significance can be rejected because, for optimized hot water temperature and calcium chloride concentration, there are significant differences between physico-chemical parameters and sensory attributes on the ripening of Keitt mango and Cavendish banana fruits from Mozambique.

4. High Cavendish banana fruits shelf-life were obtained in samples from Manica and treated with calcium chloride and kept on refrigerator storage conditions where the shelf-life increased from 17 days up to 25 days. Farther, Keitt mangoes shelf-life in samples from Nampula and treated with calcium chloride and kept on refrigerator storage conditions was improved from 13 days up to 27 days.

   iv. Therefore, the null hypothesis at $p < 0.05$ level of significance can be rejected because, for optimized hot water temperature and calcium chloride concentration, there are significant differences between physico-chemical parameters and sensory attributes on the shelf-life of Keitt mango and Cavendish banana fruits from Mozambique.

5.2 Recommendations

Mango and banana are major fruits growing in Mozambique mostly by the small-holder farmers. They are living tissues and perishable products that require coordinated activity to maintain quality, reduce food loss and enhance the shelf life. This study, used fruit dip treatment either in hot water or calcium chloride solution after optimization of those postharvest treatments and characterization of the mango and banana raw material, then stored in refrigerator or in the fridge to understand the best technique that delay the fruit ripening and improve shelf-life. The results showed enhancement of the quality of banana and mangoes on calcium chloride treatment and refrigerator storage conditions with a possibility to be adopted as the techniques by the fruit industry chain. Therefore, the following recommendation can be made from this study:

1. Further studies are necessary considering the pros (effective) and cons (cost) of hot water dipping and/or calcium treatment, and the potential time and temperature-controlled quality of these postharvest treatments for the farmers. Evaluation of feasibility and financial benefits of the mentioned postharvest technologies to the producers has not been documented properly.
2. The result of the study may assist the relevant institutions (government, non-government and education) in planning and organizing SMEs programs to include hot water dipping and/or calcium treatment in fruit post harvesting management activities.
3. The results may serve, also, as a way of sensitizing all the stakeholders in the Mozambique about the importance of post harvesting pretreatment and fruit stage ripeness skills for fruit producers or community leaders for proper integration in their community, organizations and cooperatives work.
4. The study may also be used to sensitize community-based organizations and cooperatives in rural areas and put emphasis on the need for every fruit producer to be knowledgeable, skilled and trained in fruit post harvesting treatment namely, hot water dipping and/or calcium treatment.

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APPENDICES

Appendix 1: Scientific contribution of the current study/Journal Publication

Title of the paper: Physico-chemical Characterization of Keitt Mango and Cavendish Banana Fruits Produced in Mozambique

Journal: Food and Nutrition Sciences, 2018, 9, 556-571

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Abstract

Mangoes (*Mangifera indica*) and bananas (*Musa acuminata*) are climacteric fruits with a high potential for export due to their exotic aroma and sweet taste. This study aimed to characterize the physical and chemical parameters of Keitt mangoes and Cavendish bananas from different regions of Mozambique. The fruits were collected from Gaza, Manica and Nampula districts of south, central and north parts of Mozambique, respectively. The banana and mango samples were collected Mid-August 2016 and in January 2017, respectively. The fruits collected were at three different maturity stages (green, green-yellowish an yellow). The sample materials were characterised according to their proximate composition, size, weight, firmness and colour. Analyses of soluble solids and ascorbic acid were, also, performed. The results revealed that the parameters were a good indicator of the maturity stage as well as for multivariate mango and banana applications and consumption. The parameters confirmed that mango fruits with low moisture (green with 83.62%), and fibers (0.44%), high ash (2.05%) crude lipids (0.29%), protein (0.85%) and carbohydrate (13.81%), high total soluble solids (24.60%), and high vitamin C content (14.83mg/100g) were collected in Nampula. However, banana fruits with low moisture (73.18%) and fibers (0.27%), high crude proteins (3.44%), ash (0.58%), and crude lipids content (4.92%), high total soluble solids (24.50%) and vitamin C content (2.40mg/100g) were collected in Manica. This is the first time that Keitt mangoes and Cavendish bananas fruits have been characterized either in relation to the region of production in Mozambique or in relation to the various stages of maturity. This information can be exploited by various actors along the mango and banana value chain.

Keywords

Mangifera indica; *Musa acuminata*; Quality; Physicochemical characteristics; Maturity stage; Mozambique geographic regions.

Appendix 2: Scientific contribution of the current study/Journal Publication

Title of the paper: Optimization of Hot Water Temperature Dipping and Calcium Chloride Treatment to the Selected Physico-Chemical Parameters of Keitt Mango and Cavendish Banana Fruits

Journal: Food and Nutrition Sciences, 2017, 8, 908-931

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Abstract

Mango (*Mangifera indica* L.) and banana (*Musa acuminata*) are the most popular fruits in the world and widely cultivated crops in the tropical and subtropical zones. Keitt mangoes and Cavendish bananas are the largest cultivar of these fruits found in the Mozambique market. They are only available for a short period each year mostly during the late summer and early falls. Due to mango and banana fruits high water activity and respiration rate, are perishable foods and requires conservation methods for preservation and availability. The aim of this study was to optimize the hot water-calcium chloride concentration treatment regime for improved postharvest handling of mangoes and bananas. The fruits collected were of uniform size, and at green-yellowish maturity stage based on lengh, diameter, colour and firmness. The process was optimized by experimental central composite design using hot water temperature (50 ºC – 60 ºC) and calcium chloride concentration (2% - 4%) with the aid of desirability function. The samples were analyzed for the proximate composition, firmness, colour, ºBrix, WA, pH, titratable acidity and vitamin C. The results showed that hot water temperature and calcium chloride concentration were influent on the Keitt mangoes b^* colour attribute, pH and tritratable acidity as well as the Cavendish bananas firmness, ash and vitamin C content. The optimal conditions of the process were stabilized with the desirable function and, coincidentally for both crops, obtained at 55 ºC of hot water temperature dipping and 3% of calcium chloride concentration. The simulated data were similar to the experimental ones. This is the first time that calcium chloride-hot water treatment is being reported as a means of extending the shelf-life of mangoes and bananas.

Keywords

Mangifera, *Musa*, Optimization, Central Composite Design, Desirability Function

Appendix 3: Scientific contribution of the current study/Journal Publication

Title of the paper: Effect of Hot Water Dipping and Calcium Treatment on the Shelf-Life of Banana and Mango Fruits from Mozambique

Journal: Journal of Food Science, 2018, *, *-*

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Abstract

Mangoes and bananas are considered perishable fruits. This study aimed to determine the effects of postharvest hot water dipping and calcium treatment applications on the changes in fruit firmness, soluble solids concentrations, ascorbic acid content and chilling injury and overall shelf-life of Keitt mango and Cavendish banana fruits. These fruits were collected from Gaza, Manica and Nampula provinces of south, central and north parts of Mozambique, respectively. The bananas and mangoes samples were collected Mid-August 2016 and in January 2017, respectively. They were of uniform size, weight, colour and firmness and at green-yellowish maturity stage. Whole fruits dip treatment was conducted for 5 minutes, separately, in two stainless steel equipment (pan) having either hot water (55 ºC) or calcium solution (3 % at 40 ºC) then stored in refrigerator (8.0 ±0.2 ºC) or in the fridge (-1.0 ± 0.3 ºC) for 20 days. The control samples were included under the same conditions. The results indicated that, as the chilling injury scores increased was reported fruit firmness maintenance, total solid soluble increase, vitamin C content decrease and high shelf-life in samples treated with calcium chloride and kept on refrigerator storage conditions better fit. These qualities were reported in bananas from Manica and mangoes from Nampula where the shelf-life time reached 25 and 27 days, respectively. This is the first time that Mozambique mangoes and bananas fruits have been assessed neither in the postharvest treatment nor storage conditions. The study can potentially lead to a considerable economic benefit to the fruit industry by providing valuable information to extend shelf-life of bananas and mangoes.

Keywords: *Mangifera indica*; *Musa acuminata*; Mozambique geographic regions; Postharvest treatments; Storage conditions; Fruit shelf-life.

Appendix 4: Scientific contribution of the current study/Journal Publication

Title of the paper: Evaluation of Postharvest Hot Water Dipping and Calcium Treatment on the Titratable Acidity and Chilling Injury of Banana and Mango Fruits from Mozambique;

Journal: African Journal of Rural Development, 2018, *, *-*

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Abstract

Mangoes and bananas are considered perishable fruits. The present work aimed to evaluate the effect of postharvest hot water dipping and calcium treatment applications on the changes in fruit titratable acidity and overall chilling injury of banana and mango fruits from Mozambique and kept in different storage conditions. These fruits were collected in Gaza, Manica and Nampula provinces of south, central and north parts of Mozambique, respectively. The bananas and mangoes samples were collected mid-august 2016 and in January 2017 respectively on uniform weight, colour, size and firmness and at green-yellowish stage of maturity. Whole fruits dip treatment was conducted for 5 minutes, separately, in two stainless steel equipment (pan) having either hot water (55 ^{o}C) or calcium solution (3 % at 40 ^{o}C) then stored in refrigerator (8.0 ± 0.2^{o}C) or in the fridge (-1.0 ± 0.3 ^{o}C) for 20 days. The control samples were included under the same conditions. The result indicated that, as the chilling injury scores increased was reported fruit titratable acidity increase from the first measurement till the time in which the product was not in conditions of consumption and samples treated with calcium chloride and kept on refrigerator storage conditions better fitted. These qualities were recorded in bananas from Manica and mangoes from Nampula where the shelf life time reached 25 and 27 days, respectively. The work is the first study in what Mozambique mangoes and bananas fruits have been assessed neither using these postharvest treatment nor these storage conditions. This study can bring economical benefits to the industry of fruits supplying valuable information of fruit qualities to increase the shelf-life of bananas and mangoes.

Keywords: *Mangifera indica*; *Musa acuminata*; Mozambique geographic regions; postharvest treatments; Storage conditions; chilling injury.

Appendix 5: Model of ballot used on the acceptance test of samples submitted to post harvest treatment at different maturity stage

Affective test

Name: ____ Data: _____________

Age: ________ Gender: ( ) Female ( ) Male

You are receiving a coded sample of fruit. Evaluate its flavour, sweetness, astringency and overall acceptance by marking using the scale below to describe your feelings in accordance to the attributes mentioned. Drink water between samples.

	Sample	Flavour	Sweetness	Astringency	Overall acceptance
1 = very low	(Code)	(Value)	(Value)	(Value)	(Value)
2 = low	__________	______	______	______	______
3 = moderate	__________	______	______	______	______
4 = high	__________	______	______	______	______
5 = very high	__________	______	______	______	______
	__________	______	______	______	______
	__________	______	______	______	______

Suggestions/Comments:

____

____

Appendix 6: Model of ballot used on the acceptance test of samples submitted to post harvest treatment and storage conditions

Affective test

Name: ____ Data: ___________

Age: _______ Gender: ( ) Female ( ) Male

Please evaluate the sample using the scale below to describe how much do you feel in accordance to the attributes mentioned. Drink water between samples.

	Sample (Code)	Flavour (Value)	Astringency (Value)	Overall acceptance (Value)
	________	_____	_____	_____
	________	_____	_____	_____
1 = very low	________	_____	_____	_____
2 = low	________	_____	_____	_____
3 = moderate	________	_____	_____	_____
4 = high	________	_____	_____	_____
5 = very high	________	_____	_____	_____
	________	_____	_____	_____
	________	_____	_____	_____

Suggestions/Comments:

____

____

Appendix 7: Model of ballot used on the chilling injury test of samples submitted to post harvest treatment and storage conditions

Visible chilling injury test

Name: ____ Data: ___________

Age: _______ Gender: ( ) Female ( ) Male

Please see the samples and evaluate them using the scale below to describe how it looks in accordance to the attributes mentioned.

	Sample (Code)	Chilling injury (Value)
	________	_____
	________	_____
0 = none	________	_____
1 = slight injury	________	_____
2 = moderate injury	________	_____
3 = moderate to severe injury	________	_____
4 = severe injury	________	_____
5 = spoiled (damaged) fruit.	________	_____
	________	_____

Suggestions/Comments:

____

____

Appendix 8: Effect of central composite design variables

Table 5ba: Effect of central composite design variables on the proximate composition of Cavendish banana fruits

Variable	Moisture	Ash	Lipids	Protein	Fiber	Carbohy
R^2	0.74	0.93	0.76	0.26	0.66	0.57
Average	80.10	0.63	1.94	2.59	1.86	12.88
X_1	-2.94	0.01	-0.39	0.33	0.14	2.86
X_1^2	-5.84*	-0.08*	0.24	0.22	0.81	4.65
X_2	1.54	0.02	-0.43	-0.26	0.06	-0.93
X_2^2	-5.26*	0.08*	0.21	0.46	0.28	4.22
X_1X_2	0.16	-0.09*	-1.27*	0.73	2.05*	-1.58

*Significant effects at 95% confidence level. X_1 and X_2 correspond to the independent variable. X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration (%); X_1^2 and X_2^2 are the variable quadratic coefficients; X_1X_2 is the coefficients of interaction between independent variables and R^2 is the determination coefficient. Ma – mango fruits; Ba – Banana fruits.

Table 5bb: Effect of central composite design variables on the proximate composition of Keitt mango fruits

Variable	Moisture	Ash	Lipids	Protein	Fiber	Carbohy
R^2	0.76	0.62	0.71	0.26	0.66	0.56
Average	84.96	0.16	0.27	0.52	1.86	12.39
X_1	0.84	0.02	0.07	0.07	0.14	-1.13
X_1^2	0.09	-0.02	-0.01	0.05	0.81	-1.11
X_2	1.72	-0.03	0.09*	-0.05	0.06	-1.74
X_2^2	-2.55*	-0.01	0.05	0.09	0.28	2.03
X_1X_2	-1.01	0.03	0.07	0.15	2.03*	-1.27

*Significant effects at 95% confidence level. X_1 and X_2 correspond to the independent variable. X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration (%); X_1^2 and X_2^2 are the variable quadratic coefficients; X_1X_2 is the coefficients of interaction between independent variables and R^2 is the determination coefficient. Ma – mango fruits; Ba – Banana fruits.

Table 6ba: Effect of central composite design variables on the firmness and colour attributes of Cavendish banana fruits

Variable	Firmness	L*	a*	b*
R^2	0.95	0.20	0.79	0.73
Average	7.75	43.84	-35.81	40.08
X_1	-1.41*	0.21	1.79*	-2.04*
X_1^2	1.00*	-0.03	-0.18	-0.32
X_2	-0.32	-0.63	-1.48*	0.81
X_2^2	-0.17	-0.18	0.00	-0.01
X_1X_2	-0.17	0.10	-1.93	1.50

*Significant effects to 95% confidence level. X_1 and X_2 correspond to the independent variable. X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration (%); X_1^2 and X_2^2 are the variable quadratic coefficients; X_1X_2 is the coefficients of interaction between independent variables and R^2 is the determination coefficient; L, a^* and b^* are the colour attributes.

Table 6bb: Effect of central composite design variables on the firmness and colour attributes of Keitt mango fruits

Variable	Firmness	L*	a*	b*
R^2	0.75	0.56	0.68	0.83
Average	11.43	43.58	-1.93	20.07
X_1	-2.37	0.06	-0.32	-1.37*
X_1^2	-4.16	-1.10*	-4.37	-0.24
X_2	-0.76	-0.07	-0.37	0.40
X_2^2	-2.66	-0.66	0.78	-1.27*
X_1X_2	6.73*	-0.06	-6.14*	2.31*

*Significant effects to 95% confidence level. X_1 and X_2 correspond to the independent variable. X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration (%); X_1^2 and X_2^2 are the variable quadratic coefficients; X_1X_2 is the coefficients of interaction between independent variables and R^2 is the determination coefficient; L, a^* and b^* are the colour attributes.

Table 7ba: Effect of central composite design variables on the ºBrix, WA, TA and vitamin C of Cavendish banana fruits

Variable	Brix	WA	pH	TA	Vit. C
R^2	0.18	0.57	0.64	0.64	0.80
Average	16.06	0.92	4.84	0.17	1.68
X_1	0.48	0.01	0.18	0.00	-0.11*
X_1^2	-0.47	0.00	0.62	-0.04*	-0.21
X_2	-0.19	0.01	-0.11	-0.01	-0.15
X_2^2	-0.39	-0.04	0.59	0.00	0.29
X_1X_2	0.08	-0.02	-0.59	-0.03	-0.57*

*Significant effects to 95% confidence level. X_1 and X_2 correspond to the independent variable. X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration (%); X_1^2 and X_2^2 are the variable quadratic coefficients; X_1X_2 is the coefficients of interaction between independent variables; R^2 is the determination coefficient; WA is the water activity; pH is the potential hydrogenionic; TA is the titratable acidity (%) and Vit. C is the vitamin C content (mg/100g).

Table 7bb: Effect of central composite design variables on the ºBrix, A_w, TA and vitamin C of Keitt mango fruits

Variable	Brix	A_w	pH	TA	Vit. C
R^2	0.34	0.57	0.84	0.80	0.18
Average	14.36	0.97	4.05	0.07	11.40
X_1	0.02	0.00	0.03	-0.03*	-0.13
X_1^2	0.17	0.01	1.06*	0.01	0.29
X_2	-0.23	-0.01	-0.33	0.01	-0.19
X_2^2	0.10	0.00	0.57*	0.02	1.50
X_1X_2	0.27	-0.01	-0.02	-0.01	0.83

*Significant effects to 95% confidence level. X_1 and X_2 correspond to the independent variable. X_1 is the hot water temperature (ºC); X_2 is the calcium chloride concentration (%); X_1^2 and X_2^2 are the variable quadratic coefficients; X_1X_2 is the coefficients of interaction between independent variables; R^2 is the determination coefficient; A_w is the water activity; pH is the potential hydrogenionic; TA is the titratable acidity (%) and Vit. C is the vitamin C content (mg/100g).

ANNEXES

Annex 1: Copy of research authorization

NATIONAL COMMISSION FORSCIENCE, TECHNOLOGY ANDINNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website:www.nacosti.go.ke
Whenreplying pleasequote

9thFloor, Utalii House
Uhuru Highway
P.O.Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/17/35726/18493**

Date: **3rd August, 2017**

Dovel Branquinho Ernesto
Egerton University
P.O. Box 536-20115
EGERTON.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Effect of hot water and calcium treatment on the shelf life of keitt mangoes and cavendish bananas from Mozambique,"*** I am pleased to inform you that you have been authorized to undertake research in **Nakuru County** for the period ending **3rd August, 2018.**

You are advised to report to **the County Commissioner and the County Director of Education, Nakuru County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

Kalerwa

GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Nakuru County.

The County Director of Education
Nakuru County.

Annex 2: Copy of research clearance permit

CONDITIONS

1. The License is valid for the proposed research, research site specified period.
2. Both the Licence and any rights thereunder are non-transferable.
3. Upon request of the Commission, the Licensee shall submit a progress report.
4. The Licensee shall report to the County Director of Education and County Governor in the area of research before commencement of the research.
5. Excavation, filming and collection of specimens are subject to further permissions from relevant Government agencies.
6. This Licence does not give authority to transfer research materials.
7. The Licensee shall submit two (2) hard copies and upload a soft copy of their final report.
8. The Commission reserves the right to modify the conditions of this Licence including its cancellation without prior notice.

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH CLEARANCE PERMIT

Serial No.A 15267

CONDITIONS: see back page

THIS IS TO CERTIFY THAT:
MR. DOVEL BRANQUINHO ERNESTO
of EGERTON UNIVERSITY, 536-20115 Egerton, has been permitted to conduct research in *Nakuru County*

on the topic: *EFFECT OF HOT WATER AND CALCIUM TREATMENT ON THE SHELF-LIFE OF KEITT MANGOES AND CAVENDISH BANANAS FROM MOZAMBIQUE*

for the period ending:
3rd August,2018

Permit No : NACOSTI/P/17/35726/18493
Date Of Issue : 3rd August,2017
Fee Recieved :Ksh 4000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

Annex 3: Copy of research authorization for bananas from Nampula

ISPM

Instituto Superior Politécnico de Manica

DEPARTAMENTO DE RECURSOS HUMANOS

Guia de Marcha Nº 217/DRH/ISPM/029.2.1/16

Em missão de serviço segue a apresentar-se no distrito de Ribaue, província de Nampula, o senhor **Dovel Branquinho Ernesto** docente do ISPM, a fim de fazer pesquisa e colheita de dados por um período de cinco (05) dias, de 10 á 14 de Setembro de 2016.

Matsinho, aos 08 de Setembro de 2016

O chefe do Departamento de Recursos Humanos

Armando Francisco Tesoura

(dr. Armando Francisco Tesoura)

/Técnico Superior N1/

Declaração

Eu Dovel Br. Ernesto, com a categoria de Assistente, declaro que viajei em missão de serviço para a província Nampula Distrito de Ribaue, com partida no dia 10/09/2016, às 08:00 Horas e o regresso no dia 14/09/2016, às 13:00 Horas.

Edificio do centro cultural Acadêmico Montalto rua Dr Araújo de Lancerda R/c tel (+258)- 25124841, fax (+258)-25124847
Campus de Matsinho- Distrito de Gondola Estrada nacional N6 ,devio nas antennas km 4 Tel fax (+258) 25124425

Annex 4: Copy of research authorization for bananas from Gaza

ispm

Instituto Superior Politécnico de Manica

DEPARTAMENTO DE RECURSOS HUMANOS

Guia de Marcha N°200 /DRH/ISPM/029.2.1/16

Em missão de serviço segue a apresentar-se no distrito de Xai-Xai, o senhor **Dovel Branquinho Ernesto,** docente do ISPM a fim de realizar Actividades de Pesquisa por um período de seis (06) dias, de 24 a 29 de Agosto de 2016.

Matsinho, aos 22 de Agosto de 2016

O chefe do Departamento de Recursos Humanos

(dr. Armando Francisco Tesoura)
/Técnico Superior N1/

Declaração

Eu Dovel B. Ernesto, com a categoria de Assistente, declaro que viajei em missão de serviço para a província Gaza, Distrito de Xai-Xai, com partida no dia 24/08/16, às 07:00 Horas e o regresso no dia 29/08/16, às 13:00 Horas.

Edificio do centro cultural Acadêmico Montalto rua Dr Araújo de Lancerda R/c tel (+258)- 25124841, fax (+258)-25124847
Campus de Matsinho- Distrito de Gondola Estrada nacional N6 ,devio nas antennas km 4 Tel fax (+258) 25124425

DIRECÇÃO DE EDUCAÇÃO E CULTURA
DA CIDADE DE XAI-XAI

82 3935960

Annex 5: Copy of research authorization for bananas from Manica

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Instituto Superior Politécnico de Manica

DEPARTAMENTO DE RECURSOS HUMANOS

Guia de Marcha N° 214 /DRH/ISPM/029.2.1/16

Em missão de serviço segue a apresentar-se no distrito de Macate, o senhor **Dovel Branquinho Ernesto** docente do ISPM, a fim de fazer colheita de amostra de banana por um período de um (01) dia, 08 de Setembro de 2016.

Matsinho, aos 06 de Setembro de 2016

O chefe do Departamento de Recursos Humanos

(dr. Armando Francisco Tesoura)

/Técnico Superior N1/

Declaração

Eu Dovel B. Ernesto, com a categoria de Assistente, declaro que viajei em missão de serviço para a província Manica Distrito de Macate, com partida no dia 08/09/2016, às 07:00 Horas e o regresso no dia 08/09/2016, às 17:00 Horas.

Edificio do centro cultural Acadêmico Montalto rua Dr Araújo de Lancerda R/c tel (+258)- 25124841, fax (+258)-25124847
Campus de Matsinho- Distrito de Gondola Estrada nacional N6 ,devio nas antennas km 4 Tel fax (+258) 25124425

Annex 6: Copy of research authorization for mangoes from Nampula

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INSTITUTO SUPERIOR POLITÉCNICO DE MANICA

DEPARTAMENTO DE RECURSOS HUMANOS

Guia de Marcha Nº 16 /DRH/ISPM/029.2.1/17

Em missão de serviço segue a apresentar-se no Distrito de Rubaue, Província de Nampula, o senhor **Dovel Branquinho Ernesto** docente do ISPM a fim de fazer pesquisa e colheita de dados de manga por um período de 5 (cinco) dias, 30 de Janeiro a 3 de Fevereiro de 2017.

Matsinho, aos 09 de Janeiro de 2017

O chefe do Departamento de Recursos Humanos

Armando Francisco Tesoura

dr. Armando Francisco Tesoura

/Técnico Superior N1/

Declaração

Eu Dovel B. Ernesto com a categoria de Assistente, declaro que viajei em missão de serviço para a Província Nampula Distrito de Ribaue, com partida no dia 30/01/17 às 06:30 horas e o regresso no dia 03/02/17, às 19:00 horas.

Edifício do Centro Cultural Académico Montalto. Rua Dr. Araújo Lacerda R/c C.P.417, tel (+258)25124841, fax (+258)25124847
Campus de Matsinho-Distrito de Vanduzi. Estrada Nacional nº 6, Desvio nas Antenas Km4, Tel Fax (+258)25124425

Annex 7: Copy of research authorization for mangoes from Gaza

ispm

INSTITUTO SUPERIOR POLITÉCNICO DE MANICA

DEPARTAMENTO DE RECURSOS HUMANOS

Guia de Marcha Nº 15 /DRH/ISPM/029.2.1/17

Em missão de serviço segue a apresentar-se no Distrito de Xai-xai, Província de Gaza, o senhor **Dovel Branquinho Ernesto** docente do ISPM a fim de fazer pesquisa e colheita de dados de manga por um período de 6 (seis) dias, de 16 a 21 de Janeiro de 2017.

Matsinho, aos 09 de Janeiro de 2017

O chefe do Departamento de Recursos Humanos

Armando Francisco Tesoura

dr. Armando Francisco Tesoura

/Técnico Superior N1/

Declaração

Eu Dovel B. Ernesto com a categoria de Assistente, declaro que viajei em missão de serviço para a Província Gaza Distrito de Xai-Xai, com partida no dia 16/01/17 às 06:30 horas e o regresso no dia 21/01/17, às 12:00 horas.

Edifício do Centro Cultural Académico Montalto. Rua Dr. Araújo Lacerda R/c C.P.417, tel (+258)25124841, fax (+258)25124847
Campus de Matsinho-Distrito de Vanduzi. Estrada Nacional nº 6, Desvio nas Antenas Km4, Tel Fax (+258)25124425

Annex 8: Copy of research authorization for mangoes from Manica

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INSTITUTO SUPERIOR POLITÉCNICO DE MANICA

DEPARTAMENTO DE RECURSOS HUMANOS

Guia de Marcha Nº 14 /DRH/ISPM/029.2.1/17

Em missão de serviço segue a apresentar-se no Distrito de Macate, Província de Manica, o senhor **Dovel Branquinho Ernesto** docente do ISPM a fim de fazer pesquisa e colheita de dados de manga por um período de 1 (um) dia, 12 de Janeiro de 2017.

Matsinho, aos 09 de Janeiro de 2017

O chefe do Departamento de Recursos Humanos

Armando Francisco Tesoura

dr. Armando Francisco Tesoura

/Técnico Superior N1/

Declaração

Eu Dovel B. Ernesto com a categoria de Assistente declaro que viajei em missão de serviço para a Província Manica Distrito de Macate, com partida no dia 12/01/17 às 05:00 horas e o regresso no dia 12/01/17, às 19:00 horas.

Edifício do Centro Cultural Académico Montalto. Rua Dr. Araújo Lacerda R/c C.P.417, tel (+258)25124841, fax (+258)25124847
Campus de Matsinho-Distrito de Vanduzi. Estrada Nacional nº 6, Desvio nas Antenas Km4, Tel Fax (+258)25124425