UNIVERSITY OF CAPE COAST

EFFECT OF WOODEN CABINET AND POT-IN-POT EVAPORATIVE COOLER STORAGE METHODS ON THE STORAGE PERFORMANCE OF 1-MCP TREATED PLANTAIN

FRANCIS ANNAN HUGHES

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BY

FRANCIS ANNAN HUGHES

Thesis submitted to the Department of Agricultural Engineering of the School of Agriculture, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfilment of the requirements for award of Master of Philosophy Degree in Food and Post-Harvest Technology

AUGUST 2023

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my original research and that no part of it has been presented for another degree at this university or elsewhere.

Candidate's Signature……………… Date………………….

Name: Francis Annan Hughes

Supervisor's Declaration

I hereby declare that the preparation and presentation of the thesis were supervised following the guidelines on supervision of thesis laid down by the University of Cape Coast.

Supervisor's Signature……………… Date………………………….

Name: Prof. Ernest Teye

ABSTRACT

Postharvest losses in plantain production negatively impact the profitability of smallholder farmers. The work studied the effect of 1-MCP gas (0, 15, 30, and 60 µl/l) on green mature plantains (Apentu) stored for 30 days in wooden cabinet and clay-pot in-pot evaporative cooler on weight loss, peel colour, firmness, shrinkage, and sensory characteristics. Two-factor experiment (2×4×3) in Completely Randomized Design (CRD) was used. The mean temperature and relative humidity of the wooden cabinet (WC) and pot-in-pot evaporative cooler (EC) were 28.91±0.69°C & 74.16±8.64 % and 25.41±0.36°C & 94.20±1.23 % respectively. Plantains treated with 15 µl/l 1-MCP and stored in pot-in-pot evaporative cooler recorded the lowest percentage shrinkage and weight loss ($P<0.05$) of 3.64±0.04% and 6.18±0.06% respectively. 1-MCP (15 µl/l) treated plantain and stored in pot-in-pot evaporative cooler maintained fruit firmness and peel colour greenness (a*) from 50.51 to 33.39 N and -19.94 to 4.69 respectively over the 30 days storage. Carbohydrate, potassium and vitamin C ($P<0.05$) for 15 µl/l 1-MCP treated plantain stored in pot-in-pot evaporative cooler was retained from 90.13 % to 91.68 %, 3965 to 4921 µg/g, and 1.10 to 21.95 mg/100g respectively over the 30 days of storage compared to the control. The sensory evaluation showed panellists had higher preference for the 15 µl/l 1-MCP treated plantain stored in pot-in-pot evaporative cooler for 15 days, colour (8.4), texture (8.4), odour (8.6), appearance (8.8), and overall acceptability (8.6) compared to the control (untreated plantain) stored in wooden cabinet for 15 days with, colour (3.8), texture (3.4), odour (4.2), appearance (3.4), and overall acceptability (4.0). The results show that 1-MCP (15 µl/l) treated plantain stored in pot-in-pot evaporative cooler could improve storage life and increase farmers profitability.

KEY WORDS

1-MCP

Evaporative cooler

Plantain Storage

Wooden cabinet

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DEDICATION

This work is dedicated to my mother Alice Fosu, my wife Alice Sankye, our daughter Michelle Adobea Hughes and the Hughes family of Cape Coast.

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LIST OF ABBREVIATIONS

1-MCP	1-Methylcyclopropene
AA	Ascorbic Acid
ANOVA	Analysis of Variance
CA	Controlled Atmosphere
CHO	Carbohydrate
CTA	Agricultural and Rural Cooperation
DF	Dietary fibre
EC	Pot-in-pot Evaporative cooler
FAO	Food and Agricultural Organization
FV's	Fruit and Vegetables
GA	Gibberellic Acid
IRB	Institutional Review Board
MA	Modified Atmosphere
MC	Moisture Content
PPB	Parts per billion
PPM	Parts per million
WC	Wooden Cabinet

CHAPTER ONE

INTRODUCTION

Background to the Study

Plantain (*Musa paradisiaca*) is a crop that is grown and consumed for its dietary energy due to its high starch content as well as rich source of iron, potassium, zinc and calcium (Oguntade et al., 2019). It is a good source of vitamin A, vitamin B complex and vitamin C. The crop is grown mainly in tropical and sub-tropical countries (Aaron et al., 2017). According to the FAO, the world production of plantains stands at 60 million metric tonnes (Adheka et al., 2018). The per capita annual consumption of plantain in Ghana is 141.0 kg (Addisou et al., 2018). The national per capita consumption figure shows the importance of plantain relative to other starch staples (Asante-Kyei et al., 2019). However, a major challenge in plantain production is decay and deterioration after harvest. Post-harvest loss assessment of plantains at Takoradi market circle revealed high losses approximately 53.3% as a result of poor handling and the use of inappropriate storage methods (Asante-Kyei et al., 2019).

Studies have shown higher starch levels in unripe plantains compared to ripe ones which have higher glucose, sucrose, and fructose levels (Aaron et al., 2017). Increasing urbanization and high demand for convenient energy foods by the urban dwellers have caused the consumption of plantains to rise sharply in Ghana in recent times(Agbemafle et al., 2017). Besides being the staple for many people in sub-Saharan Africa, roasted plantain is a favourite snack for Ghanaians and other nationals (Addisou et al., 2018).

The processing of plantains into plantain chips has also contributed to the rise in demand for plantains in Ghana (Akinyemi et al., 2010). According to Dedo et al. (2019), Ghana leads in plantain production in West Africa and the third highest producer of plantain in Africa after Uganda and Rwanda. Plantain production constitute 13% of the Ghana's agricultural gross domestic product and is third in production volume for starchy crops in Ghana (Agbemafle et al., 2017). Plantain farming contributes to the income of rural households in major areas of production in Ghana (Agyeman Boateng & Adu-Amankwa, 2011). Unlike other starchy crops whose demand tends to fall with rising income, demand for plantain rises with increase in income (Justina et al., 2014). Plantain production has potential for industrial production and processing. Both small and large-scale farms in the country have contributed to the rise in volume of production. Plantain is classified as the fourth global important food commodity after maize, wheat and rice, however due to high rate of deterioration, it has dropped in rank to sixth globally (Dimelu, 2015). Plantain farming increases at yearly mean rate of 2.3% to 2.6% in Ghana (Agyeman Boateng & Adu-Amankwa, 2011). Despite the huge quantities of plantains harvested, there are storage problems that limit the availability of plantains all year round (Dedo et al., 2019). Plantains have occupied vital positions in crop production in sub-Saharan Africa (Olumba et al., 2020). Plantains and bananas come second globally for fruit crop yearly production of 129,906,098 metric tons and are among the important food crops in sub-Sahara Africa (Dimelu, 2015). Plantain is boiled and consumed in the unripe state as ampesi with stews or as fufu (pounded boiled unripe plantain and cassava) with soup (Gomasta, 2016). Plantains are also consumed at the various ripening stages i.e. (yellowish-green to brownish-yellow as roasted plantain or fried plantain (Juncai et al., 2015). Plantain for both local consumption and export plays a major role in food and income security and has the potential to contribute to rural poverty reduction (Fischer et al., 2014).

Plantain being climacteric fruit ripens upon maturity by releasing ethylene gas (Dedo et al., 2019). Plantain ripens at high temperatures up to 35℃ to produce the desirable sweet soft pulp (Foukaraki et al., 2016).The ripening of plantain results in changes in physicochemical properties. This include skin colour changes, starch conversion to sugars, softening of fruit, astringency loss, changes in respiration rate and ethylene production, changes in phenolic levels, pigments, aroma and development of unique flavour (Zakari et al., 2016). 1-MCP treatment and evaporative cooler storage used separately for plantain storage produced good results in retarding ripening, prolonging storage life, and reduced post-harvest losses (Baswal et al., 2021). However, there is not much scientific work on the combined effect of 1-MCP and pot-in-pot evaporative cooler storage on the physical qualities and storage life of plantain (Kranthi-Kumar et al., 2018).

Statement of the Problem

Increase in population and change in consumer preference and life style have resulted in high demand for foods particularly fruits and vegetables. Majority of farmers in Ghana operate on a small and that contribute almost 80% of fruits and vegetable produced in sub-Sahara Africa, meanwhile a greater portion of fruits and vegetables produced get rotten due to inadequate storage facilities as well as poor food handling practices on the farms and at the markets (Kranthi et al., 2018). This reduces the meagre income of farmers (Mariño-

González et al., 2019). A major challenge preventing the subsistence farmer from scaling up their farming operations is the high deterioration rate experienced after harvest and during storage. Green mature plantains take less than fifteen days to go bad and this is a huge problem to farmers, consumers and plantain traders (Hosseini et al., 2020).

Crude storage methods adopted by traders include covering harvested plantains with polyethene and tarpaulins, others also put the plantains on the bare floors at the market under direct sunlight and harsh weather conditions (Xie et al., 2016). These outmoded methods of storing plantains facilitate the ripening and decay of plantains (Hagan et al., 2017). Quality of fruits and vegetables can be maintained by providing optimum storage conditions which also differs with fruit type and intended use (Sipho et al., 2020). Appropriate technologies have been developed to preserve plantains and to extend their storage life. These include food irradiation technology (Sarkar et al., 2021), combined salicylic acid and 1-MCP (Min et al., 2018), shea butter (Sugri et al., 2010), 1-MCP application (Wasala et al., 2020), evaporative cooling (Zakari et al., 2016), modified atmosphere and controlled atmosphere for plantain storage (Murmu et al., 2018), however most of these technologies are complicated and expensive and beyond the means of the smallholder farmer. In addition some of the chemical substances could cause harm to human health and the environment if not used properly (Xu et al., 2019). Therefore, a combination of 1-MCP and pot-in-pot evaporative cooler storage that is less complex and affordable serves as alternative postharvest technology for plantain storage to significantly reduce the high postharvest losses of plantains between 10-30 %

due to deterioration while improving farmers' incomes (Agyeman Boateng & Adu-Amankwa, 2011).

Significance of the Study

Plantain's short storage life means it cannot store for long, unlike dried grains (Jia et al., 2018). Appropriate postharvest technologies and interventions that will help eliminate or reduce the incidence of plantain decay are needed to reduce postharvest losses (Pongprasert & Srilaong, 2014). 1-MCP produced reliable results in retarding ripening, extending storage life, and decreasing post-harvest losses in fruits including pear, apple, papaya, plantain, and banana (Baswal et al., 2021). However, there isn't much scientific knowledge on the combined effect of 1-MCP and pot-in-pot evaporative cooler storage on the storage life of plantain although temperature and humidity significantly play major role in ripening especially during storage (Kranthi-Kumar et al., 2018).

Thus, to extend the storage life of fruits including plantain, it is important to retard the ripening by suppressing the effect of ethylene and modifying the humidity and temperature of the storage environment (Biswas et al., 2014). The work seeks to contribute knowledge to reduce postharvest spoilage of plantains and improve food security (Sipho et al., 2020). The work is in line with the 2025 FAO food security target, which focuses on improving food security in sub-Sahara Africa (Haddad et al., 2015).

General Objective

The main objective of the study is to improve the storage duration of plantains by using simple storage technology (pot-in-pot evaporative cooler and 1-MCP treatment).

Specific Objectives

1. To determine the effect of 1-MCP treated plantains stored in wooden cabinet and pot-in-pot evaporative cooler on percentage weight loss, percentage shrinkage, firmness, and colour.
2. To determine the effect of 1-MCP treated plantains stored in wooden cabinets and pot-in-pot evaporative cooler on decay, proximate and mineral composition, and vitamin C content.
3. To investigate the effect of 1-MCP on plantains stored in wooden cabinet and pot-in-pot evaporative cooler on sensory attributes of plantain fruit and boiled pulp.

Research Questions

1. What effect will 1-MCP treated plantains stored in a wooden cabinet and pot-in-pot evaporative cooler have on the weight loss, shrinkage, firmness, and colour of plantains?
2. What effect will 1-MCP treated plantains stored in wooden cabinet and pot-in-pot evaporative cooler have on decay, proximate and mineral composition, and Vitamins C content of plantain?
3. What effect will 1-MCP treated plantains stored in wooden cabinet and pot-in-pot evaporative cooler have on the sensory attributes of plantain fruit and boiled plantain?

Limitations of the Study

Due to the resource constraints, four (4) units of the pot-in-pot evaporative coolers were used for the cooler storage of the four different 1-MCP treatment levels as against the required twelve (12) units to be able to cater for the three (3) replications separately. This necessitated that all the replications were put together in one pot-in-pot evaporative cooler.

Organization of the Study

The work is grouped into five main chapters. The first chapter discusses background to the study, problem statement, the study's significance, the objectives of the research which include both the general and specific objectives, and the research questions. Chapter two covers reviewed literature on 1-MCP and its applications and benefits, the effect of temperature and humidity on fruits storage and pot-in-pot evaporative coolers, other technologies for fruits storage and their effect on fruit quality. Chapter three has the materials and methods used to undertake all experiments and data collection; the methods used in analysing the data. Chapter four present the results and discussion, which are presented in tables and graphs. Chapter five summarizes the entire work, conclusions, and recommendations.

CHAPTER TWO

LITERATURE REVIEW

Origin of Plantain

Plantain was first discovered in South-East Asia. It is classified into three major classes, the Horn plantain, the French horn, and the False horn plantain (Kwami & Nitty, 2014). The French type and the Horn type are known to come from one location. These two are also grown extensively in Africa, Tropical America, and India. The French forms are also cultivated in Indonesia and the Pacific Islands (Hapsari et al., 2017). It is documented that the plantain triploids (AAB) were the earliest to be grown in the area between Nigeria and Gabon and which have been designated as the centre of diversity for plantains (Bragard et al., 2021).

Cultivation and Distribution

Plantain cultivars require warm and humid climate with no major variations (Akinyemi et al., 2010). It will not survive dry season that lasts more than 3 months and temperatures below 10℃ for more than a few nights with few exceptions (Nansamba et al., 2020). The crop is, however, mostly cultivated in tropical Africa (Asante-Kyei et al., 2019). Notable plantain growing areas in Ghana include Agogo, the Afram Plains (Maame Krobo), Hwediem, and Goaso (Dedo et al., 2019).

Importance of Plantain

Plantain contains carbohydrates, minerals such as calcium, iron, copper, potassium and magnesium. Plantains are good source of vitamin B complex (thiamine, niacin riboflavin and B_6), vitamin C (ascorbic acid) and vitamin A (carotene) (Oyeyinka et al., 2019). Plantains serve as good source of vitamin A compared to other fruit crops. It is known to be high in potassium and low in sodium (Obiageli et al., 2016). Plantain is grown in 52 countries and the world production stands at about 60 million metric tonnes (Adheka et al., 2018). In the Caribbeans, Central and West Africa, plantain is of high socio-economic importance (Olumba & Onunka, 2020). It serves as source of income to smallholder farmers who produce them under monocropping and mixed cropping farming systems (Agbemafle et al., 2017). Plantain grown locally guarantee income and food security while reducing rural poverty (Fischer et al., 2014). An estimated 70 million persons in Africa obtain approximately 25% of their carbohydrate and 10% of energy from plantains consumption (Cai et al., 2018). According to Dimelu (2015).Wageningen, small scale farmers in plantain production are important source of revenue that contribute to poverty reduction

Plantain maturity indices

Plantain takes nine to twelve months to be matured after planting and ready for harvesting (Dimelu, 2015). Several indices are used to determine the maturity of plantains. These are the diameter of fruit, age of bunch, angularity, length of fruit finger and colour of the peel (Juncai et al., 2015). Plantain fruits maintain a constant weight at maturity for two to four days, before the weight begins to reduce, accompanied by changes in the colour of the peel from green to yellow and then to black. A matured plantain fruit exhibits brittleness of floral ends and the angularity of fruit fingers disappears (Adheka et al., 2018). Plantain fruits meant for the local market are harvested when matured as against fruits meant for the external market, thus the stage of harvest depends on the intended market destination (Dhake et al., 2020). Adheka et al. (2018) noted that fruits destined for the external market could be harvested a day or two earlier to the shipping day to delay ripening and weight loss.

The calliper is used to measure the diameter of the fruit finger at the mid-section (Hapsari et al., 2017). A record of the age of the bunch is another approach to measure plantain maturity. This takes note of the period in which the fruit bunch is observed and is recorded (Olumba & Onunka, 2020). Bunches are also identified by tagging using different ribbon colours starting from the time of shooting to the exact time of harvest depending on the cultivar type and the season (Obiageli et al., 2016). Maturity can also be determined by using the angularity of the plantain fruit. Plantain fruits that are immature are angular at the cross-section with clear ridges. However, the extent of fruit angularity varies among different cultivars and the fruit hand location on the bunch (Ngamchuachit et al., 2014). The fullness of the fruit is normally measured from the middle hand. The right shape to harvest fruits also depends on the distance of the farm to the market (Murmu & Mishra, 2018). Fruits intended for the domestic market must be round (Hagan et al., 2017). Peel colour changes from green to yellow to brown-black when fruits reach physiological maturity. Fruits must also be harvested green to withstand the shocks during handling (Li et al., 2020).

Plantain storage

Plantain fruits require cool temperatures of about 14℃ to store. They are normally shipped in refrigerated containers (Addisou et al., 2018). In Ghana, some farmers and sellers adopt crude methods such as the use of polypropylene sheets, and other unprescribed fabrics to cover plantain on the market floor, others also sell produce in the open space exposed directly to sunlight and leaving them at the mercy of the weather (Jiang et al., 2018). Loss assessment undertaken for plantains at Takoradi market circle showed 53% postharvest loss of plantains annually, mainly due to the use of poor storage structures and poor handling practices (Asante-Kyei et al., 2019). These methods of storing plantains rather worsen the situation thereby making the plantains go bad (Addisou et al., 2018).

Ripening of plantain

Respiration pattern of harvested fruits can be classified into climacteric and non-climacteric fruits. Climacteric fruits exhibit dramatic rise in respiration after harvest (Chen et al., 2020). The climacteric pattern involves an initial decline of respiration called the pre-climacteric minimum, followed by a sharp rise (climacteric rise) to a climacteric peak at the onset of ripening, and a gradual decline during a post-climacteric period (Adheka et al., 2018). The increase in respiration during the climacteric stage shows improvement in metabolic activity and this takes place during the change from the growth stage of the fruit to the senescence stage (Adheka et al., 2018). Plantain ripens when mature by releasing ethylene gas (Ekiti et al., 2017). The ripening of plantain leads to changes in its physicochemical characteristics. Observable changes that occur at ripening are as follows: change in peel and pulp colour, change of starch to sugar, firmness of pulp, change in the ratio of pulp to peel, change in the total soluble solids content, pH of pulp, peel and pulp moisture levels, amount of dry matter, total titratable acidity, rate of respiration, production of ethylene, phenolic content, pigments, flavour and aroma (Dedo et al., 2019). Plantain ripening is mostly characterized with skin colour changes, loss of astringency, and development of characteristic flavour (Satekge et al., 2020). Ripening of plantain depends on temperature as plantain ripens at higher temperatures up to 35°C to produce the desirable sweet soft pulp (Gajewski et al., 2014).

Effects of Ethylene on plantain

Ethylene, a plant growth hormones that regulate development and growth in plants (Yasmin et al., 2021). It is a carbon and hydrogen compound that moves through the plants internal structures to achieve its action. This hydrocarbon has been well researched to understand its action and biosynthesis (Fan et al., 2018). Ethylene can significantly influence the quality of harvested products. Its influence can be deleterious and beneficial based on the produce, its ripening stage, and the intended use (Gajewski et al., 2014). Ethylene produced internally is an essential component of the climacteric fruit ripening which is able to regulate ethylene-dependent processes (Satekge et al., 2020). External application of ethylene is used to promote uniform ripening for fruits including bananas (Fan et al., 2018). Commercially, horticultural produce are managed by keeping away from ethylene gas exposure or minimizing the production and action of ethylene during harvesting, ripening, storage, transport, and handling by controlling temperature of the produce environment (Yasmin et al., 2021). A novel technique for regulating ethylene production in order to check ripening and senescence of fruits, notably climacteric ones, as well as senescence of vegetative tissues led to the discovery and commercialization of the inhibitor of 1-MCP (Addisou et al., 2018).

Ethylene gas is an organic compound that is physiologically active in plants. It is described as the aging and ripening hormone and is physiologically active in trace amounts (Hagan et al., 2017). It causes several effects in plants and this depends on the age of the plant and its sensitivity to ethylene (Manigo et al., 2020). The effect of ethylene gas can be pleasant or unpleasant contingent on the selected product (Manigo et al., 2020). The effects include: fruit ripening, degreening of citruses, and flower initiation, change sex expression (increases female flowers on cucurbits), yellowing and senescence of vegetative tissues (leafy vegetables) and immature fruits (cucumber, squash), leaf abscission (dropping) and quick senescence of most flowers (Gajewski et al., 2014).

Mode of action of ethylene

Ethylene is a plant growth regulator that acts in conjunction with other plant hormones including auxins, gibberellins, kinins, and abscisic acid (Guleria, 2021). There is substantial information about the relation of ethylene to fruit ripening due to the availability of this sensitive gas. Chromatographic method for measurement of ethylene has enabled detailed studies of this relationship (Jiang et al., 2018). The relationship of the other plant hormones to ripening is not clear (Hagan et al., 2017). Concerning other plant hormones, ethylene is understood to bind to a specific receptor(s) to form a complex that initiate ripening (Huan et al., 2018). Ethylene's action can be affected by changing the number of receptors (Jogdand et al., 2017). Extensive studies of the structural requirements for the biological activity of ethylene receptors have brought up the proposal that binding takes place reversibly at a site containing a metal (Manigo et al., 2019). From kinetic studies on the responses of plant tissue to added ethylene, it has been suggested that the affinity of the receptor for ethylene is increased by the presence of oxygen and decreased by the presence of carbon dioxide (Kumar et al., 2018).

The occurrence of a metal-containing receptor has not been confirmed, but the proposition is supported by studies with silver ions (Biswas et al., 2014). Treatment of fruits, flowers, and other tissues with silver ion has been shown to inhibit the action of ethylene (Guleria, 2021). The need for specific structural requirements for ethylene action has been demonstrated by treating tissues with analogues and antagonists of ethylene (Manigo et al., 2019). The gaseous cyclic olefins, 2, 5-norbornadiene, and 1-MCP, have been shown to be highly effective inhibitors of ethylene action. 1-MCP has been shown to bind irreversibly to the ethylene receptors in sensitive plant tissues and a single treatment with low concentrations for a few hours at ambient temperatures confers protection against ethylene for several days (Jia et al., 2018).

Control of fruit ripening

Control of fruit ripening, initiation, or delay, is generally dependent on factors that affect ethylene production or action (Hajam et al., 2017). Treatment of pre-climacteric fruits with exogenous ethylene advances the onset of ripening (Sunisha et al., 2019). This response is used widely in commercial practices to achieve controlled ripening of fruits that are packed and transported in a mature, but unripe state and ripened just before marketing (Onojah & Emurotu, 2017). Delay of fruit ripening and prolonging shelf-life can be achieved by different post-harvest operations related to ethylene production or action, including low temperature. Low temperature can be used to achieve delay in the onset of ripening in climacteric fruits (Sipho et al., 2020).

Lowering the temperature not only reduces the production of ethylene by the tissues but also minimizes the rate of response of the tissue to ethylene action (Quillehauquy et al., 2020). According to Kim et al. (2015), colour changes are the first visual indication of ripening or spoilage and thus determine the eating quality of fruits. The changes in fruit colour are mainly due to the breakdown of chlorophyll, and changes in carotenoid and other pigments (Delgado-Pelayo et al., 2014). For climacteric fruits, breakdown of chlorophyll usually occurs during the climacteric phase (Kumar et al., 2017). The colour of fruits may also be altered through the action of light, temperature, oxygen, and metal ions (Tan et al., 2021). Plantain quality parameters places premium value on the colour (Olumba & Onunka, 2020). The different colour grades are the deep green colour for the unripe plantain, the yellow colour for the ripe plantain, and the deep yellow colour for the aged and dehydrated plantain. On the Ghanaian market, the overripe fruits are usually sold at a lower price than unripe fruits. This grading system helps to determine the price of plantain fruits on the market (Tortoe et al., 2020).

Ethylene removal and exclusion

The removal of ethylene from the environment surrounding the commodity is the preferable method of preventing the deterioration of products sensitive to ethylene. Ventilation of ripening rooms can reduce ethylene concentration (Sugri et al., 2017). Removal of endogenous ethylene was the first benefit ascribed to the hypobaric or low-pressure system of storage (Tan et al., 2021). The shelf life of bananas can be extended considerably by a low-pressure system (Oko et al., 2015). Odenigbo (2013) reported that ethylene production and respiration activity of bananas held in hypobaric storage at 20°C with gas mixtures of 1 to 10% O_2 under one-fifth atmospheric pressure were considerably depressed. No climacteric rise of respiration was apparent and fruit remained green and firm until the end of the 14-days storage period (Tan et al., 2021).

The fruit showed a rapid increase in ethylene production and respiration activity and started to ripen normally almost immediately after being transferred to air (Tan et al., 2021). Mahajan et al. (2019) found that slowing of banana ripening is inversely related to atmospheric pressure of storage.

Inhibitory effect of Ethylene

Delaying of fruit ripening can be achieved by modified atmosphere (MA) or controlled atmosphere (CA) storage (Leon, 2018). Ethylene production and respiratory activity of banana fruits held in CA storage at 20℃ in gas mixtures of 1 to 10% O_2 were greatly depressed (Jia et al., 2018). No climacteric was apparent and fruits remained green and firm until they were removed to air after 18 days, where they showed a rapid increase in ethylene production and respiratory activity and start to ripen immediately (Jiang et al., 2004). Many of the beneficial results of modified atmosphere (MA) storage cannot simply be attributed to a reduction in respiration (Addisou et al., 2018). The greatly increased storage life was attributed to a reduction in the rate of natural ethylene production by the bananas, decreased sensitivity of the fruit to ethylene, and inhibition of ethylene action by CO_2 (Pongprasert et al., 2014). Different concentrations of potassium permanganate significantly delayed fruit ripening, maintained quality and extended storage life of bananas (Dhakal et al., 2021).

Effect of 1-MCP on respiration and ethylene production

1-MCP delays the increase in respiration. Mature-green bananas treated with 1-MCP significantly delayed the peaks of respiration and ethylene production but did not significantly reduce the peak height. Respiration was suppressed in propylene-treated bananas subsequently gassed with 1-MCP (Biswas et al., 2014). Respiration was inhibited in 'Fuji', 'Grany Smith' and 'Red

Delicious' apples (Manigo et al., 2019). Respiration increase was delayed in avocado by about 6 days and the magnitude was reduced by about 40% with 1-MCP treatment (Juncai et al., 2015). Respiration rate was reduced by 1-MCP in broccoli (Wichrowska et al., 2021), and carrot (Ergun & Hussein, 2018). The application of exogenous ethylene stimulated respiration in sweet cherry regardless of 1-MCP treatment (Karagiannis et al., 2018). 1-MCP treatment did not affect nectarine (Onojah et al., 2017) and apricot (Gomasta, 2016). The 1-MCP treatment effectively decreased ethylene production during storage and increased shelf-life in plum fruits kept for 15 and 30 days at 0°C (Lin et al., 2018). The interaction between fruits, 1-MCP, and Packaging extended the shelf life of plantain fruits. Hagan et al. (2017) increased the storage quality of plantain (Apentu) from 6 to 21 days with aqueous 1-MCP at 100 µg/l for 1 minute followed by storage at 15°C and 30°C without affecting the sensory quality.

Clay pot evaporative cooling technology (Pot-in-pot evaporative cooler)

Food is an essential physiological need of man as stated in the hierarchy of human needs of Maslow's. However climatic conditions affect food production (Aaron et al., 2017). Several indigenous technologies have been developed to increase the shelf life of fruits and vegetables so that they store longer in good condition before going bad. According to Asante-Kyei et al. (2019), the average postharvest losses for fruits and vegetables across the globe is estimated at 30%, however, postharvest losses in Africa even though is hard to estimate, is put at 50%. Pot-in-pot evaporative cooling is one such fruit and vegetable storage technology developed to store fruits and vegetables especially in the tropics and less humid regions of the world where high temperatures augment the senescence and deterioration of fresh produce (Woldemariam et al., 2014). The pot-in-pot evaporative cooler is a low-cost clay pot evaporative cooling technology, easy to operate, efficient, and affordable to subsistent and smallholder farmers in developing countries like Ghana and Nigeria where other methods of cooling fruits and vegetables for preservation are quite expensive and most peasant farmers cannot afford them. Clay mineral is available and sustainable all over Ghana and West Africa (Konadu et al., 2013). Asante-Kyei et al. (2019) reported huge clay deposits (the raw material for constructing the pot-in-pot evaporative coolers) in all the sixteen regions of Ghana. Prampram, a district in the Greater Accra region is known to hold clay deposits of over 21,779, 929 metric tonnes in reserve. The low-cost pot-in-pot evaporative cooler can help address the fruits and vegetable refrigeration in areas with high ambient temperatures and low relative humidity and where electricity is unavailable and unreliable (Chinenye, 2014).

The process of evaporative cooling in pot-in-pot evaporative coolers

Water in the liquid state evaporates from the surface of the clay pot and this reduces the temperature of the evaporation surface. Water has a high enthalpy of vaporization (the latent heat of vaporization). Enthalpy of vaporization is the quantity of energy that must be given to the quantity of water to change it into water vapour (Zakari et al., 2016). Water in the moist sandy-clay pad between the outer pot and the inner pot of the pot-in-pot evaporative coolers enters the pores of the clay pot material. The water in the clay pores serves as a medium of heat exchange between the surrounding air at room temperature and a sandy-clay moist pad. Water in the sandy-clay moist pad converts heat energy to the water in the clay pores and surrounding air to evaporate. This results in a temperature reduction of the surrounding sandy-clay moist pad. The cooled sandy-clay moist pad helps keep fruits and vegetables fresh in the inner chamber of the pot-in-pot evaporative cooler (Chinenye, 2014). The standard requirement for this process is to use single-fired and unglazed clay pots. Clay pots are porous after firing, light in weight, and chemically inert (Asante-Kyei et al., 2019). The Evaporative cooling process functions best when the atmosphere is dry, temperatures are high and humidity is relatively low (Basediya et al., 2013).

Storage of fruits and vegetables come with its own challenges that affect the quality of fruits and vegetables in terms of weight loss, texture, freshness, and colour of fruits and vegetables. However, these parameters to a greater extent dictate the prices consumers will pay for the produce. The shelf life of fruits and vegetables can be extended by controlling the relative humidity and temperature of the storage environment. Fruits and vegetables especially plantain and banana stored using domestic refrigeration are prone to chilling injury (Okonkwo et al., 2013). According to Basediya et al. (2013) evaporative cooling system not only reduces the air temperature surrounding the product but also increases the moisture content of the air and this helps to prevent the drying of the product, thereby extending the storage life of horticultural produce and maintain the freshness of the produce. Bayogan et al. (2017) reported slower decline in moisture content, longer acceptable visual quality, reduced weight loss and improved firmness for the storage of two different sweet pepper cultivars in an evaporative cooler maintained at 23.91℃ and high relative humidity of 93.84%. Zakari et al. (2016) stored fresh tomatoes using evaporative cooler and ambient condition to assess the effectiveness of the two storage methods in terms of weight loss, colour, and firmness of the fresh tomatoes. Percentage weight loss of tomatoes was high for the ambient storage (0.30 to 0.60%) as against evaporative cooler storage (0.05 to 0.18%). Firmness decreased rapidly for tomatoes stored under ambient condition as against tomatoes stored in the evaporative coolers. Colour change was rapid for tomatoes stored under ambient conditions (deep red to reddish black) as against tomatoes stored in the evaporative coolers (yellowish-red to red). Statistically, the experimental results showed that using evaporative coolers to store fresh tomatoes was significantly better than ambient storage of fresh tomatoes. According to Bayogan et al. (2017) respiration and transpiration rate increased rapidly for temperature range from 15℃ to 35℃ as shown by Van Hoff temperature relationship. The rise in physiological activities related negatively to storage life of fruits and vegetables. For 1℃ reductions in temperature, shelf-life extension increased by approximately 2 days.

The effect of 1-MCP on weight loss of fruits stored in WC and EC

Consumer preference and willingness to purchase plantain depends on quality attributes including weight, colour, texture and firmness, the palatability or the flavour of fruits, and to a greater extent the storage life (Bayogan et al., 2017). Fruit weight loss was significantly lower in ‘mangoes treated with 1-MCP at 250 and 500 ppb, compared with the control (Abu-Bakr et al., 2019).1-MCP application at 50 and 500 nl/l for 8 hours under ambient storage reduced weight loss in ‘Magallanes’ pommelo (Citrus maxima) (Lacerna et al., 2018). Cherry tomato fruits weight loss after treatment with 0.10 µl/l 1-MCP was better than control fruits and 0.035 µl/l 1-MCP treatment throughout the storage duration for both maturity stages (Taye et al., 2019). ‘Golden Delicious’ apples recorded decrease weight loss after 625 nl /l 1-MCP treatment at different maturity stages (early, middle and late harvest date) and stored at room temperature of 22℃ (Gago et al., 2015). Pear fruits harvested at optimum maturity and treated with 500, 750 and 1000 ppb 1-MCP for four hours at 20℃ and stored at 0 - 1℃. 1000 ppb 1-MCP treated pear recorded the minimum weight loss (Mahajan et al., 2010). Fresh weight loss was delayed without negative impacts on the qualitative or quantitative aroma composition of the fruits (Abu-Goukh., 2013). Orange weight loss was not affected by 1-MCP or ethylene (Rosa et al., 2016). The effect of ethylene and 1-MCP applied at different developmental stages with strawberry fruits attached to the parent plants. 1-MCP did not affect the mass of the fruit, however ethephon treatment affected fruit mass but this effect depended on fruit developmental stage at which treatment was applied (Reis et al., 2020).

The effect of 1-MCP on dimensional shrinkage of fruits stored in WC and EC

Fresh produce, including plantain, lose water and shrinks after harvest (Hagan et al., 2017). This quality parameter is essential in the value chain of plantain as the size helps to determine the market value of the produce. 1-MCP reduced fruit shrinkage according to the species of fruit. Cherry tomato treated with 0.10 µl/l 1-MCP significantly reduced shrinkage than 0.035 µl/l 1-MCP treatment and control (Taye et al., 2019). ‘Golden Delicious’ apple treated with 625 nl/l 1-MCP effectively reduced shrinkage during storage at 0.5℃ and at room temperature i.e., 22℃ (Gago et al., 2015). Pear fruits were treated with 500, 750, and, 1000 ppb of 1-MCP concentrations. The 1000 ppb 1-MCP treated pear recorded the minimum shrinkage for 75 days storage at 0 - 1℃ and 90 –

95% RH compared to the control stored under ambient conditions at 30 - 35℃ and 60 – 65% RH (Mahajan et al., 2010). Orange shrinkage was affected by 1-MCP treatment at 0.1, 0.5 and 1.00 µl/l 1-MCP for 12 hours and stored at 7℃ for 45 days, however the higher dose recorded the highest shrinkage and this was due to chemical stress to the oranges which resulted in increased rate of respiration and hence increased shrinkage (Rosa et al., 2016). 'Lakatan' Banana treated with 400 nl/l 1-MCP through gas exposure for 20 hours significantly recorded slower shrinkage than control as was clear on the 4th day of storage onwards (Manigo & Limbaga, 2019). 1-MCP application imposed underlying impact on the maintenance of shrinkage of mango fruit stored under ambient conditions. 1-MCP treatment retarded shrinkage in mango (Li et al., 2020). 1-MCP application to plantain at 100 µg/l aqueous formulation for 1 minute significantly lowered the respiration rate and ethylene production, and reduced shrinkage, however these effects were more pronounced at 15℃ storage temperature than 30℃ storage temperature (Hagan et al., 2017). The effect of ethylene and 1-MCP application at different developmental stages with the strawberry fruits attached to the parent plant. 1-MCP application did not affect strawberry shrinkage, however ethephon affected strawberry fruit shrinkage but the effect was dependent on fruit developmental stage at which ethephon was applied (Reis et al., 2020).

The effect of 1-MCP on firmness of fruits stored in WC and EC

Fruit firmness is one common physical parameter used to assess the quality of fruits as it undergoes ripening. Firmness or softness of plantain is an indication of either ripening or otherwise. 1-MCP mediate through the inhibition of ethylene perception of plant tissues, it over takes the binding of ethylene to its receptors thereby inhibiting ethylene signal transduction and downstream action (Serek et al., 2015). Also, the effectiveness of inhibition of ripening and/or senescence of fruit is a function of the 1-MCP concentration applied. 1-MCP delayed fruit softening in most fruits, while other fruits were not affected. Pear fruits were treated with 500, 750, and, 1000 ppb of 1-MCP concentrations. The 1000 ppb 1-MCP treated pear maintained acceptable firmness for 75 days storage at 0 - 1°C and 90 – 95% RH compared to the control stored under ambient conditions at 30 – 35°C and 60 – 65% RH (Mahajan et al., 2010). 'Golden Delicious' apple treated with 625 nl/l 1-MCP effectively slowed down softening during storage at 0.5°C and at room temperature i.e., 22°C (Gago et al., 2015). 1-MCP application on 'Lakatan' banana through gas exposure for 20 hours at 400nl/l under room temperature significantly maintained firmness of banana fruit than control, this was clear from the 4th day of storage onwards (Manigo & Limbaga, 2019). 1-MCP application imposed underlying impact by retarding the decline in the firmness of mango fruit stored under ambient conditions compared to the control (Li et al., 2020).

Firmness of avocado fruit was delayed without negative impact to fruit quality, however detailed examinations of fruit softening showed that polygalacturonase (PG) and cellulase activities were lowered by 1-MCP, but the activities of both enzymes were still present and avocado fruit ripened and softened normally (Meyer et al., 2010). Younai plum fruit treated with 1.2 µl/l 1-MCP exhibited higher firmness, lower activities of cell wall-degrading enzymes (pectinesterase, polygalacturonase, cellulase and β-galactosidase), higher content of cell wall polysaccharides (sodium carbonate-soluble pectin, chelate soluble pectin, cellulose and hemicelluloses and lower content of water-soluble pectin). The results showed 1-MCP applied under ambient temperature significantly inhibited the activities of cell wall degrading-enzymes and decrease disassembly of cell wall polysaccharides which subsequently retarded softening in Younai plums (Lin et al., 2018).

The effect of 1-MCP on of fruits and pulp colour of plantain fruits stored in WC and EC

The attractive appearance of the peel and pulp colour to a greater extent influences consumer preference for plantain. The good quality fresh mature plantain depicts deep green peel colour with inner light-yellow pulp colour (Hagan et al., 2017). 1-MCP delays chlorophyll degradation by overtaking the binding of ethylene to its receptors, inhibiting ethylene signal transduction and downward action. 1-MCP significantly delayed the development of the yellow peel colour in plantains during ripening. Mature plantain fruits (Apentu) treated with 1-MCP at 1 ppm and 2 ppm and kept in perforated and non-perforated polyethylene bags. The plantains treated with 2 ppm and kept in the non-perforated bags recorded the longest shelf life of 33 days (complete yellow colour) according to the banana colour chart stage 7 (Addisou et al., 2018). Three mango varieties were treated with 1 ppm and 2 ppm for 24 hours and stored at 32℃ and 20℃. Mango ripening was not delayed in treated fruits stored at 32℃, however fruit colour changes were delayed during storage, rather ripening was delayed for fruits stored at 20℃ for up to 25 days (Faasema et al., 2014). 1-MCP at 0.1 µl/l applied to 'unicorn' cherry tomato significantly affected the surface colour of the tomato and was effective on the quality and shelf life of the 'unicorn' cherry tomato (Taye et al., 2019). The postharvest quality of 1-MCP (400 nl/l) treated 'Lakatan' banana through gas exposure for 20 hours under room temperature significantly retarded ripening as evident by delayed fruit yellowing (Manigo et al., 2019). The main observed effect of 1-MCP application on postharvest storage performance of non-climacteric fruits included the inhibition of degreening or colour change, as observed in citrus fruits, strawberry, pitaya, prickly pear and olive, however 1-MCP application had divergent effects on fruit respiration and ethylene production rate, and on decay with different and sometimes contradictory effect observed in different crops. 1-MCP application also had minor effect on internal fruit quality parameters, including flavour and nutritional quality (Li et al., 2016). Mature plantain at stage 2-3 of the Von Loesecke colour chart were dipped into 100 µg/l aqueous 1-MCP for 1 minute and stored at 15℃ and 30℃ and 75% relative humidity. 1-MCP application significantly reduced the ripening rate as measured by changes in peel colour quality of treated plantain (Hagan et al., 2017). The pre-treatment of cape gooseberry fruits with 1-MCP at 1.0 µl/l and maintained at 20℃ and 75% RH for 11 days delayed most of the ripening associated parameters including reduction in the respiration rate, ethylene production, and skin colour development. The 1-MCP pre-treatment of cape gooseberry fruits was efficient postharvest treatment to delay maturity and extend the postharvest storage (Balaguera-López et al., 2017). Evaluation of 1-MCP and ethylene application on the postharvest physiology of peach fruit harvested with 100% green skin colour and stored at room temperature showed decrease colour index of the skin as a result of decrease rate of respiration (Mariño-González et al., 2019).

The effect of 1-MCP on decay of fruits stored in WC and EC

Fruits are vulnerable to mechanical injury, physiological deterioration, highly perishable, and subject to fungal decay, limiting postharvest life of most fruits to a few days under ambient environment. Fruits also undergo rapid metabolic processes and senescence that result in decay after harvest due to high ambient temperatures (Xu et al., 2017). Plantain pulp moisture content increases with ripening. The high moisture content (MC) of ripe plantain contribute to the high perishability of plantains when ripe, this is because the high MC encourages the growth of microorganisms and increases the rate of enzymatic reactions which results in deterioration (Ayo-Omogie et al., 2010). 'Wonhwang' pear fruit treated with 1-MCP at 1 µl/l and stored at 25℃ increased the incidence and severity of fruit decay at the end of the shelf life period (Phyu et al., 2021). Application of 1-MCP at 5 µl/l to mango fruits and stored at 25℃ suppressed anthracnose of post-harvest mango fruit by directly inhibiting spore germination and growth of *Colletotrichum gloeosporiodes* (Xu et al., 2017). 1-MCP treatment had divergent effects on fruit respiration, ethylene production rates, and decay development with different and contradictory effect in different crops (Li et al., 2016). 1-MCP combined with salicylic acid (SA) inhibited decay incidence and that the efficiency of the combined treatment was better than either 1-MCP and SA only. The combination of 1-MCP and SA effectively enhanced activities of enzymes including superoxide dismutase, peroxidase and catalase in bananas (Xu et al., 2019). Postharvest application of 1 µl/l 1-MCP to apple fruits (Golden Delicious) reduced the incidence of decay and rot after 8 weeks of storage at high temperatures of 21℃ (McArtney et al., 2011). Strawberries treated with 1-MCP only and the combination of 1-MCP and chlorine dioxide extended shelf life and inhibited decay incidence. 1-MCP alone maintained fruit quality during storage but had little effect on microbial growth resulting in quick decay during storage, however 1-MCP and chlorine dioxide combination was superior in maintaining high superoxide dismutase activities, enhanced the inhibition of microbial growth and decay (Yang et al., 2018).

The application of methyl salicylate (MeSA) and 1-methylcyclopropene (1-MCP) separately at 0.05mol/l and 0.5 µl/l respectively delayed fruit ripening and reduced grey mould caused by Botrytis cinerea, however the combination of MeSA and 1-MCP was more effective and a useful technique to maintain quality and alleviate grey mould fungal decay and delayed fruit ripening in post-harvest tomato fruit during storage (Min et al., 2018). The effect of 1-MCP pre-treatment of freshly harvested loquat fruits with 50 nl /l for 24 hours at 20°C and stored at 1°C for 35 days showed that 1-MCP pre-treated fruits reduced decay incidence by slowing the fruit senescence process than control fruits (Cao et al., 2011).

Effectiveness of ripening inhibition and senescence resulting in decay reduction in fruit and vegetables is a function of the 1-MCP concentration applied, up to saturation of the binding sites (Oliveira Anese et al., 2019). Suppression of ethylene activity neutralizes many adverse effects on postharvest fruits and vegetables such as increased respiration rate and ethylene production, accelerated softening, senescence, colour change, starch breakdown, and other physiological disorders, therefore, the activities of 1-MCP reduce ethylene production which results in the reduction of fruit decay (Wasala et al., 2020).

The effect of 1-MCP on fruits protein content stored in WC and EC

Plantains are poor source of proteins. Proteins are however essential component of diet needed to supply adequate amount of required amino acids for the maintenance, and repair of tissues and the development of organs within the body as well as other related metabolic activities. Protein deficiency causes growth retardation and muscle wasting (De et al., 2019). Li et al. (2020) reported that protein content in fruits is composed mainly of metabolic enzymes; hence, protein concentration increased during the ripening of fruits because numerous enzymes are synthesized. Fruits generally are known to be poor source of crude protein, and plantains are no exception, however the low protein content found in the refrigerated fruit may be attributed to decreased metabolic rate caused by the postharvest treatments and refrigerated storage (Brizzolara et al., 2020). According to Moreno-hernández et al. (2014), soursop fruit showed a reduction in ethylene production rate and probably had a decreased protein synthesis including enzymes when kept under refrigeration at 16℃ compared to soursop stored at 25℃. The effectiveness of inhibition of ripening and senescence of soursop fruit by 1 -MCP resulted in the reduction of the protein content of soursop fruit, as the applied 1-MCP concentration saturated the binding sites to reduce the rate of respiration. Protein content was reduced in 1-MCP-treated strawberries stored under refrigeration at 4℃ for ten days (Langer et al., 2022). 1-MCP treatment of mango fruits helped to maintain fruit quality and nutritional values including protein content during storage. This was as a result of 1-MCP treatment capacity to inhibit the climacteric peaks of both ethylene generation and respiration rate in mango fruits over the period of ripening (Li et al., 2020). Protein content increased in tomato fruit during ripening which the response to control ethylene sensitivity, however after the onset of ripening the levels of proteins started to decline. The tomato fruit was used as the model fruit to study changes in protein abundance involved in ethylene signal transduction during tomato fruit ripening (Romera, 2018). Treatment of 'Empire' apple fruits with 1-MCP gave an understanding of the metabolic processes. Levels of amino acids were significantly affected. Amino acids level increased towards the end of storage period (Lee et al., 2012). Suppression of ethylene activity neutralizes many adverse effects on postharvest fruits such as increased respiration rate and ethylene production, softening, colour-change, starch breakdown, and other physiological disorders (Ergun et al., 2018).

The effect of 1-MCP on fruits pulp fat content stored in WC and EC

Plantains are poor source of fats, despite fat being important food components required to provide the body with energy when accompanied by carbohydrates (Sankhon et al., 2013). In food products, fat serve as soluble medium for fat-soluble vitamins including vitamins (A, D, E, and K) that facilitates their absorption into the intestine (Boakye et al., 2014). 1-MCP is confirmed to have a positive effect on the fat content due to its ability to reduce the rate of ethylene biosynthesis which causes ripening of fruits leading to the reduction of fat content. Fat content generally decreases with ripening of fruits. The loss of fat content in control fruits or fruit without the application of 1-MCP was due to the softening, which occurs in the cell membrane by the loss of phospholipids during fruit ripening. It could also be attributed to the conversion of lipids to volatile compounds in the synthesis of aroma compounds (Baiyeri et al., 2011). 1-MCP maintained apple fat content better than controlled atmosphere (CA) storage (Kwon et al., 2021). The application of 1-MCP and wax emulsion (candelilla and flava) alone and combined to soursop fruit and stored at 16°C and 25°C (control) significantly affected the fat content of treated fruits. The low fat content in the control could be attributed to the conversion of lipids to volatile compounds in the synthesis of aroma compounds during storage as well as the softening which occurs in the cell membrane by loss of phospholipids during fruit ripening (Moreno-hernández et al., 2014).

Olivares et al. (2020) found that the combination of 1-MCP and CA was better than either alone and avocado fruits treated with 500 nl /l 1-MCP were higher in fat content than fruits treated with 100 nl /l 1-MCP and all 1-MCP treated fruits recorded higher fat content than untreated fruits. Treatment of 'Empire' apple fruits with 1-MCP gave an understanding of the metabolic processes. Most organic acids were not appreciably affected (Lee et al., 2012). The effect of 1-MCP pre-treatment of freshly harvested loquat fruits with 50 nl /l for 24 hours at 20°C and stored at 1°C for 35 days showed that organic acids including malic acid, lactic acid and fatty acids remained higher in 1-MCP pre-treated loquat fruits than control fruits (Cao et al., 2011). 1-MCP application retarded softening resulting in the maintenance of fat content in banana fruit (Abu-goukh, 2013). The fat content of tomato fruits treated with 1000 ml/l 1-MCP was higher than control fruits after 17 days at 20±1°C and 85-95% relative humidity of storage (Zhang et al., 2020).

The effect of 1-MCP on fruits carbohydrate content stored in WC and EC

Carbohydrate is a vital component of food. It serves as a source of energy for daily metabolic activities (Bibiana et al., 2014). The consumption of food with high amount of carbohydrates provides the body and brain with energy (Sankhon et al., 2013). Plantains are rich sources of complex carbohydrates which comprise of sugars and starches (Adheka et al., 2018). Sugars as source of carbohydrates are necessary to maintain the energy supply. Sugars accumulate in the peel tissue of banana fruit which regulate chlorophyll degradation (Bantayehu et al., 2020). 1-MCP delays fruit softening and ripening in most fruits. The effectiveness of inhibition of ripening by 1-MCP result in the reduction of the carbohydrate content of fruit which is dependent on the 1-MCP concentration applied, up to saturation of the binding sites (Wasala et al., 2020). 1-MCP treatment of oranges (cv pera) with different concentrations i.e., 0.1, 0.5 and 1.0 µl /l for 12 hours and stored at 7℃ for 45 days showed no significant difference for total sugars between control fruits and 1-MCP treated fruits (Franco Rosa et al., 2016). 1-MCP treatment of cavendish banana with different concentrations i.e., 3.5, 10.5 and 17.5 µl /l for 24 hours in combination with three levels of export standard banana packaging materials with modified atmospheric storage and ambient environment 22℃ and 80% RH for 36 days showed no significant difference for starch and total sugars between control fruits and 1-MCP treated fruits. A blue-black colour due to starch staining was observed more on unripe fruits (1-MCP treated) than ripe fruits due to loss of starch during the ripening process. The decrease in starch and corresponding increase in pulp sugar content (TSS) was due to hydrolysis of starch into simple sugars (Zenebe et al., 2016).

The evaluation of 'Hass' avocado pear for delay in softening during ripening at 20°C after harvest, and after cold storage and after 1-MCP treatment exhibited solubilization of neutral sugars such as arabinose and rhamnose as well as loss of galactose in the control fruits resulted in the loss of firmness of control fruits due to the ripening process (Defilippi et al., 2018). 1 -MCP was confirmed to reduce the carbohydrate content due to its ability to reduce the rate of ethylene synthesis which causes ripening of fruits leading to the increase in carbohydrate content. 'Ambul' banana treated with 1-MCP at 0.5 ppm and 1 ppm for 12 and 18 hours combinations under ambient conditions showed increase in sugar content for 1-MCP treated and untreated samples during storage, however the lowest change in sugar content were fruits treated with1-MCP 1ppm for 18 hours (Wasala et al., 2020). Apples maintained carbohydrate content in untreated samples after 1-MCP application (Win et al., 2021). Treatment of 'Empire' apple fruits with 1-MCP gave an understanding of the metabolic processes. Most carbohydrates were not appreciably affected (Lee et al., 2012). The effect of 1-MCP pre-treatment of freshly harvested loquat fruits with 50 nl /l for 24 hours at 20°C and stored at 1°C for 35 days showed a decrease in TSS during storage for all the treated loquat, however 1-MCP pre-treated fruits maintained high TSS values than control fruits (Cao et al., 2011).

The effect of 1-MCP on fruits fibre content stored in WC and EC

Dietary fibre (DF) is considered as an important nutrient in food (Salgado et al., 2011). According to Martínez-Villaluen et al. (2014), an increased intake of DF products appreciably reduce obesity. 1-MCP was confirmed to have a positive effect on the fibre content due to its ability to reduce the rate of ethylene which causes ripening of fruits leading to the maintenance of fibre content in an unripe fruit or plantain as compared to the ripened plantain. Studies delineated that 1-MCP application retarded softening and therefore reduce the rate of fibre loss in banana fruit (Saeed et al., 2013) and apple (Win et al., 2021). Fibre content of tomato fruits treatment with 1000 ml/l 1-MCP was higher (89%) than control fruits after 17 days at 20±1℃ and 85-95% relative humidity (Moretti et al., 2002). Apples maintained high fibre content after 1-MCP treatment (Win et al., 2021). Avocado fruits treated with 500 nl /l 1-MCP were higher in fibre content than fruits treated with 100 nl /l 1-MCP and all 1-MCP treated fruits were also higher in fibre content than untreated fruit (Woolf et al., 2005). Fibre content increased without negative impacts on the qualitative or quantitative aroma composition of the fruits (Abu-Goukh, 2013).

After cold storage, 1-MCP did not allow mango to ripen normally, compared with ethylene-treated fruits, which softened normally (Abu-Goukh, 2019). The fibre content of orange was not affected by 1-MCP or ethylene (Li et al., 2016). 1-MCP application retarded softening resulting in the elevation of fibre content in banana fruit (Saeed & Abu-Goukh, 2013) and apple (Win et al., 2021). The application of 1-MCP and wax emulsion (candelilla and flava) separately and combined to soursop fruit stored at 16℃ and 25℃ (control) significantly affected the fibre content (Total fibre) of treated fruits. Total dietary fibre (TDF) was significantly high in fruits stored at 16℃ and 1-MCP treated fruits. The low total dietary fibre content in soursop fruits stored at 25℃ (control) could due to the activity of pectinmethylesterases, polygalacturonases and celluloses in the mature control soursop fruits. These enzymes catalysed the de-esterification and depolymerization of the polysaccharides that are part of soluble dietary fibre (SDF) and TDF such as pectin, hemicellulose and celluloses in the cell wall. Fruits treated with 1-MCP and wax emulsion had greater amount of TDF than the control fruits and refrigerated fruits without 1-MCP (Moreno-hernández et al., 2014).

The effect of 1-MCP on fruit pulp moisture content (MC) stored in WC and EC

The high moisture content (MC) of ripe plantain contribute to the high perishability of plantains when ripe, this is because the high MC encourages the growth of microorganisms and increases the rate of enzymatic reactions which results in deterioration (Ayo-Omogie et al., 2010). Mould, yeast and bacteria activity as well as physical deterioration of has a relationship with MC (Weinberg et al., 2008). At high MC, the rate of deterioration may be high, which affect the shelf life of plantain and its related product (Angioloni et al., 2011). Ripe plantains high moisture content and high water activity as such they tend to relatively soft and highly perishable, susceptible to mechanical injury, physiological deterioration, water loss, and microbiological decay, limiting postharvest life of cooking bananas to 5-10 days under ambient temperature (Yan et al., 2008). 1-MCP reduced or did not affect the moisture content of some fruits. While 1-MCP did not affect moisture content in some non-climacteric fruits such as oranges (Li et al., 2016), it delayed moisture loss in climacteric fruits including avocado (Olivares et al., 2022). Moisture loss and shrinkage of plantain could be indirectly delayed by the action of 1-MCP that slows the rate of respiration. 1-methylcyclopropene maintained Granny smith apples moisture content and shrinkage better than controlled atmosphere (CA) storage (Zanella, 2003). Watkins et al. (2012) found that the combination of 1-MCP and CA was better in maintaining moisture content in apples than controlled atmosphere only which increased the moisture due to ripening. 'Hass' avocado fruits treated with 500 nl /l 1-MCP were low in moisture content than fruits treated with 100 nl /l 1-MCP and all 1-MCP treated fruits were lower moisture content than untreated control due to the ripening nature of the 1-MCP untreated samples (Woolf et al., 2005). Orange moisture content loss and shrinkage were very low and not affected by 1-MCP or ethylene (Li et al., 2016). The application of 1-MCP and wax emulsion (candelilla and flava) alone and combined to soursop fruit and stored at 16°C and 25°C (control) did not significantly affect the moisture content of treated fruits including 1-MCPtreatment only. The noticeable difference in moisture content could be due to uncontrolled relative humidity during storage (Moreno-hernández et al., 2014). No effective loss of moisture was detected between fruits treated with 1-MCP with ethylene and ethylene treatment only in strawberry fruits (Tian et al., 2000). Loss of moisture in tomato fruits treated with 1000 ml/l 1-MCP was significantly lower than control fruits after 17 days at 20°C and 85-95% relative humidity (Moretti et al., 2002). High relative humidity gave a minimal reduction in moisture content of banana stored or treated with 1-MCP as compared with the untreated banana.

The effect of 1-MCP on fruits ash content stored in WC and EC

Ash content provide indication of the mineral composition available in fruits (Ayele et al., 2017). The standard ash content of fruits is confirmed to fall within the range of 1.5 to 3.5% on the bases of 13.5% wet base (w.b), which depends on the variety of fruit including plantain and the environmental factors including the soil properties on which it was produced (Boakye et al., 2014). Higher ash may contribute to the flavour and taste of banana and plantain and the nutrient quality but may also compromise the fibre content in fruits (Kitabchi et al., 2013). Despite the variations in 1-MCP concentration, storage method, storage duration, and post-storage ripening conditions used, all show that 1-MCP treatment increases the levels of individual minerals and the ash content. Furthermore, it is important to note that in these reports, the 1-MCP-treated pears were higher in ash content compared to untreated pears, which could indicate that the reduced volatile production was due to different physiological ripeness stages. The application of 1-MCP and wax emulsion (candelilla and flava) alone and combined to soursop fruit and stored at 16°C and 25°C (control) significantly affected the ash content of treated fruits. The high ash content in soursop fruit stored at 16°C could be the result of alterations in the structure of cell wall polysaccharides and their cross links with minerals during cold storage (Moreno-hernández et al., 2014).

According to Chukwu et al. (2011), the percentage crude fibre content, ash content, and lipid content increased daily throughout the storage days. Also, the decrease in ash content in the untreated banana may be due to the respiration of banana fruits that changed as the banana got ripped. Avocado fruits treated with 500 nl /l 1-MCP were confirmed to attain a higher ash content than fruits treated with 100 nl /l 1-MCP and all 1-MCP treated fruits were also higher in ash content than untreated controls (Woolf et al., 2005). 1-MCP treatment was confirmed to have a positive effect on the ash content due to its ability to reduce the rate of ethylene action which causes ripening of fruits leading to the increase of ash content. The results were confirmed by Manigo et al. (2020),

The effect of 1-MCP on fruits (Iron, Zinc, Potassium, and Calcium) stored in WC and EC

Minerals play key roles in our body's development to undertake such necessary functions as building strong bones, transmitting nerve impulses for health and life. In recent years, there have been scientific efforts to overcome mineral malnutrition in developing countries, because the deficiency of Fe, Zn, K, and Ca, in the world's population is about 60, 30, 30, and 15%, respectively (Haddad et al., 2015). The decrease in the mineral content of plantain is a result of ripening or deterioration and therefore, the action of 1-MCP is mediated through the inhibition of ethylene perception of plant tissues by interacting with the receptor and competing with ethylene for binding sites (Watkins et al., 2012). Also, the effectiveness of inhibition of ripening and/or senescence of fruits and vegetables is a function of the 1-MCP concentration applied, up to saturation of the binding sites. 1-MCP retains most of the minerals in fruits, while some crop species were not affected. 1-MCP application retarded minerals such as Ca, K, Zn, and Fe in mango fruit (Li et al., 2020) guava (Bassetto et al., 2005) and tomato (Moretti et al., 2002). There was a retention of minerals in tomato fruits treatment with 1000 ml/l 1-MCP was higher than control fruits (88%) after 17 days at 20±1℃ and 85-95% relative humidity (Ochida et al., 2018). Similar results were reported for apple fruits after 1-MCP treatment (Watkins et al., 2012). Bai et al. (2005) found that the combination of 1-MCP and Cold storage was better than either alone. Avocado fruits treated with 500 nl /l 1-MCP were higher in minerals such as Ca, K, Fe, and Zn than fruits treated with 100 nl /l 1-MCP and all 1-MCP treated fruits were higher in minerals than untreated controls (Olivares et al., 2022). After cold storage, 1-

MCP did not allow nectarines to ripen normally, compared with ethylene-treated fruits, which softened normally (Dong et al., 2001). The mineral content of orange was not affected by 1-MCP or ethylene (Li et al., 2016). Also, there was no significant difference in the mineral content between fruits treated with ethylene alone or 1-MCP with ethylene-treatment in blueberry fruits (Wang et al., 2018). Aguayo et al. (2006) found that 1-MCP maintained high mineral content in strawberry fruit. Similar results were reported by Manigo et al. (2020) for Cavendish banana which may be due to the ripening stage result of the control sample.

The effect of 1-MCP on fruits vitamin C content stored in WC and EC

Ascorbic acid (AA) or vitamin C is water soluble vitamin found mostly in fruits and vegetables. A dose of 25-40 mg/day and 45 mg/day are recommended for children and adults respectively. Vitamin C cannot be stored in the human body in large quantities. It is an essential antioxidant in human metabolism serving as oxidizing or reducing agent. Vitamin C plays critical role in many biochemical processes and helps in enzyme mediated reactions in the human body. It prevents certain diseases including common colds, muscular degeneration, and cataract (Ramzan, 2017). The effects of 1-MCP and cold storage on vitamins C content has been studied in different fruits. ‘The increase in AA with ripening was attributed to increase in lipid peroxidation during ripening which is an oxidative process that requires turnover of active oxygen species. However all combinations of treatment indicated significantly lower AA than control until 10 days of storage (Wasala et al., 2020). 1-MCP treatment of oranges (cv pera) with different concentrations i.e., 0.1, 0.5 and 1.0 µl /l for 12 hours and stored at 7°C for 45 days showed large variations in results for AA between control fruits and 1-MCP treated fruits and was not possible to affirm that the highest dose of 1-MCP treatment either increased or decreased the amount of AA in the treated fruits (Franco Rosa et al., 2016). The effect of 1-MCP pre-treatment of freshly harvested loquat fruits with 50 nl /l for 24 hours at 20°C and stored at 1°C for 35 days showed decrease in AA content with storage duration and that there were no significant differences in the levels of AA between the control and 1-MCP treated fruits (Cao et al., 2011). The application of combined 1-MCP and or Carnauba wax-based nano emulsion coating -1 (NC-1) to treat honey peach fruit “yulupantao” under storage for 28 days at 0 ± 0.5°C and 90% RH for 28 days significantly maintained AA content of the yulupantao fruit. There was no significant effect on AA contents between treated fruits and untreated control fruits before the first 7 days, however the effect of 1-MCP and NC-1 combination became more evident as storage proceeded, showing significant drop in the level of AA for the control after 7 days of storage (Zhang et al., 2022). Vitamin C was also not affected by 1-MCP treated oranges (Cai et al., 2021). Control and 1-MCP treated cherry tomato fruits had similar vitamin C content during the entire experiment, but between 8 and 11 days after 1-MCP application, control fruits had a significant increase in vitamin C. Cherry tomato fruits treated with 1-MCP had an average vitamin C content of 3.80mg/100g but by the end of the storage period and there were no significant differences in the vitamin C levels for all treatments (Taye et al., 2019). In fruits stored at 20°C without 1-MCP, it was possible that chilling injury contributed to reducing the synthesis of vitamin C, while in fruits stored at 20°C with 1-MCP, this compound prevented chilling injury and at the same time delayed the synthesis of enzymes that degraded ascorbic acid, also edible coatings acted synergistically with 1-MCP to reduce gas exchange and decrease the oxidation of vitamin C (Taye et al., 2019). The effect of three storage conditions: refrigerated storage (11-12℃) and 95.5% RH; warm room storage (20-22℃) and (82-85%) RH and 12-hour cycle of 28℃ and 70% RH and 18℃ and 50% RH stimulating cyclic day/night conditions on physico-chemical characteristics of "milk" banana during storage revealed that refrigerated storage at (11-12℃) and 95.5% RH offered significant benefits in post-harvest handling of "milk" banana by enhancing vitamin C content during ripening (Opara et al., 2012).

The effect of 1-MCP on sensory attributes of fruits stored in WC and EC

Consumer acceptability of improved technology for the storage of fruits will depend on its impact on sensory quality of fruit including colour of fruit, aroma, flavour, texture, taste, mouthfeel and above all the storage life (Hagan et al., 2017). The application of 1-MCP at different concentrations (0.6 and1.0 µl /l) in combination with calcium to 'Fuji' apples stored at room temperature for over 50 and 100 days on flesh firmness and aroma volatile production. There was no significant difference between the two treatments in maintaining fruit firmness and texture, however apple fruits treated with 0.6 µl /l and calcium combination had higher aroma quality than fruits treated with 1.0 µl /l only according to sensory evaluation using electronic nose detection and texture evaluation. 1-MCP at reduced concentration of 0.6 µl /l presented an interactive effect with calcium application on promoting volatile emission and reducing softening (Lu et al., 2018). 1-MCP applied by dipping mature-green plantains into aqueous solution of 1-MCP at 100 µg /l for 1 minute and stored at 15 and 30℃, at 75% relative humidity significantly reduced the ripening rate as measured by changes in peel colour and softening, but did not affect the sensory qualities (taste, mouthfeel, appearance, aroma, flavour, peel and pulp colour and overall acceptability) of plantain fruits and boiled plantain pulp (Hagan et al., 2017). Sensory characteristics of tomato fruit are important component of fruit quality and decide to a high degree on consumer's acceptance (Azodanlou et al., 2003). Other authors have indicated the positive influence of 1-MCP treatment on the sensory characteristics of tomatoes (Lok et al., 2009). According to Gajewski et al. (2014) treatment of tomatoes with 1-MCP intensified the sensory qualities such as the taste, mouthfeel, aroma or odour, appearance, texture as well improved mineral content which may have resulted in higher ash content. Similar results have been reported in plums (Martínez-Romero et al., 2003), avocado (Jeong et al., 2002), and bananas (Abu-Goukh et al., 2013). 1-MCP application retarded softening resulting in the elevation of the sensory attribute of banana fruit (Abu-Goukh et al., 2013), plantain (Dongo et al., 2011), mango (Faasema et al., 2014), guava (Bassetto et al., 2005), Lakatan banana (Manigo et al., 2019), and Cavendish banana (Matuginas et al.,2020). It indicates, that when compared with the values of sensory attributes observed in the conducted study, only fruits subjected to 1-MCP treatment were perceived by consumers as the most acceptable over extended storage period. The untreated ones were too soft to be considered as the ones of highest quality. Cold storage had a measurable effect on the quality of the fruit. The results showed that 1-MCP-treated banana fruit were firmer and less juicy than untreated fruit, especially for fruit stored at 20℃. This suggests that 1-MCP treatment could delay softening and sweetness in banana fruit stored at colder temperatures.

CHAPTER THREE

METHODOLOGY

Experiment location

The experiment was carried out at the Department of Agricultural Engineering Research Laboratory, the University of Cape Coast in the Central Region of Ghana.

Preparation of plantain materials

Sixteen (16) bunches of matured False horn-type plantains (Apantu) were harvested early in the morning from the School of Agriculture farms (Appendix A9). Three important maturity characteristics were used to select the matured plantain bunches. These are the age of the bunch after emergence from the pseudostem, angularity of the cross-section of the fruits, and firmness and blackening of the apex of the fruits. Harvested bunches were de-handed with a knife and arranged in a paper box lined with dry plantain leaves to provide cushioning during transportation to the laboratory. De-handed plantain bunches were separated into individual fingers and similar size rounded fruits were selected. Samples with defects such as cuts, bruises, deep wounds, or insect damage were rejected. The selected fruits were washed under running water from the tap to remove latex and dirt. Thereafter, fruits were air-dried (Appendix A10), and graded by size. The plantain fingers were sorted into eight (8) treatment groups i.e., 0 µl/l WC, 15 µl/l WC, 30 µl/l WC, 60 µl/l WC, 0 µl/l EC, 15 µl/l EC, 30 µl/l EC and 60 µl/l EC. Note: WC represent wooden cabinet storage and EC represent evaporative cooler storage.

Preparation and Application of 1-MCP

1-MCP (SmartFresh^{TM}) treatment was done according to Amoah and Terry (2018) with slight modifications to obtain the following concentrations of 0 µl/l, 15 µl/l, 30 µl/l, and 60 µl/l using standard laboratory guidelines. The prepared 1-MCP solution was placed at the centre of an airtight chamber of 50-litre capacity at 28± 0.5℃ where the fruits were kept. A portable ST-09 electronic fan (Hangzhou, Zhejiang) was placed in the airtight chamber to ensure even circulation and distribution of 1-MCP gas within the chamber. Plantain fruits were exposed to1-MCP gas for 24 hours (Wasala et al., 2021). Temperature and humidity data loggers Tr-32, (Ningbo, Zhejiang) were placed in the chambers to record the inner temperature and humidity of the airtight chamber. Fruits used as control were also kept under the same condition without 1-MCP treatment. Each of the 1-MCP treated fruits was kept using two storage methods, a wooden cabinet (Appendix A 11) and pot-in-pot evaporative cooler (Appendix A 12), and monitored for 30 days.

Experimental Design and Treatments

The experiment was a two-factor experiment (2×4) in Completely Randomized Design (CRD) with three replications. The factors were (i) two storage methods i.e., wooden cabinet (WC) and pot-in-pot evaporative cooler (EC) and (ii) four concentrations of 1-MCP, i.e., 0 µl/l, 15 µl/l, 30 µl/l and 60 µl/l. The total treatment combination was 24. Each treatment contained twelve (12) fingers of green matured plantains.

Determination of physiological weight loss of plantain fruit during storage

Physiological weight loss of plantain was determined throughout the storage period of the experiment. Three plantain fruits were randomly selected for the determination of weight loss every five days (Hagan et al., 2017). The samples were weighed using an electronic weighing scale (Quanzhou, Fujian). The cumulative weight loss was expressed as percentage weight loss using Equation 1.

$$\textbf{Weight loss (\%)} = \frac{\text{Initial weight of fruit (w1)} - \text{Final weight of fruit (w2)}}{\text{Initial weight of fruit (w1)}} \times 100\%$$

(Eq.1)

Determination of fruit and pulp firmness during storage

A GY-4 digital Penetrometer (Hedao Ltd, Fujian Province, China) was used to measure the firmness of the plantain fruit throughout the storage duration. The operational principle of the penetrometer was based on the force necessary to push the plunger of the Penetrometer into the plantain fruit (Hagan et al., 2017).

Determination of percentage dimensional shrinkage of fruit during storage

The dimensional shrinkage of plantains under storage was determined by measuring the diameter of the mid-point of the plantain sample marked with masking tape using the digital calliper (WW-DC158-8) (Fuzhou, Fujian Province, China). The shrinkage was measured throughout the storage duration at the mid-point of the plantain finger. The diameter of the sample was taken every 5 days and the cumulative shrinkage calculated using Equation 2 and expressed as percentage.

$$\text{Shrinkage (\%)} = \frac{(Di - Df)}{Di} \times 100 \quad \text{(Eq. 2)}$$

Where, Di is the initial diameter of plantain, Df is the final diameter of plantain.

Determination of Storage life of fruit during storage

The plantain fruit storage life was determined by counting the number of days required for the harvested fruits peel colour to change from deep green to complete yellow which correspond to ripening stage six colour of the banana colour chart (Agbemafle et al., 2017). The change in the fruit peel colour from deep green to yellow is an indication of ripening of fruit (Onojah & Emurotu, 2017). Ripening stage seven indicates the end of the storage life of the fruits (Addisou et al., 2018).

Determination of Fruit Peel and Pulp Colour

Fruit peel and pulp colour were measured at the middle, the stalk and the blossom areas of the fruit at four different points in each area using a portable Konica Minolta Chroma Meter, CR-400 (Sensing Inc., Japan). The colorMeter was calibrated using a white standard calibration plate before taking the readings of the samples during each sampling day. The average value was recorded for the colour coordinates L* a* b* of CIE LAB colour (Hagan et al., 2017).

Determination of vitamin C (Ascorbic acid)

100 g sample was cut into small pieces and ground in a mortar with a pestle. 10 ml portions of distilled water were added several times while grinding the sample, each time the liquid extract was decanted into a 100 ml volumetric flask (Demasse Mawamba et al., 2007). The solution extracted was made up to 100 ml with distilled water. 20 ml aliquot of the sample solution was pipetted

into a 250 ml conical flask. 150 ml of distilled water and 1 ml of starch indicator solution were added. The sample was titrated with 0.005 mol l^{-1} iodine solution. The endpoint of the titration was identified as the first permanent trace of a dark blue-black colour due to the starch-iodine complex. Titration was repeated with more aliquots of sample solution until a concordant result was obtained (titres agreeing within 0.1 ml). The equation of the titration was used that is, Ascorbic acid + $I_2 \rightarrow 2\ I$ + dehydroascorbic acid to determine the number of moles of ascorbic acid that reacted which was reported in concentration (mol l^{-1}) of ascorbic acid in the solution obtained from the plantain pulp and it was reported in mg/100ml or mg/100g of ascorbic acid in the plantain fruit (Barek et al., 2021).

Compositional Analysis

The nutrient composition of plantain stored for 0, 10, 20 and 30 days, both in the wooden cabinet and pot-in-pot evaporative cooler after 1-MCP treatment was determined at five days interval to know the effect of 1-MCP at different concentrations on the nutrient quality of treated plantains. Samples were analysed using the standard procedure for moisture, protein, fat, ash, crude fibre, and carbohydrate as reported by Boakye et al. (2014).

Plantain Fruit Pulp Ash Content Determination

The ash content of plantain fruit pulp was determined at five days interval during the 30-day storage duration. The principle of ashing is to burn off the organic matter and to determine the inorganic matter left. The samples were heated in two stages to first remove the water present and char the samples and finally ash the samples at 550°C in the muffle furnace (Carbolite AAF 1100, U. K). Ash was to be white or light grey, otherwise samples covered in the crucibles were returned to the muffle furnace for further ashing according to as reported by Boakye et al. (2014).

Calculations

Ash content (%) = $\frac{Weight\ of\ ash}{Weight\ of\ sample} \times 100\%$

Minerals determination

Determination of Potassium

Potassium in the digested samples was determined using a flame photometer. In the determination, the following working standards for K was prepared: 0, 2, 4, 6, 8 and 10 μg/ml. The working standards as well as the sample solutions were aspirated individually into the flame photometer and their emissions (readings) recorded. A calibration curve was plotted using the concentrations and emissions of the working standards. The concentrations of the sample solutions were extrapolated from the standard curve using their emissions as reported by Liotta et al. (1974).

Calculation

μg K/g = $\frac{(\text{C x solution volume})}{(\text{Sample weight})}$, where c = concentrations of the working solutions

Determination of Calcium by EDTA Titration

Calcium was determined by placing an aliquot of 10 ml of the sample solution in a 250 ml conical flask and the solution diluted to 150 ml with distilled water 15 ml of buffer solution and 1ml each of potassium cyanide, hydroxyl-amine hydrochloride, potassium ferro-cyanide and triethanolamine (TEA). Five drops of Erichrome Black T (EBT) were added and the solution was titrated against 0.005M EDTA. Calcium was determined by pipetting 10 ml of the sample solution into 250 ml conical flask and diluted to 150 ml with distilled water. 1 ml each of potassium cyanide, hydroxyl-amine-hydrochloride, potassium ferro-cyanide and triethanolamine (TEA) and five drops of calcium indicator were added and the solution was titrated with 0.005M EDTA (Schaller et al., 1992).

Calculations

$\% \text{ Ca} = \frac{(0.005 \text{ x } 40.08 \text{ x } T)}{\text{Sample wt}}$, where c = concentrations of the standard solutions

Where T is the titre value and 40.08 is the molecular weight of Ca.

Determination of Iron and Zinc

Standard solutions of 1, 2 and 5μg/ml solutions of Fe and Zn were prepared. The standard solutions were aspirated into the atomic absorption spectrophotometer (AAS) and the respective calibration curves plotted on the AAS. As the sample solutions were aspirated, their respective concentrations were provided as reported by Sheng et al. (2010).

Calculations

$\text{Fe } (\mu g/g) = \frac{(\text{C x solution volume})}{\text{Sample weight}}$, where c = concentrations of the standard solutions

$\text{Zn } (\mu g/g) = \frac{(\text{C x solution volume})}{\text{Sample weight})}$, where c = concentrations of the standard solutions

Disease Incidence and Severity

Decay of plantain is a major problem during storage and transportation. Post-harvest decay of plantains is caused by fungal disease as well as mechanical injury to the plantain fruit (Xu et al., 2019). Fruit decay was visually evaluated during the course of the plantain storage experiment. Any plantain with visible mould growth and rot were considered decayed. Assessment of decay was done by observing the physical appearance of the fruits over the storage period for signs of mould growth, and location of infection site. Upon identification of decay, decay incidence was calculated as the number of fruits exhibiting the symptoms of decay out of the total number of fruits per treatment (Kuyu & Tola, 2018).

$$\text{Disease incidence (\%)} = \frac{\text{Number of decayed fruits}}{\text{Total number of fruits per treatment}} \times 100\%$$

Decay severity was evaluated by observing the extent of decayed fruit area. For each treatment, the severity of decay was measured on the scale grade of 1 to 5, where 1 = 0% i.e., no decay; 2 = decay covering $\geq$ 1% but $\leq$ 25% of the fruit surface area; 3 = decay covering $\geq$ 26 but $\leq$ 50% of the fruit surface area; 4 = decay covering $\geq$ 51% but $\leq$ 75% of the fruit surface area, 5 = decay covering $\geq$ 75% but $\leq$ 100% of the fruit surface area (Youssef et al., 2020).

Sensory evaluation

Plantains of uniform size and weight (150-300g) were washed, dry-clean and sorted into two batches. The first batch was treated with no 1-MCP i.e., 0 µl/l and the second batch treated with 15 µl/l 1-MCP in 50-liter volume fumigation chamber for 24 hours. The treated batch was also divided into two and stored in the wooden cabinet and pot-in-pot evaporative coolers. Sensory evaluation was carried out to assess the effect of 1-MCP and wooden cabinet storage and 1-MCP and pot-in-pot evaporative cooler storage on the texture, odour, appearance and overall acceptance of fruits and the effect of 1-MCP and wooden cabinet storage and 1-MCP and pot-in-pot evaporative cooler storage on the texture, taste, colour, aroma, taste, aftertaste, mouthfeel and overall acceptance of boiled plantain (Ampesi) (Table 4). Sensory evaluation was done for fruits stored for one day, five days, ten days, and fifteen days. The samples for evaluation were washed and hand-peeled. The plantain pulp was immediately cooked on electric cooker (Phillips ACH 063/PH, Poland) in measured volume of boiling pure water in stainless-steel pots (100°C at 21 m above sea level in Cape coast, Ghana with water to plantain ratio of 3:1). The cooking time was adapted to the stage of ripeness of plantain and known traditional culinary practices as well as some preliminary cooking trials, 30 mins for mature green plantain, 20 mins for half-ripe and 10 mins for fully ripe plantain (Kouassi et al., 2021).

Serving of Samples and Tasting

After each boiling, whole boiled plantains were removed from the water and cuts into 3 cm sections. The boiled plantain was wrapped in aluminium foil and placed in a labelled white styrofoam covered plates. Fruit peel colour was determined using seven-member trained panel (Table 4) to assessed the peel colour of all the treated plantains under storage using the standardized Von Loesecke banana colour chart at every sampling period. The colour chart shows the peel colour and the corresponding stage of ripeness of plantain (Shahir et al., 2014). The plantains were boiled without any spices or seasoning. Four different treatment samples with unique random three-digit number codes (634, 216, 432, and 523) for both boiled and raw plantain were used for identification purposes for fruits and boiled plantain and served. The boiled samples were placed in a microwave oven (Robert Bosch GmbH, U. K) to keep warm at 50℃ (Akhtar et al., 2009). All the treatments were placed on a serving tray and randomly served to the panellists at the desired time. To reduce contrast, psychological and physiological effects, the samples were presented to panellist in a randomized order. A trained panel (n=7) consisting of 4 females and 3 males were asked to carry out preference or acceptance test using the 9-point hedonic scale to determine preference among the treated samples in which responses from panellists was subjective (Appendix A 3).

Panellists were expected to complete a sensory evaluation questionnaire (Appendix A 1) with the panellist number and sample numbers for both the boiled and raw plantain fruits. The panellists were also provided bottled water to rinse their mouths between sample tasting. A 7×4×4 complete randomized design representing 7 panellists, 4 treatments and 4 storage times was used for the study.

Statistical analysis

All the treatments and assays were carried out thrice and results presented as mean ± standard deviation. The analysis of variance (ANOVA) was performed using Minitab 19 statistical software. Tukey test was used to compute significant differences at ($p < 0.05$).

CHAPTER FOUR

RESULTS AND DISCUSSION

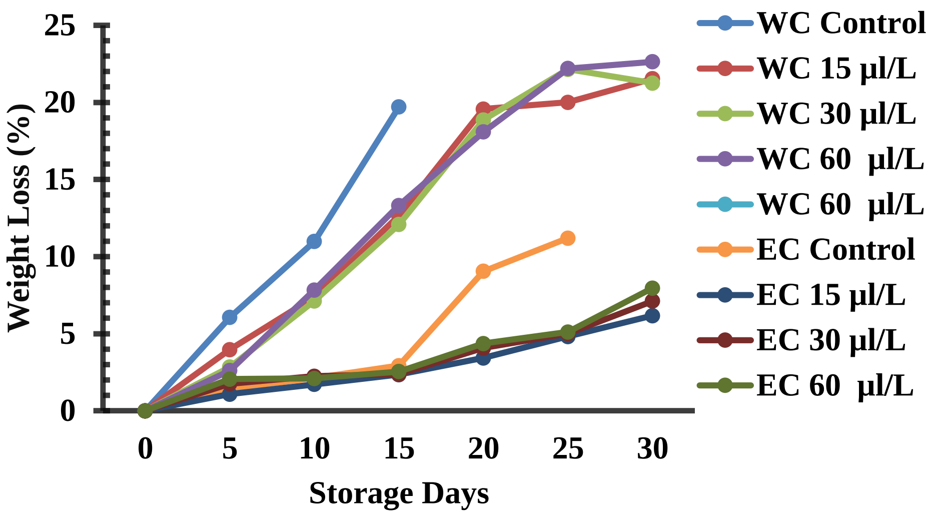

Figure 1: The effect of 1-MCP on the cumulative weight loss (%) in fruits stored in WC and EC

The effect of 1-MCP on the cumulative weight loss in plantain stored in wooden cabinet and pot-in-pot evaporative cooler for 30 days. Treated and untreated plantains i.e., control samples kept in the wooden cabinet generally recorded higher percentage weight loss than treated and untreated plantains kept in the pot-in-pot evaporative coolers. This may be due to high wooden cabinet temperature of 28.91℃ and low relative humidity of 74.16% compared to pot in pot evaporative cooler storage with relatively lower temperature of 25.41°C and higher relative humidity of 94.20%. According to Kuyu et al. (2018) temperatures in the range of 27 to 38℃ increased respiration and ethylene production resulting in rapid breakdown of cell wall and degradation of polysaccharides as well as solubilization of the cell wall and the conversion of starch to sugars resulting in increased weight loss (Agbemafle et al., 2017).

Treated fruits stored in the wooden cabinet had lower percentage weight loss compared to untreated fruits. Cumulative percentage weight loss on storage day 5 for untreated plantains was 6.06% under wooden cabinet storage compared to 60 µl/l 1-MCP treated plantains stored in the wooden cabinet of 2.61% weight loss on storage day 5 (Appendix A 3). This result agreed with Manigo and Limbaga, (2019) who reported 6.57% percentage weight loss of untreated Lakatan banana under ambient storage for 4 days compared to 1.92% weight loss for 1-MCP treated banana stored for 4 days. The cumulative percentage weight loss for the control samples in the wooden cabinet of 10.98% on storage day 10 did not agree with Addisou et al. (2018) who reported cumulative percentage weight loss of 13.42% on storage day 10 for similar work. The difference could be due to the different storage methods used i.e., ambient and wooden cabinet. Cumulative percentage weight loss for 30 µl/l 1-MCP treatment stored for 30 days in wooden cabinet was 21.25% compared 30 µl/l 1-MCP treatment for 30 days stored in pot-in-pot evaporative coolers of 7.11%. This results agreed with Hagan et al. (2017) who reported cumulative percentage weight loss of 24.7% under storage temperature of 30℃ stored for 20 days compared to weight loss of 6.1% for same treatment of 100 µg/l aqueous 1-MCP treatment of plantain stored for 20 days at 15℃. According to Hagan et al. (2017) although 1-MCP application reduced the respiration rate and ethylene production of treated plantain fruits, the effect was better observed when fruits were stored at 15℃. Weight loss at storage was influenced predominantly by storage temperature and not exposure to 1-MCP (Hagan et al., 2017). 1-MCP action may have contributed to the reducing the rate of ripening resulting in reduced moisture loss from treated plantain guaranteeing decreased rate of weight loss (Addisou et al., 2018). There were ifferences in cumulative percentage weight loss observed between plantain treated with 1-MCP and stored in wooden cabinet and 1-MCP treated plantains stored in pot-in-pot evaporative cooler over the 30-day storage period. According to Faasema et al. (2014) 1- MCP suppressed the action of enzymes and this delayed the onset of weight loss in both climacteric and non-climacteric fruits. The percentage weight loss from 1- MCP treatment was smaller when the plantain fruits were stored in the pot-in-pot evaporative coolers of lower temperature and high relative humidity. This result agreed with the reduction in weight loss observed in 1- MCP (1.0µl/l, 24 hours) treatment of orange flesh sweet potato store at 15°C (Amoah et al., 2018).

The wooden cabinet stored samples recorded increase in cumulative percentage weight loss from 6.06% to 19.71% from day 5 to day15 for the control sample compared to 1-MCP treatment of 15µl/l which gave cumulative percentage weight loss of 3.97% to 12.66% from day 5 to day 15 (Appendix A 5) of storage and cumulative percentage weight loss of 21.53% on the 30th day of storage. There was however no difference for 1-MCP treatment of 15µl/l, 30µl/l and 60µl/l for weight loss at day 15 of storage. The percentage increase in weight loss of the control sample in the wooden cabinet during storage was due to the higher temperature of 28.91^{o}C and lower relative humidity of 74.16% in the wooden cabinet as well as fruits not treated with 1-MCP, thus resulting in the rapid rate of respiration and transpiration and increased in ethylene production from increased ethylene sensitivity which hastened the ripening process of the plantain resulting in increased weight loss.

Plantain fruits treated with 60µl/l 1-MCP and stored in the wooden cabinet recorded the highest cumulative percentage weight loss of 22.63 indicating higher ripening activity followed by 15 µl/l 1-MCP concentration recording cumulative percentage weight loss of 21.53 and the least was 30 µl/l 1-MCP concentration recording cumulative percentage weight loss of 21.25% This result confirmed that, high concentrations of 1-MCP was less effective in inhibiting ethylene production. Similar observation was made by Win et al. (2006) who reported that low concentrations of 1-MCP significantly maintained quality of lime fruit during ambient storage. Low 1-MCP concentration effectively reduced ethylene production, delayed fruit yellowing and also delayed the normal rise of chlorophyllase and peroxidase enzyme action without adversely affecting fruit composition. At higher 1-MCP concentration, the less effective was the inhibitory action resulting in the increase rate of ethylene production in the clay pot-in-pot cooler storage.

The lesser weight loss in cooler storage could be due to lower temperature and higher relative humidity, and therefore slower moisture loss and reduced rate of evaporation. Similar results were reported in 'Hass' avocado (Defilippi et al., 2018), and bananas (Abu-Goukh et al., 2013). Weight loss is due to physiological processes of respiration and transpiration of water through fruit tissue as well as other biological changes that takes place in fruits (Faasema et al., 2014). During storage there is loss of moisture that affect the weight, firmness, shrinkage and general loss in value of fruit. Consumers are willing to pay good price for plantains, provided quality attributes including weight and fruit firmness etc. are appropriate. The weight of plantain is one such quality parameter that indicate maturity and ripening capacity (Adheka, Dhed'a, Karamura, Blomme, Swennen, De Langhe, et al., 2018).

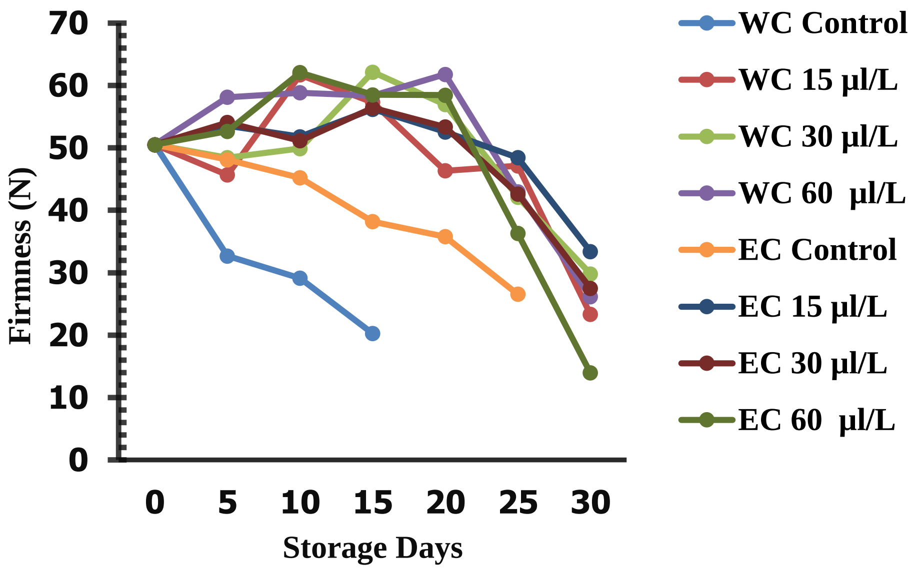

Figure 2: The effect of 1-MCP on the Firmness (N) of fruits stored in WC and EC

Fruit firmness is a quality parameter used to assess the stage of plantain ripeness. Fruit firmness of plantain progress from unripe and firm state to ripe and soft state (Addisou et al., 2018). The firmness or softness of plantain could also be an indication of ripening to deterioration state of fruit or otherwise. However, firmness is also relative because a relatively high firmness could also indicate spoilage or fruit of high quality depending on the type of fruit. Fig. 2 shows the effect of 1-MCP on the cumulative fruit firmness in plantain stored in wooden cabinet and pot-in-pot evaporative cooler for 30 days. The results showed a drop in firmness for 1-MCP untreated plantains and maintenance of firmness for 1-MCP treated plantains stored in the wooden cabinet up to storage day 15. The drop in firmness was relatively slower for 1-MCP untreated plantains stored in the evaporative coolers up to storage day 15, whiles firmness was maintained for 1-MCP treated plantains up to storage day 15, after which firmness dropped for both 1-MCP untreated and 1-MCP treated plantains although the drop was faster for 1-MCP untreated plantains. Firmness of 1-MCP untreated plantains stored in the wooden cabinet dropped from 32.68N on storage day 5 to 20.27N on storage day 15 compared to the highest firmness of 1-MCP untreated plantains stored in the evaporative cooler of 54.11N on storage day 5 which dropped to 26.57N on storage day 25. The firmness of 1-MCP treated plantains in the wooden cabinet started to drop from storage day 20 to storage day 30 with the exception of 60 µl/l 1-MCP treated plantains. The 1-MCP untreated plantains stored in the wooden cabinet by storage day 15^{th} were unsuitable to be sold on the markets according to von Loesecke banana ripening stages as they have decayed (Hagan et al., 2017). The control samples stored in the wooden cabinet recorded the highest firmness of 32.68N on storage day 5 and the lowest firmness of 29.13N on storage day 10 (Appendix A 4). The 15 µl/l 1-MCP treated plantains recorded the highest firmness of 61.70N on storage day 10 and dropped steadily to 23.33N on storage day 30. The 30 µl/l 1-MCP treated plantains recorded the highest firmness of 62.15N on storage day 15 and systematically dropped to 29.82N on storage day 30. The 60 µl/l 1-MCP treated plantains recorded the highest firmness of 61.79N on storage day 20 and gradually dropped to 26.15N on storage day 30.

The 1-MCP untreated plantains had deteriorated completely by the 15^{th} day of storage in the wooden cabinet. Firmness of 1-MCP untreated plantains in the pot-in-pot evaporative cooler storage also saw a decline in plantain fruit firmness over the extended 25 days of storage life however the rate of decline was slower compared to the wooden cabinet storage. The extension of the storage life from 5 to 15 days of the untreated sample in the clay pot-in-pot evaporative cooler storage was due to the favourable mean temperature and relative humidity of 25.41℃ and 94.20%. This may have contributed to the reduced rate of decline of plantain fruit firmness for fruits stored in the pot-in-pot evaporative coolers, thus extending the storage life of 1-MCP untreated plantain fruit stored in pot-in-pot evaporative coolers. According to Kuyu et al. (2018) temperatures below 26°C decreased respiration and ethylene production and reduce the breakdown of cell wall and degradation of polysaccharides as well as solubilization of the cell wall and also reduce the conversion of starch to sugars resulting in reduced rate of loss of firmness (Agbemafle et al., 2017), improved the storage life of fruits stored in pot-in-pot evaporative coolers. According to Faasema et al. (2014) loss of fruit firmness is a significant process which affect fruits during storage as well as ripening. The storage life of the 1-MCP treated plantain was extended from 5 to 25 days in the wooden cabinet storage, although the 15µl/l 1-MCP treated plantains gave a better extended storage life appearance as well as highest firmness of 47.14N on storage day 25. 1-MCP was able to suppress the production of ethylene which reduced the rate of ripening and senescence (Addisou et al., 2018). There was no linear correlation between the concentration of 1-MCP for the wooden cabinet storage at day 10, when the concentration of 1-MCP was increased from 15 µl/l to 30µl/l, this rather decreased the firmness of plantain from 61.7 to 58.83N and decreased drastically from 58.83N to 49.89N, when the concentration of 1-MCP increased from 30 to 60µl/l.

The result agreed with storage life extension to 36 days using 17.5 µl/l 1-MCP in modified atmosphere packaging (Zenebe et al., 2016). However, a linear correlation was observed for the clay pot-in-pot evaporative cooler storage, where an increase in the concentration of 1-MCP from 15µl/l to 60µl/l resulted in the elevation of the firmness on day 10, day 15 and day 20 of storage however from day 25 to day 30 of storage, an increase in concentration from 15µl/l to 60µl/l resulted in decrease in firmness from 36.30 N to 13.96 N. Similar results were reported by Manigo et al. (2020) and Jiang et al. (2018) for Cavendish banana and yard-long beans respectively. There was general improvement in the storage life of plantain stored using the combination of 1-MCP and clay pot-in-pot evaporative cooler method.

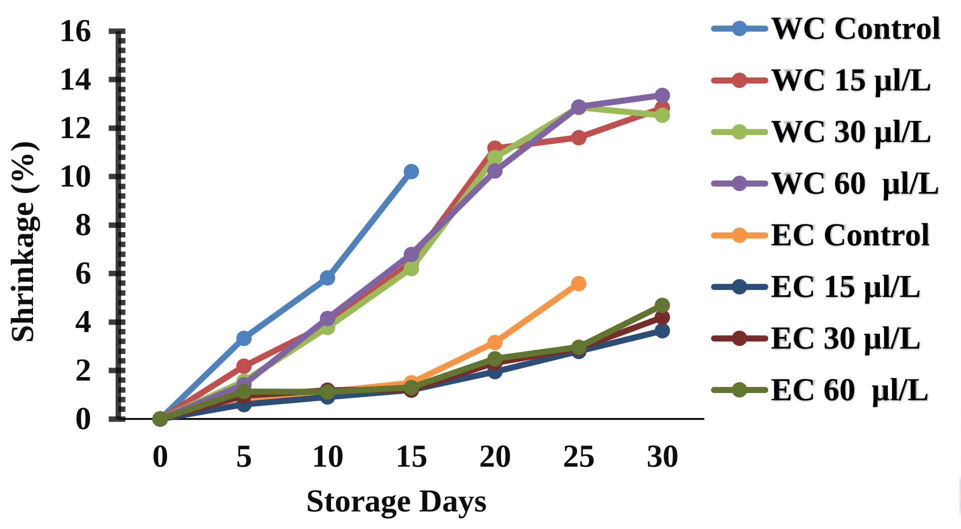

Figure 3: The effect of 1-MCP on dimensional shrinkage (%) of fruits stored in WC and EC

Fresh produce, including plantain lose water and shrinks at postharvest. Plantain fruit shrinkage is the change in diameter and size from large to smaller size. This is due to the exit of plantain moisture during storage which causes pressure change balance between the inner part and outer part (Farahmandfar et al., 2019). This quality parameter is essential in the value chain of plantain as the shrinkage can be equated to the loss of economic value of produce (Kikulwe et al., 2018). Dimensional shrinkage is due to physiological processes of respiration and transpiration of water through fruit tissue as well as other biological changes that takes place in fruits (Faasema et al., 2014). Dimensional shrinkage of plantain was observed to directly relate to the rate of water loss, meaning the higher the rate of water loss, the higher the shrinkage and the vice versa. Figure 3 shows the effect of different concentrations of 1-MCP on percentage dimensional shrinkage of plantain fruits stored in wooden cabinet and pot-in-pot evaporative cooler for 30 days. 1-MCP treated plantains and 1-MCP untreated plantains stored in wooden cabinet and pot-in-pot evaporative cooler. 1-MCP treated and 1-MCP untreated plantains kept in the wooden cabinet generally recorded higher percentage dimensional shrinkage than 1-MCP treated and 1-MCP untreated plantains kept in the pot-in-pot evaporative cooler. This was due to the high mean temperature of 28.91℃ and low mean relative humidity of 74.16% of the wooden cabinet storage compared to the pot-in-pot evaporative cooler storage with relatively lower mean temperature of 25.41°C and higher mean relative humidity of 94.20%. According to Kuyu et al. (2018) high temperatures in the range of 27 to 38℃ increased respiration and ethylene production resulting in ripening of plantain fruit. Physiological processes including the rapid breakdown of cell wall and degradation of polysaccharides as well as cell wall solubilization and the conversion of starch to sugars also resulted in increased percentage shrinkage for wooden cabinet storage (Agbemafle et al., 2017). 1-MCP treated plantains stored in the wooden cabinet had significantly lower percentage dimensional shrinkage compared to 1-MCP untreated plantains stored in the wooden cabinet for 5 and 10 days. Cumulative percentage dimensional shrinkage on storage day 5 for 1-MCP untreated plantains was 3.33% under wooden cabinet storage compared to cumulative percentage dimensional shrinkage of 1.42% for 60 µl/l 1-MCP treated plantains stored in the wooden cabinet. The cumulative percentage shrinkage for 1-MCP untreated fruits in the wooden cabinet on storage day 10 was 5.82% compared to the cumulative percentage dimensional shrinkage of 3.78% for 30 µl/l 1-MCP treated plantains stored in the wooden cabinet. Cumulative percentage dimensional shrinkage for 30 µl/l 1-MCP treated plantains stored for 30 days in wooden cabinet was 12.53% compared to the cumulative percentage dimensional shrinkage 30 µl/l 1-MCP treatment for 30 days stored in pot-in-pot evaporative coolers of 4.20%. There were no significant differences for 1-MCP treatment concentrations of plantains stored for 25 and 30 days in wooden cabinet. There were also no significant differences for 1-MCP treatment concentrations for plantains stored in the pot-in-pot evaporative cooler for 15, 20 and 25 except for the 30 days storage.

According to Hagan et al. (2017) although 1-MCP application reduced the respiration and ethylene production rate of treated plantain fruits by blocking ethylene receptors, the effect was better observed in 1-MCP treated plantain fruits stored at 15℃, which reduced the rate of ripening of plantain as well as reduced moisture loss from treated plantain and decreased rate of dimensional shrinkage (Addisou et al., 2018). Workneh et al. (2010) reported that mean high temperature of 28.91℃ in the wooden cabinet environment contributed to increase rate of plantain fruits respiration and ethylene production resulting in increased ripening and senescence rate as well as increased percentage shrinkage for plantain fruits stored in the wooden cabinet. However, reduced mean temperature of 25.41℃ in the pot-in-pot evaporative cooler storage environment resulted in reduced rate of respiration and reduced ethylene production that contributed to lower cumulative percentage dimensional shrinkage recorded for plantains kept in the pot-in-pot evaporative cooler. According to Nunes et al. (2013), for maximum quality and storage life, plantains and bananas should be stored between 15-20°C and 92% RH. Faasema et al. (2014) observed that 1- MCP could have suppressed the action of enzymes which delayed dimensional shrinkage in both climacteric and non-climacteric fruits. The result agreed with dimensional shrinkage observed in 1-MCP (1.0µl/l, 24 hours) treated orange flesh sweet potato store at 15°C (Amoah et al., 2018). Similar results were reported in bananas (Abu-Goukh et al., 2013). During plantain storage, there is loss of water from the fruits and this reduced fruit weight, firmness, dimensional shrinkage and general loss in value of plantain (Yildiz, 2021). According to Workneh et al. (2010) theoretically for every10°C rise in temperature, the rate of respiration doubles. There was also increase positive correlation between dimensional shrinkage and 1-MCP, which implied that at low 1-MCP concentration, the rate of shrinkage of plantain recorded was low and the vice versa, or increasing the concentration of 1-MCP improved the dimensional shrinkage of plantain. Li et al. (2016) reported that exposing non-climacteric fruits such as strawberry, grapes and pomegranate to 1-MCP inhibited senescence processes and delayed shrinkage. According to Akinyemi et al. (2010), consumers are more than willing to offer good price for good plantains, provided quality attributes including weight and fruit firmness etc. are appropriate. The observed extended storage life of fruits could be due to the effective action of 1-MCP and favourable storage temperature and humidity in the pot-in-pot evaporative cooler (Hagan et al., 2017), which reduced the rate of ethylene production and slowed down both the rate of ripening and senescence of plantains. The storage life of fruits is significant to the fresh produce industry, thus the pot-in-pot evaporative cooler provided suitable temperature and relative humidity as well as preventing chilling injury.

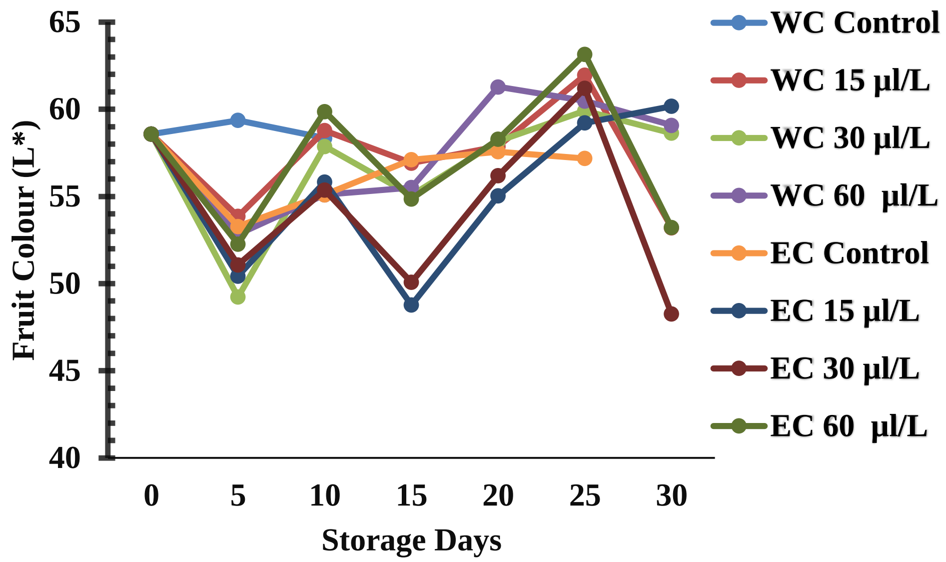

Figure 4: The effect of 1-MCP on Fruit Peel colour lightness (L*) of fruits stored in WC and EC

Figure 4 show the effect of 1-MCP concentrations on fruit peel colour of plantain stored in wooden cabinet and pot-in-pot evaporative cooler for 30 days. On storage day 5, the L* for 1-MCP untreated plantains kept in the wooden cabinet changed from 58.58 at storage day 0 to 59.37 indicating increased lightness and ripening of 1-MCP untreated plantains kept in the wooden cabinet compared to L* for 1-MCP treated plantains (15, 30 and 60 µl/l) 53.86, 49.23 and 52.83 respectively indicating decreased lightness which implied delayed ripening of 1-MCP treated plantains (15, 30 and 60 µl/l) kept in the wooden cabinet. On day 10 of storage, L* for 1-MCP untreated plantains kept in the wooden cabinet decreased from 59.37 to 58.35 whereas L* for 1-MCP treated plantains (15, 30 and 60 µl/l) kept in the wooden cabinet increased to 58.78, 57.87 58.70 respectively. The decrease in L* for 1-MCP untreated plantains and increased in L* for 1-MCP treated plantains (15, 30 and 60 µl/l) 58.78, 57.87 and 58.70 respectively indicated decreased lightness for1-MCP untreated plantains kept in the wooden cabinet which implied the 1-MCP untreated plantains kept in the wooden cabinet were overripe whereas the 1-MCP treated plantains (15, 30 and 60 µl/l) kept in the wooden cabinet increased lightness and therefore were ripening. On day 5 of storage in the pot-in-pot evaporative cooler, L* for 1-MCP untreated plantains decreased to 53.29 on day 5 of storage from 58.58 on storage day 0. L* for 1-MCP treated plantains (15, 30 and 60 µl/l) as well decreased to 50.43, 51.08 and 52.23 respectively from storage day 0 indicating decreased lightness and delayed ripening. L* for 1-MCP untreated plantains kept in the pot-in-pot evaporative cooler increased to 55.10 on storage day 10 compared to L* for 1-MCP treated plantains (15, 30 and 60 µl/l) kept in the pot-in-pot evaporative cooler which also increased to 55.83, 54.39 and 59.87 respectively from storage day 5. On storage day 15, 1-MCP untreated plantains kept in the wooden cabinet had decayed whiles L* for 1-MCP treated plantains (15, 30 and 60 µl/l) in the wooden cabinet decreased from 58.78, 57.87 58.70 in day 10 to 56.91, 55.07 and 55.51 on storage day 15 respectively indicating reduced lightness and therefore delayed ripening of plantains, even though the 15 µl/l 1-MCP treated plantains comparatively showed increased ripening. L* for 1-MCP untreated plantains kept in the pot-in-pot evaporative cooler on storage day 15 increased to 57.11 which meant increased lightness and ripened plantains whereas L* for 1-MCP treated plantains (15, 30 and 60 µl/l) stored in the pot-in-pot evaporative cooler decreased to 48.78, 50.08 and 54.86 indicating reduced lightness which implied delayed ripening. On storage day 25, L* for 1-MCP treated plantains (15, 30 and 60 µl/l) kept in the wooden cabinet increased from 56.91, 55.07 55.51 on storage day 15 to 61.95, 59.91 and 60.47 on storage day 25 respectively indicating increased lightness and therefore ripened plantains. L* for 1-MCP untreated plantains kept in the pot-in-pot evaporative cooler on storage day 25 increased from 57.11 on storage day 15 to 57.19 which meant increased lightness and ripened to overripe plantains. L* for 1-MCP treated plantains (15, 30 and 60 µl/l) kept in pot-in-pot evaporative cooler on storage day 25, increased from 48.78, 50.08 and 54.86 on storage day 15 to 59.22, 61.20 and 63.20 on storage day 25 respectively indicating increased lightness and therefore ripened plantains. On storage day 30, L* for 1-MCP treated plantains (15, 30 and 60 µl/l) kept in the wooden cabinet decreased from 61.95, 59.91 60.47 on storage day 25 to 53.21, 58.63 and 59.08 on storage day 30 respectively indicating decreased lightness and therefore overripened plantains. On storage day 30, 1-MCP untreated plantains kept in pot-in-pot evaporative cooler had decayed while L* for 1-MCP (15 µl/l) treated plantains kept in the pot-in-pot evaporative cooler increased from 59.22 to 60.18 which implied increased lightness and ripening of fruits. L* for 1-MCP treated plantains (30 and 60 µl/l) kept in the pot-in-pot evaporative cooler decreased from 61.20 and 63.20 on storage day 25 to 48.27 and 53.22 respectively on storage day 30.

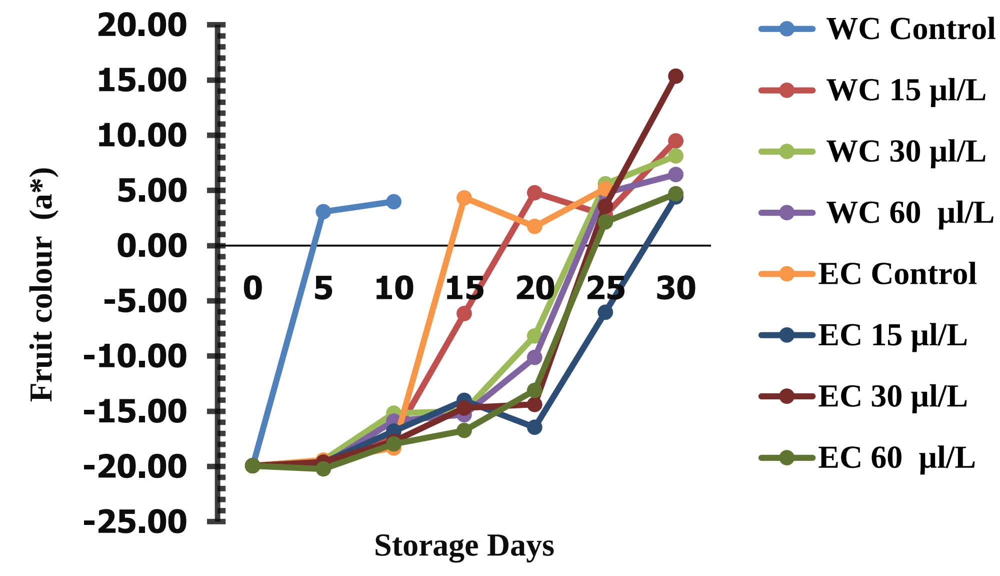

Figure 5: The effect of 1-MCP on Fruit Peel colour Greenness (a*) of fruits stored in WC and EC

The green colour of the plantain outer peel during storage was influence by the method of storage and the concentration of 1-MCP hence difference between the treated and untreated plantain. On the starting day of storage (day 0), all the 1-MCP treated and untreated samples stored in wooden cabinet and pot-in-pot evaporative cooler recorded greenish colour coordinates of -19.94 indicating green peel colour for unripen plantains. Figure 5 showed the greenness of the 1-MCP treated and untreated plantain stored in wooden cabinet and pot-in-pot evaporative cooler decreased with increased storage days from day 0 to day 5, with 1-MCP untreated plantain or control stored in wooden cabinet (0 µl/l 1-MCP WC) attaining the highest greenness colour coordinate of 3.07 and 60 µl/l 1-MCP treated plantains stored in pot-in-pot evaporative cooler (60 µl/l 1-MCP EC) attaining the lowest greenness colour coordinate of -20.23. An increase in a* value indicates a decrease in greenness of the plantain and a decrease in a* value indicates an increase in greenness. The rapid decrease in greenness of 0 µl/l 1-MCP WC on day 5 of storage was due to non-application of 1-MCP and higher storage temperature and lower relative humidity in the wooden cabinet compared to the 60 µl/l 1-MCP EC which recorded extremely slow greenness colour change. The green colour of the plantain outer peel during storage continued to reduce from day 5 to day 10, with 0 µl/l 1-MCP WC recording the highest green colour coordinate of 3.99 while 0 µl/l 1-MCP EC had the lowest greenness of -18.32 on day 10. The greenness colour of 1-MCP treated and untreated plantains continued to decrease as the storage days increase from day 10 to day 20 with 15 µl/l 1-MCP WC recording the highest green colour coordinate of 4.80 while the 15 µl/l 1-MCP EC had the lowest greenness of -16.46 on day 20 of storage, however 0 µl/l 1-MCP WC had decayed on day 15 of storage. The greenness colour of 1-MCP treated and untreated plantains continued to decrease as the storage days increase from day 20 to day 30 with 30 µl/l 1-MCP EC recording the highest green colour coordinate of 15.35 while the 15 µl/l 1-MCP EC had the lowest greenness of 4.40 on day 30 of storage, however 0 µl/l 1-MCP EC had decayed by day 30 of storage. The decreased in greenness could be the result of the ripening process due to physicochemical changes in plantain during normal ripening and storage (Dedo et al., 2019). It was observed that 15 µl/l 1-MCP EC maintained the greenness of the treated plantain up to 25 days while clay pot-in-pot evaporative cooler storage alone maintained plantain greenness to 10 days. Abu-Goukh et al. (2013) observed similar pattern for 1-MCP treated bananas. Manigo et al. (2019) reported that 1-MCP treatment-maintained greenness colour of “Lakatan” banana over extended cold storage period. Generally, there was an improvement in the plantain peel colour greenness of the 1-MCP and pot-in-pot evaporative cooler storage combination. Manigo et al. (2020), reported similar results for 1-MCP treated “Cavendish” bananas.

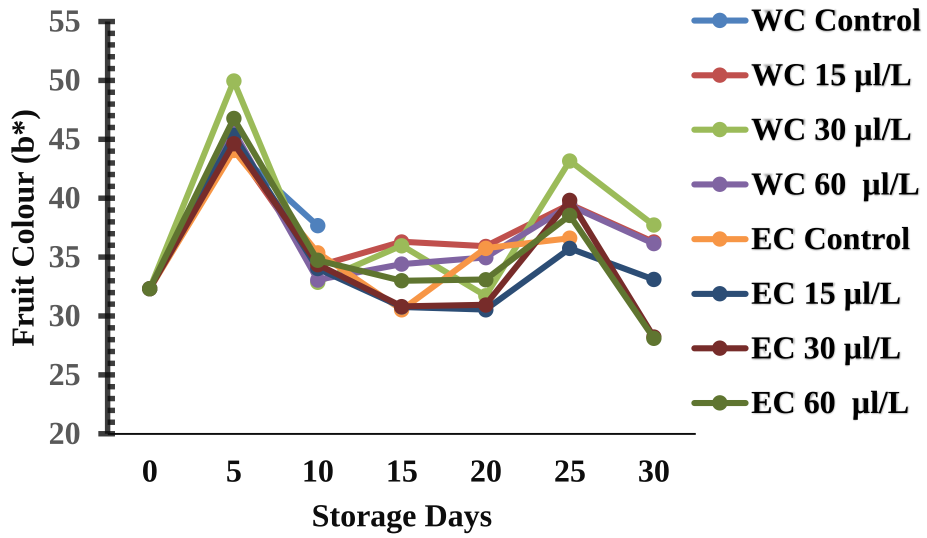

Figure 6: The effect of 1-MCP on Fruit Peel colour Yellowness (b*) of fruits stored in WC and EC

Yellowness of plantain external peel colour appearance indicates the stage of ripeness according to Von Loesecke colour chart (Agbemafle et al., 2017). There were no significant differences between the concentrations of 1-MCP and the yellowness of the plantain peel colour stored in the wooden cabinet and pot-in-pot evaporative cooler (Figure 6). The yellow colour coordinates of all treated and control plantains kept in the wooden cabinet and pot-in-pot evaporative cooler were initially low indicating unripe state of all treatment on storage day 0. There was increase in the yellow colour coordinates for all treated and control plantains on storage day 5 with 30 µl/l 1-MCP stored in the wooden cabinet having the highest yellow colour coordinate (49.95) and 15 µl/l 1-MCP stored in pot-in-pot evaporative cooler having the lowest yellow colour coordinate (43.34). There was drop in the yellow colour coordinates on storage day 10 with 0 µl/l 1-MCP treated (control) plantain stored in the wooden cabinet having the highest yellow colour coordinate (37.68) and 60 µl/l 1-MCP stored in wooden cabinet having the lowest yellow colour coordinate (32.88). The 0 µl/l 1-MCP treated plantain stored in the wooden cabinet was well ripe on day 10 of storage, thus attaining the high yellow colour coordinate. There was marginal decrease in yellow colour coordinate for 15 µl/l, 30 µl/l and 60 µl/l 1-MCP treated plantain stored in pot-in-pot evaporative cooler and 30 µl/l 1-MCP treated plantain stored in wooden cabinet from day 10 to day 20 indicating reduced rate of ripening while the yellow colour coordinates increased for 15 µl/l and 60 µl/l 1-MCP treated plantain stored in wooden cabinet and 0 µl/l 1-MCP treated plantain stored in pot-in-pot evaporative cooler could be the due to the high temperature and low humidity in the wooden cabinet despite the 1-MCP treatment the control not given 1-MCP treatment. There was no colour measurement between day15 to day 30 for the control stored in the wooden cabinet due to decay. The yellowness (b*) of 1-MCP treated and untreated plantains stored in both the wooden cabinet and pot-in-pot evaporative cooler increased from day 20 to day 25, with 30 µl/l 1-MCP treated plantain stored in wooden cabinet attaining the highest yellow colour coordinate (43.17) and 15 µl/l 1-MCP treated plantain stored in pot-in-pot evaporative cooler having the lowest yellowness (35.74) on storage day 25. The low yellow colour coordinate indicated not fully ripe plantain due to combine effect of 1-MCP treatment and lower temperature of pot-in-pot evaporative cooler. The yellowness (b*) of 1-MCP treated plantains stored in both the wooden cabinet and pot-in-pot evaporative cooler decreased from day 25 to day 30, with 30 µl/l 1-MCP treated plantain stored in wooden cabinet attaining the highest yellow colour coordinate (37.73) and 60 µl/l 1-MCP treated plantain stored in pot-in-pot evaporative cooler having the lowest yellowness (28.13) on storage day 30. This observation confirmed that 1-MCP at high concentration rather hasten ripening and that low concentration effective in delaying ripening (Blankenship et al., 2003). The results was confirmed in plantain treated with 100 µg/l 1-MCP aqueous and stored at 15℃ and 30℃ (Hagan et al., 2017).

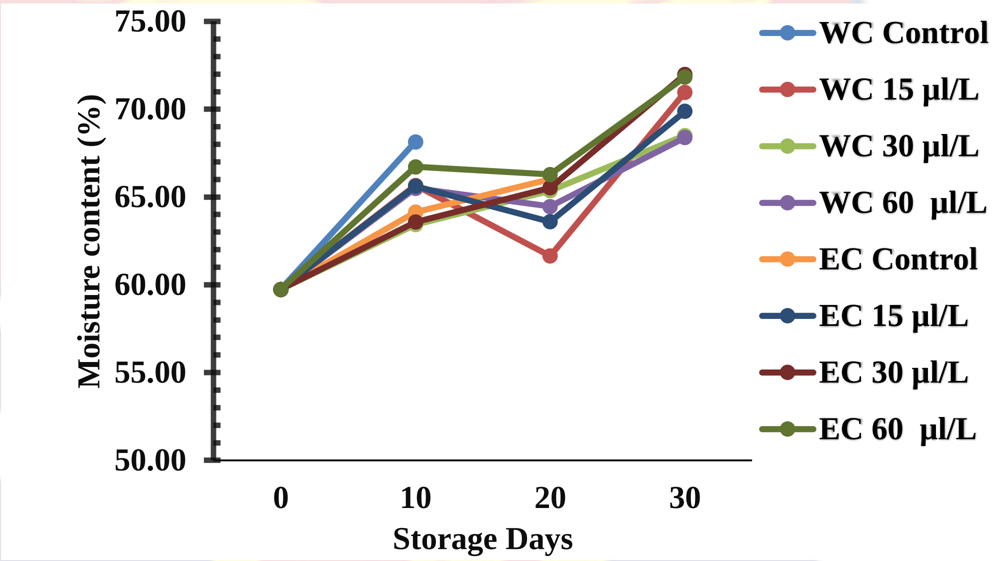

Figure 7: The effect of 1-MCP on moisture content (%) of fruits stored in WC and EC

Moisture level for both 1-MCP untreated and 1-MCP treated plantain fruits stored in the wooden cabinet and pot-in-pot evaporative cooler increased with increase in storage days. This could be due to ripening of plantains as the storage duration increased (Sánchez et al., 1969). 1-MCP may reduce or may not reduce the fruit moisture content during storage (Li et al., 2016). The highest percentage moisture content of 71.83% (Figure 7) was observed on storage day 30 for 60 µl/l 1-MCP treated plantains stored in the pot-in-pot evaporative cooler. According to Win et al. (2006) low 1-MCP concentration delayed ripening in lime which resulted in the reduction of two chlorophyll-degrading enzyme action; chlorophyll degrading peroxidase and chlorophyllase. Some scientist have also reported that 1-MCP usage in low temperature storage was effective in slowing down chlorophyll degradation. Addisou et al. (2018) did not observe the effectiveness of low 1-MCP concentration in delaying ripening of plantain fruits treated with 0 ppm, 1 ppm and 2 ppm, instead high concentration of 1-MCP (2 ppm) was effective in slowing ripening of green pre-climacteric plantains and extended the storage life while maintaining the physical quality characteristics of two varieties of plantains throughout the study. The highest percentage moisture content of 70.29% was observed on storage day 15 for 1-MCP untreated plantains stored in wooden cabinet, by this time the 1-MCP untreated plantains in wooden cabinet had decayed.

There was no difference in the moisture content of 1-MCP treated plantain stored in the wooden cabinet and pot-in-pot evaporative cooler. The moisture content of 1-MCP untreated plantain stored in the wooden cabinet on storage day 10 was 68.15% and increased to 70.29% on storage day 15 compared to 1-MCP untreated plantain of moisture content 65.62% kept in the pot-in-pot evaporative cooler on storage day 10 which increased to 67.34% on storage day 15. MC increased for 1-MCP untreated plantain stored in the wooden cabinet compared to 1-MCP untreated plantain stored in the pot-in-pot evaporative cooler. This was due to the low temperature of the pot-in-pot evaporative cooler. According to Workneh et al. (2010) the rate of respiration depends on the quantity of oxygen available as well as storage temperature, as such the pot-in-pot evaporative cooler storage supported the decrease in the rate of respiration which increased the storage life of plantain fruits. Reduced respiration led to reduced ethylene production. All the 1-MCP (15, 30 and 60µl/l) treated plantains stored in the pot-in-pot evaporative cooler recorded lower moisture content (61.65, 65.37 and 64.46%) compared to moisture content (63.60, 65.53 and 66.27%) of wooden cabinet storage respectively for storage day 20. The 1-MCP (15, 30 and 60µl/l) treated plantains stored in the pot-in-pot recorded moisture content (69.89, 71.98 and 71.83%) compared to moisture content (70.97, 68.51 and 68.39%) of wooden cabinet storage respectively for storage day 30. The storage life of 1-MCP untreated plantain stored in wooden cabinet was different from that of the pot-in-pot evaporative cooler. This was due to the variation in temperature and relative humidity. Increasing the concentration of 1-MCP treated plantain from 15 to 60µl/l rather increased moisture indicating full ripeness which brought about plantain deterioration. There was however a positive correlation between moisture content and the concentration of 1- MCP. Previous studies confirmed that pear treated with 0.5µl/l 1-MCP plus micro-perforated film packaging material maintained protein content than pear treated with 1.0µl/l 1-MCP plus micro-perforated film packaging material (Li et al., 2013). According to Jiang et al. (2018), 1-MCP has no effects on the moisture content of some non-climacteric fruits such as oranges. Stored plantains when ripe attain high moisture which makes ripe plantain soft together with conversion of starch to sugars including glucose, fructose and sucrose. Ripe plantains become highly perishable, susceptible to physiological deterioration and mechanical injury and microbiological decay (Sánchez et al., 1969).

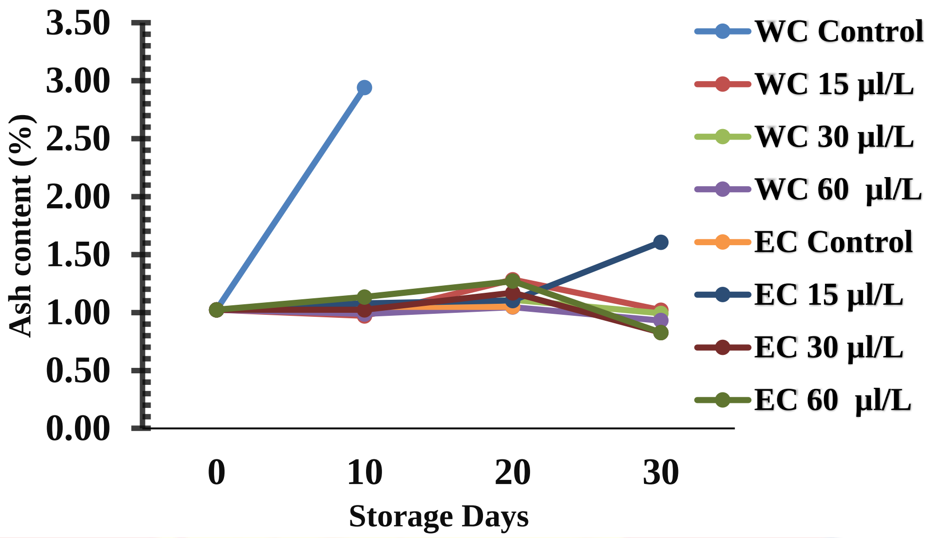

Figure 8: The effect of 1-MCP on the Ash content (%) of fruits stored in WC and EC

Differences were found in the ash content (%) of 1-MCP treated plantain stored in the wooden cabinet and pot-in-pot evaporative cooler with respect to storage days. At harvest, the initial ash content of mature green plantain was 1.02%. 1-MCP affected the ash content of plantains stored in the wooden cabinet and clay pot-in-pot evaporative cooler. A non-linear relationship existed between the ash content of 1-MCP treated plantains stored in the wooden cabinet and pot-in-pot evaporative cooler with increase storage days (Figure 8). The highest ash of 2.94% was recorded for 0µl/l 1-MCP WC (control) on day 10 of storage, however 0µl/l 1-MCP WC (control) on day 15 was decayed even though the pulp of such plantains are used in preparing wines and other traditional foods in Ghana and Nigeria (Dedo et al., 2019). The 1-MCP untreated plantains stored in the wooden cabinet were ripe on storage day 5 and 10 and decayed on storage day 15 and 20. These findings agreed with reported ash content of 2.56 to 3.44% for untreated ripe plantain and 2.03 to 2.34% for untreated unripe plantain. High ash content in ripe plantains was due to the physicochemical changes and bioavailability of minerals during the ripening process (Odenigbo et al., (2013). The results also agreed with reported figures of 2.92% and 3.31% as ash content for unripe and fully ripe plantains respectively when the effects of cooking methods and ripening stages on the nutritional compositions of plantains (Agbemafle et al., 2017). However, Obiageli et al. (2016) reported the ash content of ripe plantain as 1.09%, and green matured plantain as 0.82% in their study of mineral compositions of three Musa species at three stages of development, the ripe plantain was higher in ash content. Ash content of 15µl/l1-MCP treated plantains stored in the wooden cabinet rose from 0.97 to 1.40 as the storage days increased from 10 to 15 in the wooden cabinet indicating delay ripening of 15µl/l1-MCP treated plantains. The ash content decreased from 1.40 to 1.02% as storage days increased to 30 due to the overripe state of 15µl/l1-MCP treated plantains compared to the ripe 15µl/l1-MCP treated plantains stored in the pot-in-pot evaporative cooler. Similar pattern was observed for 30µl/l and 60µl/l 1-MCP treated plantains stored in the wooden cabinet. It was again observed that an increase in 1-MCP concentration had positive impact on the ash content of the 1-MCP treated plantain as the ash content was rather low at concentration 60µl/l due to overripe state of such plantains as the storage days increased, indicating the higher the concentration, the lesser the effectiveness 1-MCP action. The ineffectiveness of higher 1-MCP concentration (60µl/l) to delay ripening on storage days 25 and 30, as ripening rate rather increased due to increase ethylene production. This was due to the inability of higher 1-MCP concentration (60µl/l) to delay the increase of chlorophyllase and peroxidase enzymes which increases ripening (Win et al., 2006). Previous studies confirmed that pear treated with 0.5µl/l 1-

MCP plus micro-perforated film packaging material maintained protein content than pear treated with 1.0µl/l 1-MCP plus micro-perforated film packaging material (Li et al., 2013). It was observed that ash content of 1-MCP untreated plantains stored in the pot-in-pot evaporative cooler increased from 1.05 to 1.15 as storage days increased from 10 to 15 which was low compared to 1-MCP untreated plantains stored in the wooden cabinet. 1-MCP untreated plantains stored in the pot in pot evaporative cooler had storage life extended to 20 days.

There was a steady rise in the ash content of 1-MCP treated plantain fruits (15µl/l) from 1.08 to 1.61% as storage days increased from 10 to 30. This could be due to the effective action of 1-MCP and the clay pot-in-pot evaporative cooler that provided suitable cold temperature and relative humidity to reduce ripening rate and senescence and increased ash content. Increasing the concentration of 1-MCP to 60µl/l had no positive correlation with delay ripening of treated plantains stored in the pot-in-pot evaporative cooler, as it rather increased ethylene action and increased the ripening rate. The results agreed with Manigo et al., (2020) who studied the effect of 1-MCP application on postharvest quality including peel yellowing, weight loss, disease incidence, sensory firmness and visual quality of Cavendish' banana. Ash and dry matter were low at high moisture content and therefore the relatively low moisture level of 15µl/l 1-MCP EC recorded higher dry matter and ash levels (Obiageli et al., 2016).

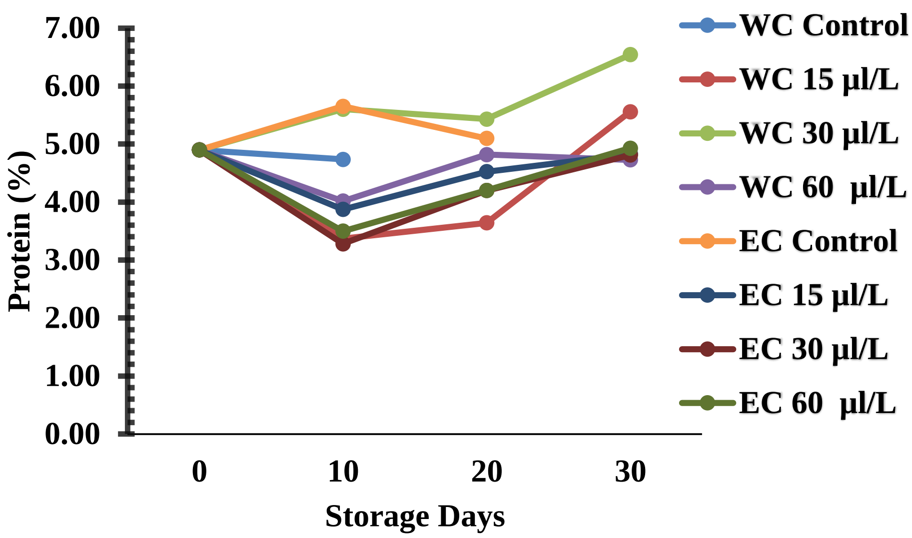

Figure 9: The effect of 1-MCP on the Protein content (%) of fruits stored in WC and EC

According to Boakye et al. (2014), the maximum required protein for adult ranges from (6-12%) while that for children range from (25-30%) for growth and development. There were differences in the percentage protein content (PC) for 1-MCP treated and untreated plantain stored in wooden cabinet and pot-in-pot evaporative cooler Figure 9). The PC of 0µl/l WC, 0µl/l EC, 1-MCP WC, and 1-MCP EC ranged from (3.81-4.74%), (4.55-5.62%), (3.18-5.60%) and (3.45-4.93%) respectively. The PC observed in the study was within the range of 1.88-6.80% reported by Iliyasu and Ayo-Omogie (2019). The PC of 1-MCP treated and untreated plantain stored in wooden cabinet and pot-in-pot evaporative cooler increase with increase in storage days and ripening after day10 to day 30 of storage. The high PC (4.72-6.54%) of 1-MCP treated plantain stored in wooden cabinet (ripe and over ripe) compared to relatively low PC (4.81-4.93%) on day 30. This result agreed with reported figure of 4.76-6.52% for crude protein by Famakin et al. (2016) in their assessment of nutritional quality, glycaemic index, anti-diabetic, and sensory properties of plantain (Musa paradisiaca). The high PC for ripe and over ripe plantain also agreed with the reported PC of 4.44% for fully ripe plantain compared to 3.85% for unripe plantain by Agbemafle et al. (2017) in their study of the effect of cooking methods and ripening stages on nutritional composition of plantains. The result however disagreed with Ekiti et al., (2017) who reported higher PC of 5.14% for unripe plantain pulp and lower PC of 3.50% for ripe plantain pulp. The PC decreased for all the treatments except the 30µl/l WC and 0µl/l EC which increased on day 10 and decreased by day 20 and increased again by day 30. The 0µl/l WC and 0µl/l EC plantain samples were decayed on days 20 to 30 respectively due to the increase rate of ripening leading to deterioration. There was increase in the storage life of untreated plantain from 15 to 20 days using the pot-in-pot evaporative cooler which could be due to the low temperature (25.41℃) and high humidity (94.20%) provided by the clay pot-in-pot storage system. The plantain treated with 15µl/l concentration recorded the higher PC which may be as a result of the effective action of the 1-MCP inhibiting the production of ethylene, delaying the ripening process, and maintaining the protein content. Previous studies confirmed that pear treated with 0.5µl/l 1-MCP plus micro-perforated film packaging material maintained protein content than pear treated with 1.0µl/l 1-MCP plus micro-perforated film packaging material (Li et al., 2013). Increasing the concentration of 1-MCP from 15 to 60µl/l was rather hurting the protein content of the plantain due to its inability to inhibit the rate of ethylene production resulting in the ripening of plantain which is aided by the physicochemical process leading to the decrease in protein content compared to the lower concentration.

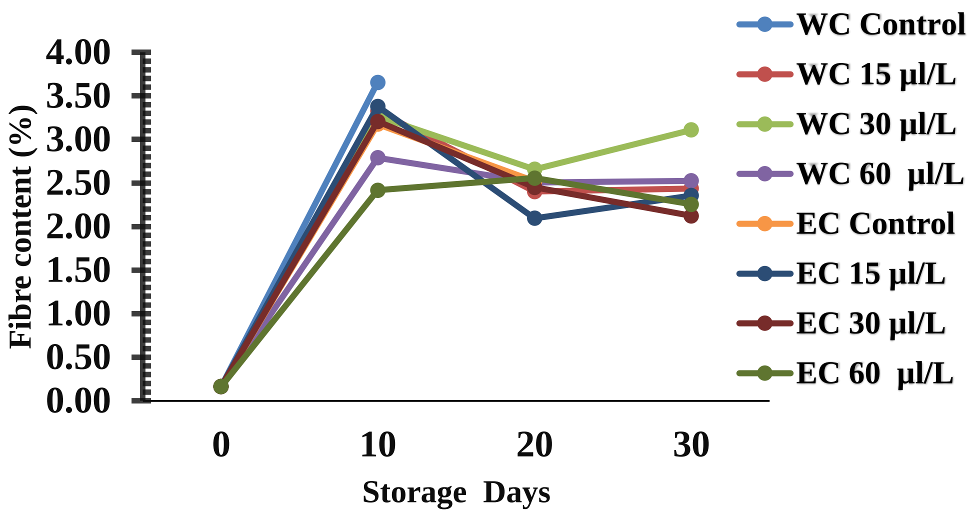

Figure 10: The effect of 1-MCP on the Fibre content (%) of fruits stored in WC and EC

1 -MCP has been confirmed to have a positive effect on the fibre content of fruits due to its ability to reduce the rate of ethylene synthesis which causes ripening of fruits leading to the maintenance or elevation of fibre content in unripe plantain fruits as compared to the ripe plantain fruits. There were no differences for fibre content between the untreated plantain fruits and 1-MCP treated fruits stored in both the wooden cabinet and pot-in-pot evaporative cooler. The fibre content (FC) for the 1-MCP treated and untreated plantains stored in both the wooden cabinet and pot-in-pot evaporative cooler increased from day 0 to day 10 and decreased from storage day 10 to 20, but increased slightly from day 20 to day 30. This was attributed to the production of ethylene during WC storage (Figure 10). There was an increase in ripeness and senescence leading to the deterioration of the untreated plantain resulting in no record for fibre in the WC on day 20. It was observed that the storage life of 1-MCP untreated plantain fruits kept in WC was 10 days compared to the clay pot-in-pot storage which increased the storage life from to 20 days due to the provision of colder environment and high humidity. A decreasing pattern of FC

was observed for the 1-MCP treated and untreated plantains kept in both WC and EC from storage day 10 to day 20 except 60µl/l 1-MCP EC treated plantains. FC decreased as the storage days increased from 20 to day 30 for all the 1-MCP treated and untreated plantains kept in both WC and EC except 30µl/l 1-MCP WC, 15µl/l 1-MCP EC and 15µl/l 1-MCP WC. It was observed that at concentration 15µl/l 1-MCP for both EC and WC storage, the fibre content decreases as the storage days increased but the decrease was sharper for 15µl/l 1-MCP EC treated plantains on day 20. The decrease in FC with increase in storage days from day 10 to day 30 may be due to the physicochemical changes during the storage period which increased the ripening of plantain fruits. Previous studies confirmed that pear treated with 0.5µl/l 1-MCP plus micro-perforated film packaging material maintained fibre content than pear treated with 1.0µl/l 1-MCP plus micro-perforated film packaging material (Li et al., 2013).

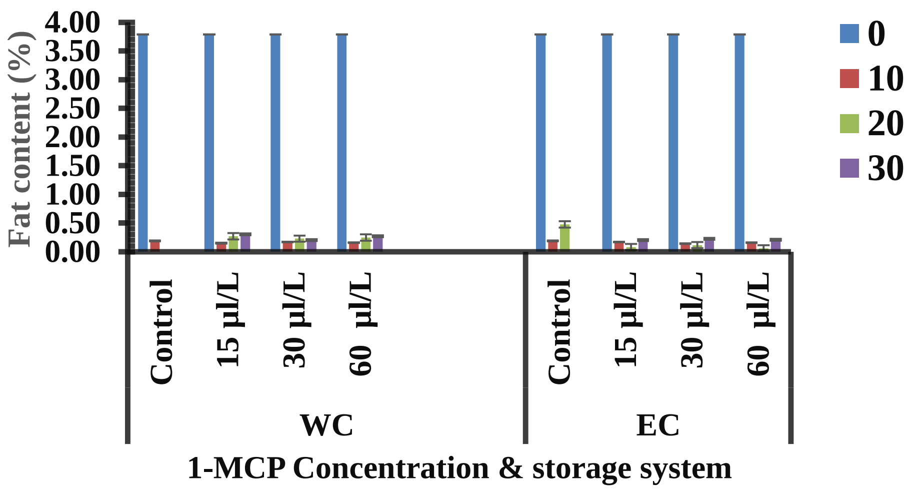

Figure 11: The effect of 1-MCP on the Fat content (%) of fruits stored in WC and EC

There were differences between the fat content of fruits stored in the wooden cabinet and pot-in-pot evaporative coolers for 1-MCP treated and untreated fruits kept in both WC and EC from storage day 10 to day 30 except 60µl/l 1-MCP EC treated plantains. as depicted in figure 11. However, there was sharp decline in fat contents from day 0 to day 10 during storage for both 1-MCP treated and untreated fruits stored in wooden cabinet and pot-in-pot evaporative coolers. Fat contents for both 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative coolers decreased with increase in storage days. This may be due to the ripening of plantain resulting in low fat content on days 10, 20 and 30. However, a slight increase was observed for the 1-MCP untreated fruits stored in the clay pot-in-pot evaporative cooler on day 20 during storage. The fat content slightly increased from 0.186 to 0.476 as the storage days increased from 10 to 30. The increase in fat content of the control sample stored in the pot-in-pot evaporative coolers may be due to the low temperature and high relative humidity of the clay-pot-in-pot evaporative cooler which resulted in the delay ripening of plantain and decreased the ethylene production rate while maintaining the fat content.

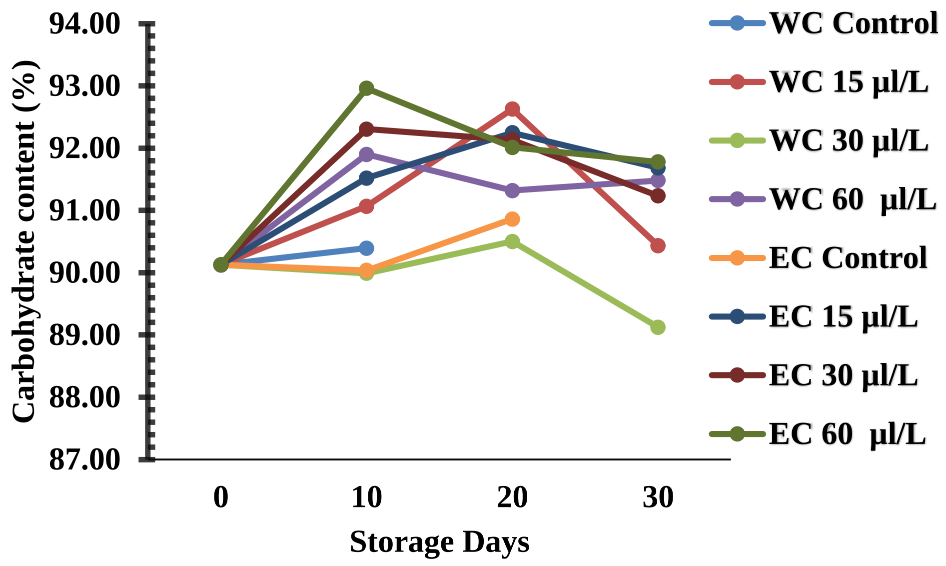

Figure 12: The effect of 1-MCP on the Carbohydrate content (%) of fruits stored in WC and EC

Sugars deposited in the peel tissue of plantain is a major factor regulating chlorophyll degradation (Yang et al., 2009). The carbohydrate content of 1-MCP treated and untreated fruits stored in wooden cabinet and pot-in-pot evaporative cooler. The carbohydrate content increased with increased storage days from day 0 to day 10 and decreased by day 30 of storage. The increase in carbohydrate was due to ripening resulting in the conversion of starch into sugars increasing the carbohydrate content. According to Dedo et al. (2019) almost all the starch in plantains is converted to sugars by day 10 of storage and starch completely disappears in the fruits. This may have caused the increase in carbohydrates on day 10 during storage. The increase in sugars in ripe plantain was the result of starch hydrolysis into simple sugars including sucrose, fructose and glucose (Sánchez Nieva et al., 1969). The carbohydrate content of 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative cooler on day 30 was low compared to day 10, probably due to the high ripening rate of overripe plantains, which resulted in the deterioration of the fruits. The high deterioration of 1-MCP untreated plantains stored in wooden cabinet may be due to the growth of fungal and other microbial organisms that flourished under high temperatures and low humidity within the wooden cabinet (Dedo et al., 2019). There was increase in carbohydrate content for 0µl/l EC and 15µl/l EC treated plantains on storage day 20. It was observed that, increasing the concentration of 1-MCP from 15 to 60µl/l for wooden cabinet storage resulted in decrease of carbohydrate content as the storage days increases from 10 to 20 and increased as storage increased to day 30. This may be due to ineffective action of 1-MCP at high concentration, resulting in the elevation of the ripening and increased sugar content which increased the carbohydrate content (Wasala et al., 2020).

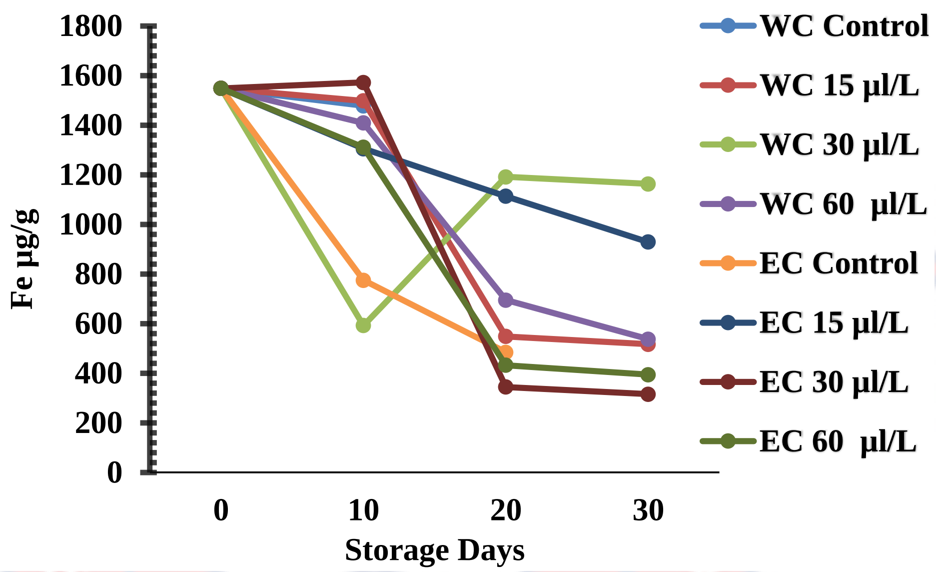

Figure 13: The effect of 1-MCP on the Iron (µg/g) content of fruits stored in WC and EC

Iron is vital for the formation of haemoglobin, a protein needed to transport oxygen in the blood. The 1-MCP treated and untreated plantains kept in the pot-in-pot evaporative coolers and wooden cabinet for iron content of plantain fruits during storage. It was noted that the 1-MCP untreated plantains kept in the wooden cabinet and pot-in-pot evaporative coolers decreased in iron content up to day 10, however the decline in iron content was very sharp from day 10 to day 20 due to ripening compared to 15µl/l 1-MCP EC treated plantains which were semi-ripe (Baiyeri et al., 2011). Optimum levels of Iron were observed at 30µl/l 1-MCP WC which experience a decrease in iron levels on day 10 followed by an increased in Iron content as the storage days increased from day 20 to day 30. But increasing the concentration from 30 to 60µl/l led to the decrease of Iron content from 1409 to 538µg/g and from 1311 to 394µg/g as storage days increased from 10 to 30 for both wooden cabinet and clay pot-in-pot evaporative storage. This may be due to ineffectiveness of 1-MCP at higher concentration. According to Agbemafle et al. (2017) plantain fruits at the unripen and semi-ripen stages were observed to be rich in iron.

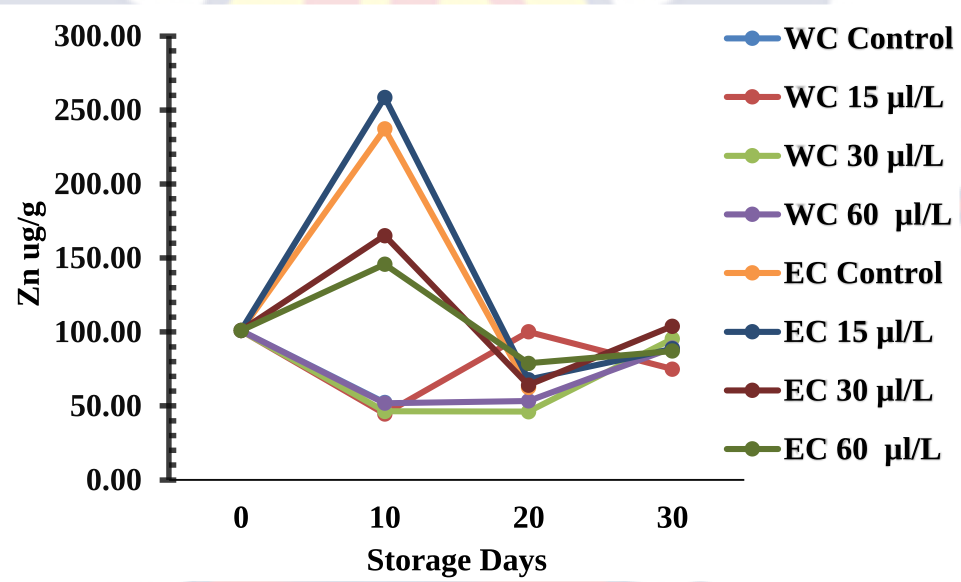

Figure 14: The effect of 1-MCP on the Zinc (µg/g) content of fruits stored in WC and EC

The Zinc content of 1-MCP treated and untreated plantain stored wooden cabinet and pot-in-pot evaporative cooler. There was sharp rise in Zinc levels on day 10 of storage for 1-MCP treated and untreated plantain stored in EC, irrespective of the 1-MCP concentration with the highest increase recorded for 15µl/l 1-MCP treated plantains stored in EC and 60µl/l 1-MCP treated plantains stored in EC recording the lowest increase on day10 of storage. Zinc levels decreased from day 10 to day 30 during storage for 1-MCP treated and untreated plantain stored in WC and EC. It was realized that the 1-MCP treated and untreated plantains kept in the WC recorded a decreased in zinc content on day 10 of storage. According to Agbemafle et al. (2017) plantain fruits at the unripen and semi-ripen stages were noted to have high levels of zinc. The decline in Zn content from day 10 to day 30 was due to the ripening of plantains. Zinc levels in ripening plantain was not significantly influenced by stage of ripeness even though the highest levels of zinc was recorded at the light yellow stage (semi-ripe) (Baiyeri et al., 2011).

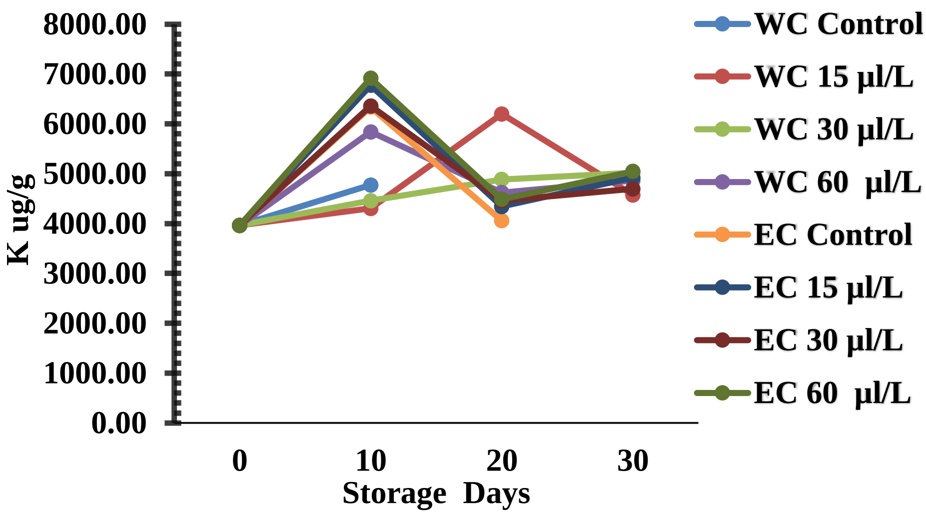

Figure 15: The effect of 1-MCP on the Potassium (µg/g) content of fruits stored in WC and EC

There were differences for potassium content in 1-MCP treated and untreated plantains stored in EC and WC, however 1-MCP treated and untreated plantain stored in EC recorded the highest levels of potassium compared to 1-MCP treated and untreated plantain stored in WC. There was increase in potassium content from 3965.09 to 4774 µg/g of 1-MCP untreated plantain kept in WC as the storage days increased from 0 to 10. Potassium content decreased as storage days increased from day 10 to day 30. As the storage days increased, the rate of ripening of 1-MCP untreated plantain stored in WC increased. This may be due to the production of ethylene due to the high temperature and low relative humidity of WC. One study reported that "Hass" avocado fruits exposed to sequential 1-MCP application were higher in potassium content than untreated fruits (Olivares et al., 2022). The results agreed with reported results for Cavendish banana by Manigo et al. (2020).

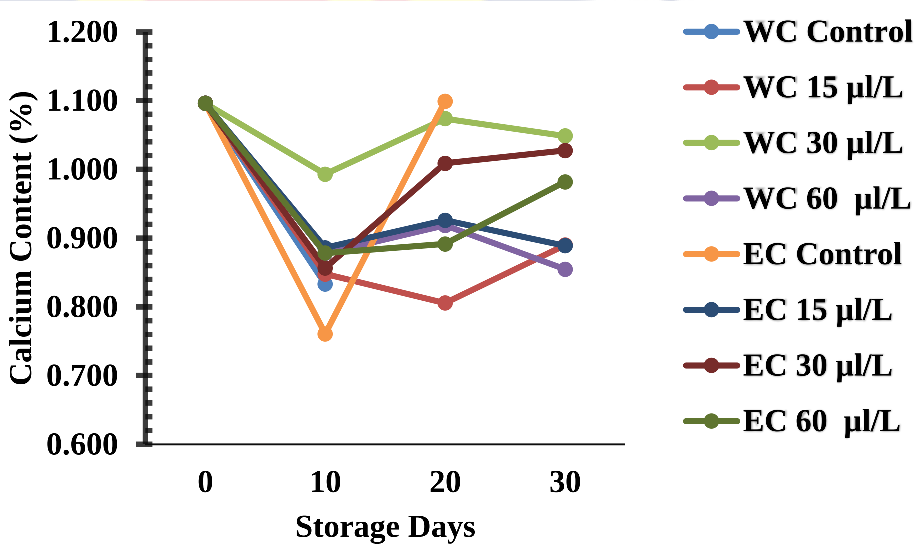

Figure 16: The effect of 1-MCP on the Calcium (µg/g) content of fruits stored in WC and EC

The 1-MCP treated and untreated fruits stored in EC and WC for calcium content. There was a reduction of calcium content of 1-MCP treated and untreated plantains stored in EC and WC as storage days increased from 0 to 10, but calcium content increased as storage days increased from 10 to 30 days. This observation agreed with Baiyeri et al. (2011) who reported that the increase in calcium during ripening may be due to tissue breakdown which caused mineral elements to be released. The calcium content of 1-MCP 60 µl/l treated plantain kept in EC increased as storage days increases from 10 to 30 compared 1-MCP 15 µl/l treated plantains kept in EC as storage days increases from 10 to 30. This observation agreed with Zenebe et al. (2016) who reported the effectiveness of 1-MCP at low concentration of 17.5 µl/l and modified atmosphere to delay ripening and improve storage of cavendish banana. Previous studies confirmed that pear treated with 0.5µl/l 1-MCP plus micro-perforated film packaging material maintained calcium better than pear treated with 1.0µl/l 1-MCP plus micro-perforated film packaging material (Li et al., 2013).

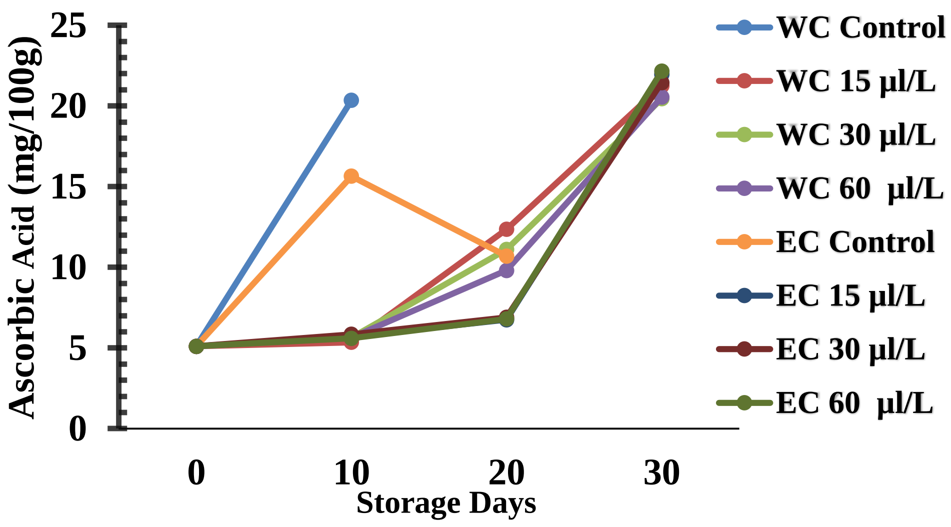

Figure 17: The effect of 1-MCP on the Vitamin C (AA) (mg/100g) content of fruits stored in WC and EC

Vitamin C (AA) is an essential antioxidant in human metabolism. It cannot be stored in large quantities in the human body. The recommended levels of Vitamin C consumed are 25-40 mg/day and 45 mg/day for children and adults respectively (Ramzan, 2017). There were differences between 1-MCP treated and untreated fruits stored in EC and WC for Vitamin C (Ascorbic acid) content. Freshly harvested mature green plantains contained low amount of 5.1mg/100g. The vitamin C content of 1-MCP untreated plantains stored in wooden cabinet increased to 20.35mg/100g compared to 15.65mg/100g for 1-MCP untreated plantains stored in pot-in-pot evaporative cooler on day 10 of storage. On day 10 of storage, the vitamin C levels of 1-MCP treated plantains stored in wooden cabinet increased to 5.35, 5.65 and 5.50mg/100g for 1-MCP treatment concentrations of 15, 30 and 60 µl /l compared to increase to 5.60, 5.55 and 5.60mg/100g for same 1-MCP treatment concentrations stored in pot-in-pot evaporative cooler.

Increase in storage days from day10 to day 20 resulted in the decay of 1-MCP untreated plantains stored in wooden cabinet, however the vitamin C levels of 1-MCP treated plantains stored in wooden cabinet and pot-in-pot evaporative cooler increased to 12.35, 11.10 and 9.80mg/100g and 6.75, 6.90 and 6.80mg/100g respectively. On storage day 30, the 1-MCP untreated plantains stored in pot-in-pot evaporative cooler had also decayed. The vitamin C levels of 1-MCP treated plantains at concentrations of 15, 30 and 60 µl /l stored in wooden cabinet increased to 21.25, 20.45 and 20.55mg/100g compared to increase of 21.95, 21.45 and 22.15mg/100g for same 1-MCP treatment concentrations stored in pot-in-pot evaporative cooler respectively. By the 30th day of storage, all the 1-MCP treated plantains stored in both the wooden cabinet and pot-in-pot evaporative cooler were overripe and decayed except the 15 µl /l and 30 µl /l 1-MCP treated plantains stored in pot-in-pot evaporative cooler. The results agreed with Wasala et al. (2020) who treated 'Ambul' banana with 1-MCP at 0.5 ppm and 1 ppm for 12 and 18-hours combinations under ambient conditions observed an increase in AA content for 1-MCP treated and untreated bananas during ambient storage. The untreated fruits showed rapid increase in AA within 5 days. The increase in AA with ripening was attributed to increase in lipid peroxidation during ripening which is an oxidative process that requires turnover of active oxygen species. All treatment combinations showed significantly lower AA than control until 10 days of storage. The results did not agree with Faasema et al. (2014) who observed that AA levels of the stored mango fruits were for most part not affected significantly by 1-MCP treatment as both treated and untreated control fruits exhibited the same pattern of AA loss.

1-MCP treated and untreated control cherry tomato fruits had similar vitamin C content during the entire experiment, but between 8 and 11 days after 1-MCP application, control fruits had a significant increase in vitamin C. Cherry tomato fruits treated with 1-MCP had an average vitamin C content of 3.80mg/100g but by the end of the storage period, there were no significant differences in vitamins for all treatments. Fruit varieties used and storage environment conditions could explain the difference. In fruits stored at 20°C without 1-MCP, it was possible that chilling injury contributed to reducing the synthesis of vitamin C, while in fruits stored at 20°C with 1-MCP, this compound prevented chilling injury and at the same time delayed the synthesis of enzymes that degraded ascorbic acid, also edible coatings acted synergistically with 1-MCP to reduce gas exchange and decrease the oxidation of vitamin C (Taye et al., 2019).

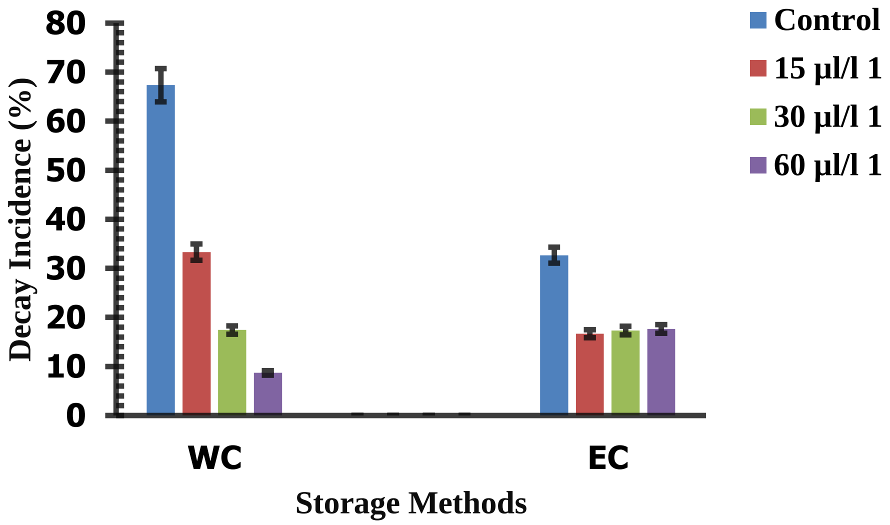

Figure 18: The effect of 1-MCP on mean decay incidence of fruits stored in WC and EC for 30-days

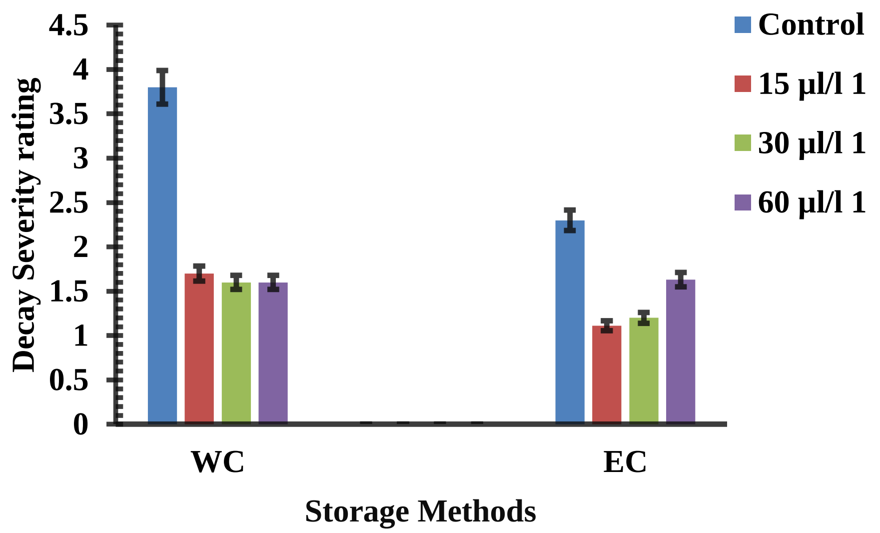

Figure 19: The effect of 1-MCP on mean decay severity of fruits stored in WC and EC for 30-days

The mean percentage decay incidence and severity varied between the eight treatments. The highest percentage decay incidence of 67.33% and severity rating of 3.80 was recorded for 1-MCP untreated plantain stored in the wooden cabinet, followed by 1-MCP untreated plantain stored in the pot-in-pot evaporative cooler of 33.67% and severity rating of 2.30. The mean percentage decay incidence and severity rating for 1-MCP treated plantain (15, 30 and 60µl/l) stored in the wooden cabinet reduced from 65.87% in the control to (33.32, 17.42 and 8.67%) respectively for decay incidence and from 3.80 in the control to (1.60, 1.50 and 1.60) respectively for severity rating. The mean decay incidence and severity rating was high with 1-MCP untreated plantain stored in the wooden cabinet at 3.80 and low in 1-MCP treated plantain (15µl/l) stored in the pot-in-pot evaporative cooler (1.11). The 1-MCP treated plantain (15, 30 and 60µl/l) stored in the pot in pot evaporative cooler reduced the mean percentage decay incidence from 32.67% to (16.67, 17.33 and 17.65%) and severity rating from 2.30 to (1.10, 1.20 and 1.6) respectively. This showed why 1-MCP untreated plantain stored in the wooden cabinet decayed by the 15th day of storage compared to the 1-MCP treated plantain (15µl/l) stored in the wooden cabinet (30th day) and the pot-in-pot evaporative cooler above (30th day) which remained marketable on storage day 30. This results corroborated with Xu et al., (2019) who concluded that bananas treated with 1-MCP only and in combination with salicylic acid (SA) suppressed the increase in decay incidence in banana. This results also agreed with Min et al., (2018) who observed that combination of methyl salicylate and 1-MCP treatment of tomato fruits controlled and delayed fungal decay of tomato. Xu et al. (2017) reported similar results with 1-MCP treatment only or a combination of 1-MCP and UV-C irradiation significantly reduced the incidence of decay in blueberry fruits.

Table 1: Sensory evaluation of treated (15µl/l 1-MCP) and untreated fruits stored in wooden cabinet and pot-in-pot evaporative cooler for days 1, 5, 10 and 15.

Storage Days	Colour	Texture	Odour	Appearance	**Overall Acceptance**
DAY 1					
Wooden Cabinet (Control)	7.400±0.548[a]	7.400± 0.894[a]	7.000±1.414[a]	7.600±0.548[ab]	7.000 ±0.707[a]
Wooden Cabinet (15µl/L)	7.600±1.342[a]	7.800± 1.304[a]	7.000±1.225[a]	8.600±0.548[a]	7.600 ±1.342[a]
Evaporative Cooler (Control)	7.200±1.304[a]	8.000± 1.000[a]	7.200±1.095[a]	7.400±0.548[b]	7.000± 0.000[a]
Evaporative Cooler (15µl/L	7.200±0.447[a]	7.400 ±1.140[a]	7.600± 1.342[a]	7.600±0.894[ab]	8.200± 0.837[a]
Day 5					
Wooden Cabinet (Control)	7.200±0.447[a]	7.800± 0.837[a]	7.400 ±0.894[a]	7.600 ±0.548[a]	8.000± 0.707[a]
Wooden Cabinet (15µl/L)	7.600±0.894[a]	7.600± 0.548[a]	8.000± 0.707[a]	7.800± 0.447[a]	8.000 ±0.707[a]
Evaporative Cooler (Control)	7.600±0.548[a]	8.000± 0.707[a]	7.800 ±0.447[a]	7.600 ±0.894[a]	7.800 ±0.837[a]
Evaporative Cooler (15µl/L)	7.600±0.548[a]	7.800 ±0.447[a]	7.600 ±0.548[a]	8.200± 0.447[a]	8.000 ±0.707[a]
DAY 10					
Wooden Cabinet (Control)	3.600 ±0.548[b]	3.200 ±0.447[b]	3.800± 0.447[b]	3.400 ±0.548[b]	3.600± 0.548[b]
Wooden Cabinet (15µl/L)	7.800 ±0.447[a]	8.400 ±0.548[a]	7.600± 0.894[a]	8.200± 0.447[a]	8.000 ±0.707[a]
Evaporative Cooler (Control)	7.800± 0.447[a]	8.200 ±0.837[a]	8.000 ±1.000[a]	8.200 ±0.837[a]	8.000± 1.000[a]
Evaporative Cooler (15µl/L	8.800 ±0.447[a]	9.000 ±0.000[a]	8.600 ±0.548[a]	8.400 ±0.894[a]	8.400± 0.894[a]
Day 15					
Wooden Cabinet (Control)	3.800 ±2.168[b]	3.400± 1.817[b]	4.200 ±2.168[b]	3.400 ±1.949[b]	4.000± 2.24[b]
Wooden Cabinet (15µl/L)	7.600 ±0.894[a]	8.000 ±0.707[a]	7.400 ±0.548[a]	7.400± 0.894[a]	8.000± 0.000[a]
Evaporative Cooler (Control)	7.400± 0.548[a]	8.200 ±0.837[a]	8.000 ±1.225[a]	7.400 ±0.548[a]	7.800 ±0.837[a]
Evaporative Cooler (15µl/L)	8.400 ±0.548[a]	8.400 ±0.548[a]	8.600 ±0.894[a]	8.800± 0.447[a]	8.600 ±0.548[a]

Values in the same column with different small letters are significantly different at $p<0.05$ accordingly to Tukey's test.

Table 2: Sensory for boiled plantain pulp (ampesi) prepared on day 1, 5, 10 and 15 of storage in wooden cabinet and pot-in-pot evaporative cooler.

Storage Days	Colour	Texture	Aroma	Mouthfeel	Aftertaste	Taste	Overall Acceptance
Day 1							
Wooden Cabinet (Ct)	7.400±0.894^{a}	7.400±0.548^{a}	7.400±0.894^{a}	7.600 ±0.894^{a}	8.000 ±0.707^{a}	7.800±0.87 ^{a}	7.400± 0.548^{a}
Wooden Cabinet (Tt)	7.800± 0.447^{a}	8.200± 0.447^{a}	7.200± 0.447^{a}	7.600 ±1.517^{a}	8.200± 0.837^{a}	8.400 ±1.342^{a}	8.200± 0.837^{a}
Evaporative Cooler (Control)	7.200 ±1.095^{a}	7.600± 0.894^{a}	8.000 ±0.707^{a}	8.000 ±0.707^{a}	7.800 ±1.095^{a}	7.600± 1.140^{a}	8.200 ±1.304^{a}
Evaporative Cooler (Treated)	7.000 ±0.707^{a}	7.200± 1.095^{a}	7.600 ±0.548^{a}	8.000± 0.707^{a}	7.800 ±0.447^{a}	7.800 ±1.095^{a}	8.000± 1.225^{a}
Day 5							
Wooden Cabinet (Ct)	7.200± 0.837^{a}	7.600 ±0.548^{a}	7.600 ±1.140^{a}	7.200± 0.837^{a}	7.000± 1.000^{a}	7.200 ±0.837^{a}	7.400± 0.894^{a}
Wooden Cabinet (Tt)	7.200± 0.837^{a}	7.000 ±1.000^{a}	6.800± 0.837^{a}	7.000± 0.707^{a}	6.600± 0.548^{a}	7.400± 0.548^{a}	7.200± 0.837^{a}
Evaporative Cooler (Control)	7.000± 0.707^{a}	7.400± 0.548^{a}	6.600 ±0.548^{a}	7.200 ±0.837^{a}	7.200± 0.837^{a}	7.000± 0.707^{a}	7.200 ±0.837^{a}
Evaporative Cooler (Treated)	7.200 ±0.837^{a}	7.600± 0.548^{a}	7.800 ±0.447^{a}	7.200± 0.837^{a}	7.000± 1.000^{a}	7.200 ±0.837^{a}	7.200 ±0.837^{a}
DAY 10							
Wooden Cabinet (Ct)	2.200± 0.447^{b}	2.200± 0.447^{b}	3.200 ±0.447^{b}	4.000± 0.707^{b}	4.600 ±1.140^{b}	3.800± 0.447^{b}	3.600± 0.548^{b}
Wooden Cabinet (Tt)	8.000 ±0.707^{a}	7.600± 0.548^{a}	7.200 ±0.447^{a}	7.800 ±0.837^{a}	7.000± 0.707^{a}	7.800± 1.095^{a}	8.000± 0.707^{a}
Evaporative Cooler (Control)	8.000 ±0.707^{a}	8.000 ±0.707^{a}	8.000± 0.707^{a}	8.000 ± 1.000^{a}	7.600 ±0.548^{a}	7.800± 1.095^{a}	8.000 ±0.707^{a}
Evaporative Cooler (Treated)	8.600± 0.548^{a}	8.400± 0.548^{a}	7.600± 0.894^{a}	8.200± 0.837^{a}	7.800± 1.304^{a}	7.600 ±1.342^{a}	8.000 ±0.707^{a}
Day 15							
Wooden Cabinet (Ct)	2.600± 0.894^{b}	2.800± 0.837^{b}	2.600 ±1.517^{b}	3.200± 1.304^{b}	5.200 ±0.447^{b}	2.400 ±1.140^{b}	2.800 ±1.304^{b}
Wooden Cabinet (Tt)	8.000 ±1.000^{a}	8.200 ±0.837^{a}	7.800 ±1.095^{a}	8.000 ±0.707^{a}	8.400± 0.548^{a}	7.800 ±1.095^{a}	8.200± 0.837^{a}
Evaporative Cooler (Control)	7.800± 0.837^{a}	8.000 ±0.707^{a}	7.800 ±1.095^{a}	8.000 ±0.707^{a}	8.800 ±0.447^{a}	8.000± 1.225^{a}	8.000± 0.707^{a}
Evaporative Cooler (Treated)	7.000± 1.000^{a}	7.200 ±1.095^{a}	7.400± 0.548^{a}	7.400 ±0.894^{a}	8.400± 0.548^{a}	8.000 ±0.707^{a}	8.200 ±0.837^{a}

Values in the same column with different small letters are significantly different at ($p<0.05$) accordingly to Tukey's test. Note; CT = Control, TT = 15µl/l 1-MCP Treated.

Table 1 shows sensory evaluation preference scores for 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative cooler in the study. Day 1 and 5 preference scores for colour, texture, odour, appearance and overall acceptability ranged from 7 to 8 for both 1-MCP treated and untreated plantains. This implied the panellist preference for both 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative cooler was moderately to very much liked. Preference scores for 1-MCP treated plantains stored in wooden cabinet and both 1-MCP treated and untreated plantains stored in evaporative cooler for 10 to 15 days recorded mean score between 8 to 9, which implied panellists liked these plantains very much, however 1-MCP untreated plantains stored in wooden cabinet for 10 to 15 days gave the mean preference score between 3 to 4 showing disliked moderately to disliked slightly. The untreated plantains stored in wooden cabinet were overripe and decayed and were not appealing as green plantains that could be stored for some time before consumption hence the low mean preference score. The 15.0 µl /l 1-MCP treated plantain stored in the pot-in-pot evaporative cooler for 15 days recorded mean preference score of 8 and above for colour, texture, odour, appearance and overall acceptance. The 15.0 µl /l 1-MCP treated and untreated plantain stored in the wooden cabinet and pot-in-pot evaporative cooler for one day recorded mean preference score ranging from 7 to 8 for colour, texture, odour, appearance and overall acceptance for boiled plantain. Table 2 shows sensory evaluation preference scores for boiled plantain prepared from 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative cooler. Day 1 and 5 preference scores for colour, texture, aroma, mouthfeel, aftertaste, taste and overall acceptance ranged from 7 to 8 for boiled plantain made from 1-MCP treated and untreated plantains after 1 and 5-days storage in wooden cabinet and pot-in-pot evaporative cooler. Preference scores for boiled plantain prepared from 1-MCP untreated plantain stored in the wooden cabinet range from 2 to 4. Preference scores for boiled plantain prepared from 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative cooler for 10 days ranged from 7 to 8. Preference scores for boiled plantain prepared from 1-MCP treated plantains stored in wooden cabinet and 1-MCP treated and untreated plantains stored in evaporative cooler for 15 days recorded mean score between 7 to 8, which implied panellists liked these plantains very much, however boiled plantain prepared from 1-MCP untreated plantains stored in wooden cabinet for 15 days gave the mean preference score between 2 to 5 showing disliked moderately to disliked slightly. The boiled plantain from untreated plantains stored in wooden cabinet were overripe and decayed and were not appealing hence the low mean preference score. The results agreed with Hagan et al. (2017) who reported that 1-MCP applied by dipping mature-green plantains into aqueous solution of 1-MCP at 100 μg /l for 1 minute and stored at 15 and 30℃, at 75% relative humidity significantly reduced the ripening and softening, but did not affect the sensory qualities of boiled plantain pulp in terms of taste, mouthfeel, appearance, aroma, flavour, peel and pulp colour and overall acceptability of plantain fruits and boiled plantain pulp. The results confirmed that 1-MCP-treated banana fruits and stored at 20°C were firmer and less juicy than untreated fruit, indicating that 1-MCP treatment could delay softening and sweetness in banana fruit stored at colder temperatures (Xu et al., 2019). The result agreed with Abu-Goukh et al. (2013) who reported that the application of 1-MCP application to banana fruits and stored at 18°C for 20 days maintained fruit firmness and delayed peel colour change. From the study, fruits giving 1-MCP treatment and stored in wooden cabinet and pot-in-pot evaporative cooler were perceived by panellists as the most acceptable after extended storage period and that cold storage had some measurable effect on the quality of the fruit.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

Plantain production mainly undertaken by small to medium scale farmers continue to increase, however plantains are predisposed to high postharvest losses in Ghana during storage. Plant growth regulator 1-MCP, an inhibitor of ethylene action and pot-in-pot evaporative cooler storage have been shown to be effective in extending the storage life of green mature plantains and maintain quality. The work seeks to increase the storage life of green mature plantains. Plantains were treated with varying concentrations of 1-MCP (15, 30, and 60 µl/l) and stored in two different structures (wooden cabinet and clay pot-in-pot evaporative cooler) for 30 days. The mean temperature and relative humidity in the pot in pot evaporative cooler were maintained at 25.41±0.36℃ and 94.20±1.23 % respectively. Monitoring was done daily and data on weight, firmness, shrinkage, peel colour, decay, proximate and minerals were collected at five days interval.

Data collected were subjected to statistical analysis using Minitab statistical tool version 19.0 to determine differences between the treatment means at 95% confident level. 1-MCP at 15 µl/l was observed as most effective concentration to delayed ripening and colour change over the 30-day storage duration. Sensory evaluation of plantains treated with1-MCP at 15 µl/l had consumer acceptance for both raw and boiled plantain (Ampesi) based on the following quality attributes such as texture, peel and pulp colour, odour, taste, aftertaste, mouthfeel and the overall acceptability of the product. Using the hedonic scale which range from 1 to 9, that is dislike extremely to like extremely. It was observed that the overall acceptability of the plantain fruit and boiled plantain pulp stored for 15-days were preferred from the 7 panellists. The percentage moisture and carbohydrate for 15µl/l 1-MCP treated plantain stored in pot-in-pot evaporative cooler improved to 63.59 % and 92.25 % respectively compared to the control which recorded to 66.01 % and 90.86 % on the day-20 of storage. Potassium recorded a higher value of 4921 µg/g for 15 µl/l 1-MCP treated plantains stored in pot-in-pot evaporative cooler.

Conclusion

Based on the results, the following conclusion were drawn:

1. 1-MCP (15µl/l) treated plantain stored in pot in pot evaporative cooler had the lowest cumulative percentage fruit weight loss of 6.17 % compared to the control figure of 19.71 %, the lowest percentage shrinkage of 1.20 % compared to control figure of 10.21 %, and plantain firmness of 56.20 N compared to the control fruit firmness of 20.27 N on day 15 of storage.
2. 1-MCP (15µl/l) treated plantain stored in pot-in-pot evaporative cooler recorded plantain peel colour lightness L* of 55.83 compared to the control fruit peel colour lightness L* of 58.35, showing peel colour change during ripening of the control fruits on day 10 of storage.

   The decay incidence and severity index after the 30-day storage were 16.67 % and 1.1 compared to 67.33 % and 3.8 for the control respectively. The sensory evaluation showed panellists had higher preference for the15 µl/l 1-MCP treated plantain stored in pot-in-pot evaporative cooler for 15 days, colour (8.4), texture (8.4), odour (8.6), appearance (8.8), and overall acceptability (8.6) compared to the control stored in wooden cabinet for 15 days with colour (3.8), texture (3.4), odour (4.2), appearance (3.4), and overall acceptability (4.0).

3. Carbohydrate, ash, potassium and vitamin C for 15 µl/l 1-MCP treated plantain stored in pot-in-pot evaporative cooler were maintained during the 30-day storage compared to the control i.e., from 90.13 % to 91.68 %, 1.02 % to 1.61 %, 3965 to 4921 µg/g, and 1.10 to 21.95 mg/100g respectively.

Recommendation

The following recommendations were made based on the results obtained

1. 1-MCP works actively at low concentrations (15 µl/l). Subsequent research study should focus on optimization to arrive at exact effective concentration of 1-MCP to use for the storage of plantain.
2. Research study should also be conducted on the effects of 1-MCP on the quality parameters of different varieties of plantain.
3. The agricultural extension department of the Ministry of Food and Agriculture could collaborate with plantain farmers' association to adopt and pilot the use of 1-MCP to store and preserve plantains.

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APPENDICE

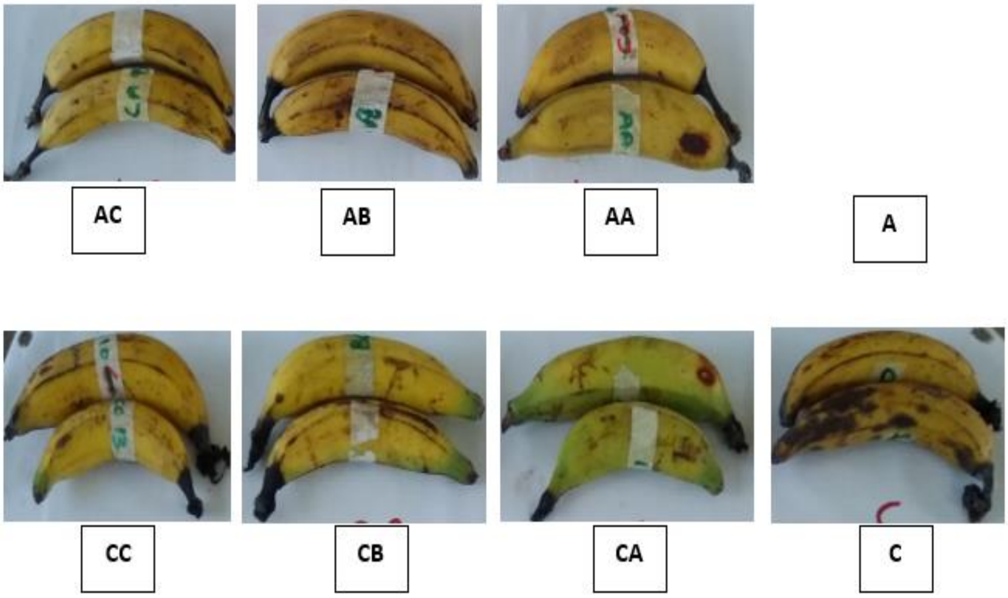
Appendix A1: 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative coolers for 5 days

Appendix A2: 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative cooler for 10 days

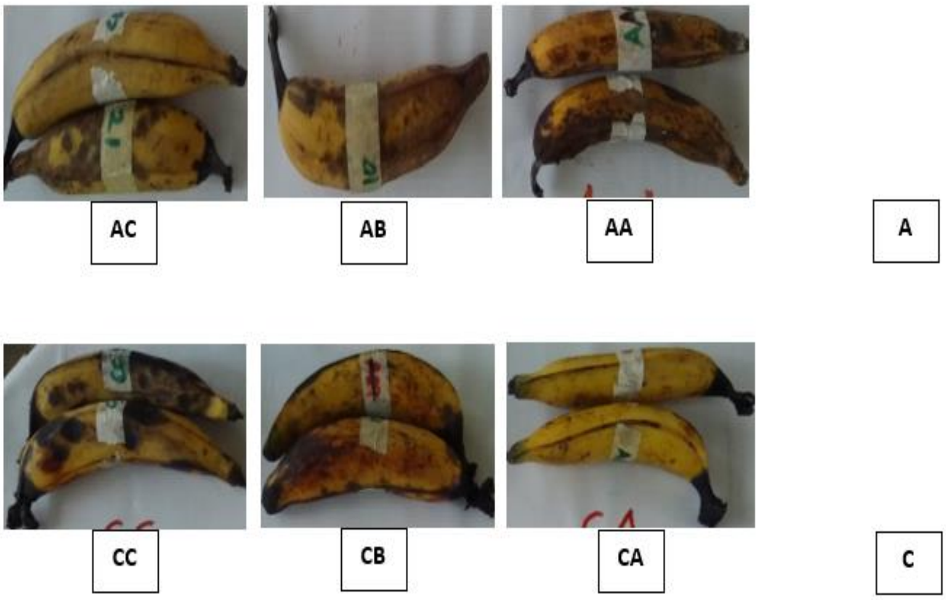
Appendix A3: 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative coolers for 15 days

Appendix A4: 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative coolers for 20 days

Appendix A5: 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative coolers for 25 days



Appendix A6: 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative coolers for 30 days



Appendix A7: 1-MCP treated plantains stored in wooden cabinet

Appendix A8: 1-MCP treated plantains stored in the pot-in-pot coolers

Table 1: Treatment labels of 1-MCP treated and untreated plantains stored in wooden cabinet and pot-in-pot evaporative cooler

Treatment	Description
0 µl/l WC	1-MCP (0 µl/l) untreated plantain stored in wooden cabinet
15 µl/l WC	1-MCP (15 µl/l) treated plantain stored in wooden cabinet
30 µl/l WC	1-MCP (30 µl/l) treated plantain stored in wooden cabinet
60 µl/l WC	1-MCP (60 µl/l) treated plantain stored in wooden cabinet
0 µl/l EC	1-MCP (0 µl/l) untreated plantain stored in evaporative cooler
15 µl/l EC	1-MCP (15µl/l) treated plantain stored in evaporative cooler
30 µl/l EC	1-MCP (30µl/l) treated plantain stored in evaporative cooler
60 µl/l EC	1-MCP (60µl/l) treated plantain stored in evaporative cooler

Table 2: Temperature and Relative Humidity of the wooden cabinet and pot-in-pot evaporative cooler storage

Treatments	Temperature ℃	Rel. Humidity %	Dew Point	Wet Bulb
0 µl/l WC	28.74±0.35	79.12±10.38	24.20	25
15 µl/l WC	29.03±0.72	76.79±6.71	24.03	25
30 µl/l WC	29.20±0.71	72.34±9.78	22.97	24
60 µl/l WC	28.67±0.99	68.40±7.67	21.49	23
0 µl/l EC	25.26±0.54	93.5±1.05	25.26	23
15 µl/l EC	25.23±0.45	95.10±2.02	25.59	24
30 µl/l EC	25.54±0.23	94.70±0.80	25.54	24
60 µl/l EC	25.61±0.20	93.50±1.05	25.61	24

Table 3: State of ripeness of treated and untreated plantains on 27th day of Storage

Treatments	**Unripe**	**Semi-ripe**	**Ripe**	**Over ripe**	**Decayed**	**Sampled**
0 µl/l WC	-	-	-	-	20	4
15 µl/l WC	-	2	8	4	-	10
30 µl/l WC	1	-	1	12	-	10
60 µl/l WC	-	1	2	11	-	10
0 µl/l EC	1	-	-	13	-	10
15 µl/l EC	4	-	9	1	-	10
30 µl/l EC	3	-	11	-	-	10
60 µl/l EC	-	-	14	-	-	10

Table 4: Sensory Characteristics of Boiled Plantain

Characteristics	Definition	Hedonic Scale
Texture	Force required for deformation in the mouth	1 – Soft 9 - Hard
Aroma	Smell of food in the mouth	1 – Offensive 9 - Pleasant
Colour	Attractiveness	1 – Poor 9 - Excellent
Taste	The sensation felt in the mouth	1 – Bad 9 - Pleasant
After taste	Persistence of taste after swallowing	1 – Bad 9 - Pleasant
Mouthfeel	Tactile sensation the food gives to the mouth	1 – Bad 9 - Pleasant
Overall Acceptance	Combined effect of all the sensory attributes	1 – Poor 9 - Excellent